

M. I. T. ANNUAL CATALOGUES AND BULLETINS

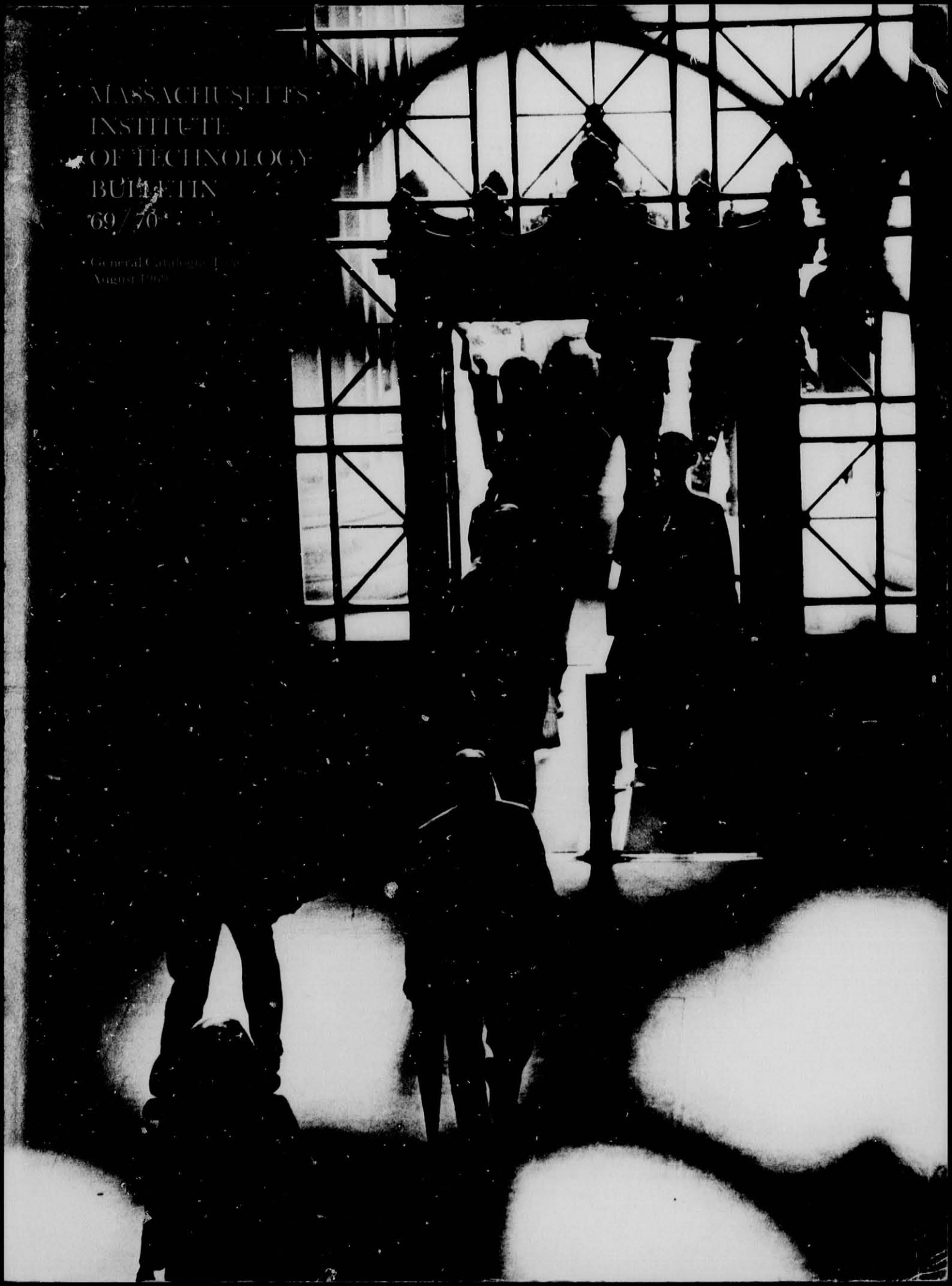
1969/70

01  
OF  
05

MASSACHUSETTS  
INSTITUTE  
OF TECHNOLOGY  
BULLETIN

69/70

General Catalogue, 1969  
August 1969



# THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY BULLETIN 1969-70

THE GENERAL CATALOGUE ISSUE



The Massachusetts Institute of Technology Bulletin is published five times yearly by the Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, in August, November, December, March and June. Issues of the Bulletin include the General Catalogue, the Reports of the Treasurer and of the President, the Summer Session Catalogue, and Publications and Theses.

Volume 105, Number 1, August, 1969. Second class postage paid at Boston, Massachusetts.

Send undeliverable copies and changes of address to Room 5-133, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.

*The Institute reserves the right to make changes in the regulations and courses announced in this Bulletin.*

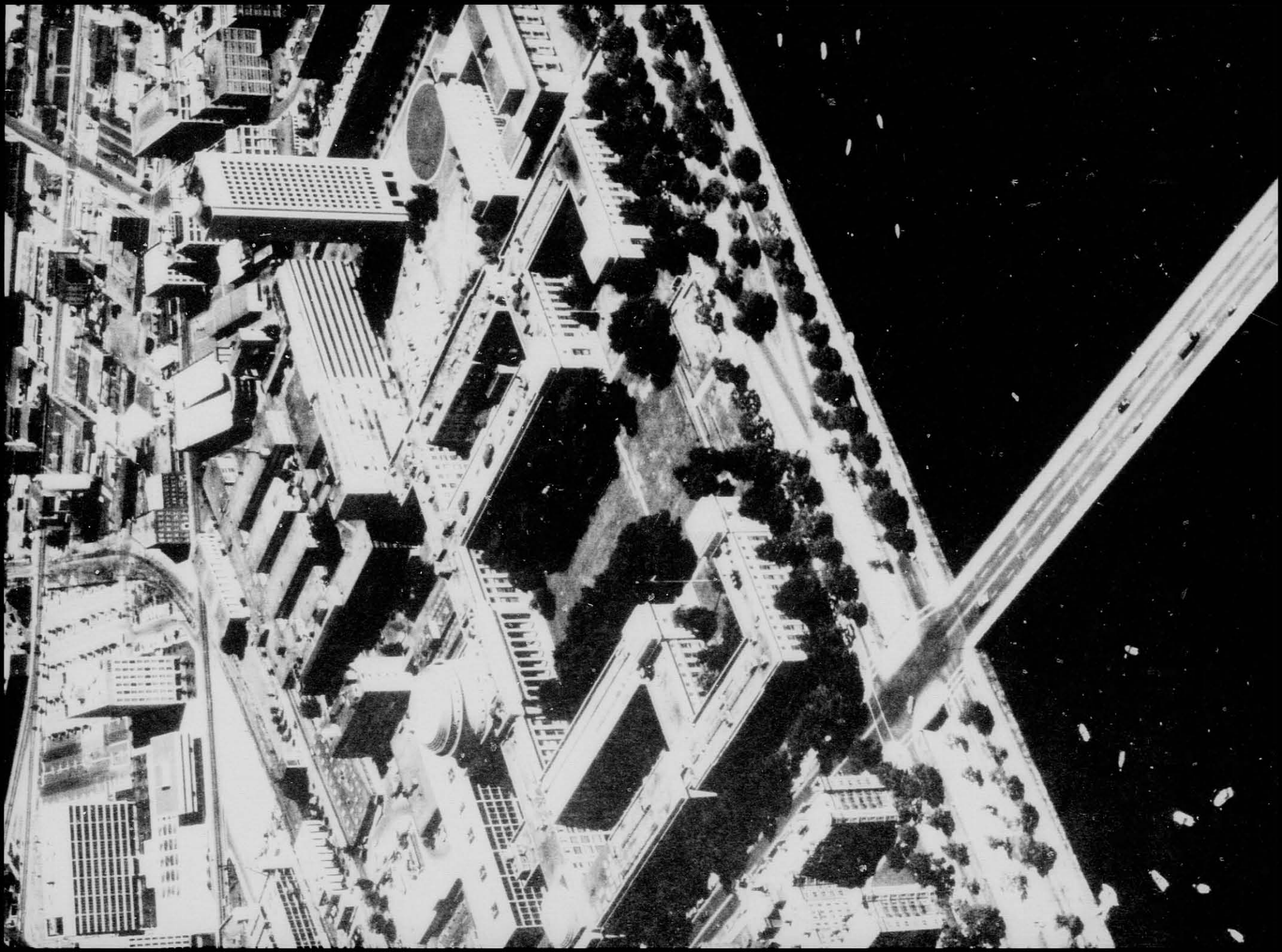


## CONTENTS

	ACADEMIC CALENDAR	vii
	THE CORPORATION	viii
	PRINCIPAL ACADEMIC OFFICERS, DEPARTMENT HEADS, AND INSTITUTE PROFESSORS	x
	THE FACULTY	xii
	AN M.I.T. EDUCATION FOR OUR TIMES, <i>by Dr. Howard W. Johnson</i>	xliv
1.	<b>GENERAL INFORMATION</b>	1
	A MODERN UNIVERSITY CENTERED IN SCIENCE	1
	THE ACADEMIC PROGRAM	5
	SCHOOLS, DEPARTMENTS, COURSES, AND DEGREES	6
	TEACHING AND RESEARCH RESOURCES	9
	OTHER TEACHING FACILITIES	16
	ORGANIZATION OF THE INSTITUTE	17
	THE CAMPUS	18
	STUDENT HOUSING	20
	CAMPUS ACTIVITIES	26
	MEDICAL SERVICES	32
	OTHER SERVICES	33
	GENERAL REGULATIONS	34
	FEES	36
	PAYMENTS	37
	FINANCIAL AIDS	38
2.	<b>UNDERGRADUATE EDUCATION</b>	41
	A TRADITION OF EXCELLENCE	41
	THE UNDERGRADUATE PROGRAMS	42
	WELLESLEY EXCHANGE SUBJECTS	43
	DEGREE REQUIREMENTS	47
	THE FIRST-YEAR PROGRAM	47
	THE SCIENCE DISTRIBUTION REQUIREMENT	50
	THE LABORATORY REQUIREMENT	51
	THE PHYSICAL EDUCATION REQUIREMENT	51
	THE UNDERGRADUATE PROGRAM IN HUMANITIES	52
	MILITARY SCIENCE, AIR SCIENCE, AND NAVAL SCIENCE	57
	SELECTIVE SERVICE OFFICE	63
	OPPORTUNITIES FOR OVERSEAS STUDY	63
	COOPERATIVE ARRANGEMENT WITH HARVARD	64
	COSTS	64
	FINANCIAL AID FOR UNDERGRADUATES	64
	UNDERGRADUATE ADMISSION TO M.I.T.	65
3.	<b>GRADUATE EDUCATION</b>	71
	CREATIVITY AND INTELLECTUAL INDEPENDENCE	71
	RESOURCES FOR GRADUATE STUDY	72
	GRADUATE STUDENT ACTIVITIES AND ORGANIZATIONS	74
	ORGANIZATION OF THE GRADUATE SCHOOL	74
	ADMISSION TO THE GRADUATE SCHOOL	77
	REGISTRATION	79
	ACADEMIC STANDARDS	79
	COOPERATIVE ARRANGEMENT WITH HARVARD	79
	COOPERATIVE ARRANGEMENT WITH BOSTON UNIVERSITY	80

	COOPERATIVE ARRANGEMENT WITH TUFTS UNIVERSITY	80
	MEDICAL SERVICES AND REQUIREMENTS	80
	MILITARY SERVICE	80
	REQUIREMENTS FOR DEGREES	81
	FINANCIAL ASSISTANCE TO GRADUATE STUDENTS	84
<b>4.</b>	<b>SCHOOL OF ARCHITECTURE AND PLANNING</b>	<b>89</b>
	DEPARTMENT OF ARCHITECTURE	91
	DEPARTMENT OF URBAN STUDIES AND PLANNING	95
<b>5.</b>	<b>SCHOOL OF ENGINEERING</b>	<b>101</b>
	DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS	104
	DEPARTMENT OF CHEMICAL ENGINEERING	109
	DEPARTMENT OF CIVIL ENGINEERING	114
	DEPARTMENT OF ELECTRICAL ENGINEERING	121
	DEPARTMENT OF MECHANICAL ENGINEERING	131
	DEPARTMENT OF METALLURGY AND MATERIALS SCIENCE	136
	DEPARTMENT OF NAVAL ARCHITECTURE AND MARINE ENGINEERING	142
	DEPARTMENT OF NUCLEAR ENGINEERING	147
	CENTER FOR ADVANCED ENGINEERING STUDY	151
<b>6.</b>	<b>SCHOOL OF HUMANITIES AND SOCIAL SCIENCE</b>	<b>156</b>
	DEPARTMENT OF ECONOMICS	158
	DEPARTMENT OF FOREIGN LITERATURES AND LINGUISTICS	161
	DEPARTMENT OF HUMANITIES	163
	DEPARTMENT OF POLITICAL SCIENCE	166
	DEPARTMENT OF PSYCHOLOGY	169
<b>7.</b>	<b>ALFRED P. SLOAN SCHOOL OF MANAGEMENT</b>	<b>173</b>
<b>8.</b>	<b>SCHOOL OF SCIENCE</b>	<b>183</b>
	DEPARTMENT OF BIOLOGY	186
	DEPARTMENT OF CHEMISTRY	189
	DEPARTMENT OF EARTH AND PLANETARY SCIENCES	192
	DEPARTMENT OF MATHEMATICS	196
	DEPARTMENT OF METEOROLOGY	200
	DEPARTMENT OF NUTRITION AND FOOD SCIENCE	202
	DEPARTMENT OF PHYSICS	207
	PROGRAM IN OCEANOGRAPHY WITH WOODS HOLE	210
	<b>DESCRIPTIONS OF SUBJECTS</b>	<b>213</b>
	CIVIL ENGINEERING	214
	MECHANICAL ENGINEERING	223
	METALLURGY AND MATERIALS SCIENCE	234
	ARCHITECTURE	239
	CHEMISTRY	244
	ELECTRICAL ENGINEERING	247
	BIOLOGY	263

PHYSICS	265
PSYCHOLOGY	272
CHEMICAL ENGINEERING	275
URBAN STUDIES AND PLANNING	279
EARTH AND PLANETARY SCIENCES	283
NAVAL ARCHITECTURE AND MARINE ENGINEERING	287
ECONOMICS	292
MANAGEMENT	297
AERONAUTICS AND ASTRONAUTICS	308
POLITICAL SCIENCE	315
MATHEMATICS	323
METEOROLOGY	331
NUTRITION AND FOOD SCIENCE	333
HUMANITIES	336
NUCLEAR ENGINEERING	351
FOREIGN LITERATURES AND LINGUISTICS	354
AEROSPACE STUDIES	361
MILITARY SCIENCE	361
NAVAL SCIENCE	362
UNDERGRADUATE SEMINAR	362
CORPORATION STANDING AND AUDITING COMMITTEES	364
CORPORATION VISITING COMMITTEES	365
ADMINISTRATION	367
OFFICERS AND STANDING COMMITTEES OF THE FACULTY	377
COUNCILS	379
APPENDIX A: STUDENT FINANCIAL AID	381
APPENDIX B: PRIZES AND AWARDS	394
ALPHABETICAL INDEX	397
INDEX TO SUBJECTS OF INSTRUCTION	400



## ACADEMIC CALENDAR

# 1969

SEPTEMBER 15	RESIDENCE/ORIENTATION WEEK FOR FRESHMEN BEGINS
SEPTEMBER 23	FIRST TERM REGISTRATION DAY
SEPTEMBER 24	FIRST TERM CLASSES BEGIN
OCTOBER 12	COLUMBUS DAY ( <i>holiday</i> ) (Exercises Omitted Monday, October 13)
NOVEMBER 11	VETERANS' DAY ( <i>holiday</i> )
NOVEMBER 27 through NOVEMBER 30	THANKSGIVING VACATION
DECEMBER 20 through JANUARY 4	CHRISTMAS VACATION

# 1970

JANUARY 16	LAST EXERCISES OF THE FIRST TERM
JANUARY 19 through JANUARY 21	READING PERIOD
JANUARY 22 through JANUARY 30	EXAMINATION PERIOD
FEBRUARY 9	SECOND TERM REGISTRATION DAY
FEBRUARY 10	SECOND TERM CLASSES BEGIN
FEBRUARY 16	OBSERVANCE OF WASHINGTON'S BIRTHDAY ( <i>holiday</i> )
MARCH 30 through APRIL 5	SPRING VACATION
APRIL 20	OBSERVANCE OF PATRIOTS' DAY ( <i>holiday</i> )
MAY 22	LAST EXERCISES OF THE SECOND TERM
MAY 23 through MAY 27	READING PERIOD
MAY 25	OBSERVANCE OF MEMORIAL DAY ( <i>holiday</i> )
MAY 28 through JUNE 5	EXAMINATION PERIOD
JUNE 12	COMMENCEMENT DAY
JUNE 22	SUMMER SESSION BEGINS
SEPTEMBER 21	FIRST TERM 1970 BEGINS

## THE CORPORATION

VANNEVAR BUSH  
*Honorary Chairman*

JAMES RHYNE KILLIAN, JR.  
*Chairman*

HOWARD WESLEY JOHNSON  
*President*

JOSEPH JULIEN SNYDER  
*Vice President and Treasurer*

WALTER HUMPHREYS  
*Honorary Secretary*

JOHN JOSEPH WILSON  
*Secretary<sup>1</sup>*

### LIFE MEMBERS

BRADLEY DEWEY  
*Former President,  
Dewey and Almy Chemical Company  
(Division of W. R. Grace & Company)*

VANNEVAR BUSH  
*Former President, Carnegie Institution of Washington*

JAMES MADISON BARKER  
*Director and Former Chairman, Allstate Insurance Company*

THOMAS CHARLES DESMOND  
*Former New York State Senator*

MARSHALL BERTRAND DALTON  
*Honorary Chairman,  
Arkwright-Boston Manufacturers Mutual Insurance Company  
and Mutual Boiler and Machinery Insurance Company*

DONALD FELL CARPENTER  
*Former General Manager, Film Department,  
E. I. du Pont de Nemours & Company, Inc.*

THOMAS DUDLEY CABOT  
*Honorary Chairman, Cabot Corporation*

CRAWFORD HALLOCK GREENEWALT  
*Chairman of the Finance Committee,  
E. I. du Pont de Nemours & Company, Inc.*

LLOYD DEWITT BRACE  
*Former Chairman of the Board,  
First National Bank of Boston*

WILLIAM APPLETON COOLIDGE  
*Retired; Corporate Director*

ROBERT CHAPMAN SPRAGUE  
*Chairman and Chief Executive Officer,  
Sprague Electric Company*

CHARLES ALLEN THOMAS  
*Chairman of the Board of Trustees, Washington University*

DAVID ALLAN SHEPARD  
*Former Executive Vice President and Director,  
Standard Oil Company (New Jersey)*

GEORGE JOHN LENESE  
*Former Chairman,  
Merrill Lynch, Pierce, Fenner and Smith, Inc.*

EDWARD JAMES HANLEY  
*Chairman of the Board,  
Allegheny Ludlum Steel Corporation*

ROBERT ABERCROMBIE LOVETT  
*General Partner,  
Brown Brothers Harriman and Company*

CECIL HOWARD GREEN  
*Director, Texas Instruments Incorporated*

HORACE WINSLOW MCCURDY  
*Chairman of the Board,  
Puget Sound Dredging Company*

JOHN JOSEPH WILSON  
*Secretary of the M.I.T. Corporation*

GILBERT MORGAN RODDY  
*President,  
Arkwright-Boston Manufacturers Mutual Insurance Company  
and Mutual Boiler and Machinery Insurance Company*

JAMES BROWN FISK  
*President, Bell Telephone Laboratories, Inc.*

GEORGE PEABODY GARDNER, JR.  
*General Partner,  
Paine, Webber, Jackson and Curtis*

ROBERT CHARLES GUNNESS  
*President,  
Standard Oil Company (Indiana)*

RUSSELL DE YOUNG  
*Chairman of the Board,  
The Goodyear Tire & Rubber Company*

WILLIAM WEBSTER  
*Chairman, New England Electric System*

WILLIAM BEVERLY MURPHY  
*President, Campbell Soup Company*

LAURANCE SPELMAN ROCKEFELLER  
*Chairman, Rockefeller Brothers, Inc.*

ROBERT HENRY WINTERS  
*President, Brazilian Light and Power Company Limited*

UNCAS AENEAS WHITAKER  
*Chairman of the Board, AMP Incorporated*

JULIUS ADAMS STRATTON  
*President Emeritus,  
Massachusetts Institute of Technology*

LUIS ALBERTO FERRÉ  
*Governor of Puerto Rico*

SEMON EMIL KNUDSEN  
*President, Ford Motor Company*

ROBERT BAYLOR SEMPLE  
*President, Wyandotte Chemicals Corporation*

IRÉNÉE DU PONT  
*Vice President and Director,  
E. I. du Pont de Nemours & Company, Inc.*

EUGENE MCDERMOTT  
*Director, Texas Instruments Incorporated*

**MEMBERS:**

WILLIAM SOUTHER BREWSTER (1970)  
*Chairman of the Board, USM Corporation*

DAYTON HARRIS CLEWELL (1970)  
*Senior Vice President, Mobil Oil Corporation*

JOHN CHARLES HAAS (1970)  
*Vice Chairman and Executive Vice President,  
Rohm and Haas Company*

DOUGLAS MAITLAND KNIGHT (1970)  
*Vice President, RCA Corporation*

<sup>1</sup>Address correspondence to the Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.

<sup>2</sup>Terms expire on June 30 of the year indicated.

ALFRED EDWARD PERLMAN (1970)  
*President, Penn Central*

JOHN KENNETH JAMIESON (1971)  
*President, Standard Oil Company (New Jersey)*

JOHN LAWRENCE (1971)  
*Chairman of the Board,  
 Dresser Industries, Inc.*

GEORGE WIDMER THORN (1971)  
*Physician-in-Chief, Peter Bent Brigham Hospital*

GEORGE RAYMOND VILA (1971)  
*Chairman and President, Uniroyal, Inc.*

ROBERT BURNS WOODWARD (1971)  
*Donner Professor of Science, Harvard University*

ALBERT HOSMER BOWKER (1972)  
*Chancellor, City University of New York*

GEORGE PHIPPEN EDMONDS (1972)  
*Honorary Chairman of the Board,  
 Wilmington Trust Company*

RALPH FREDERICK GOW (1972)  
*Former President, Norton Company*

DONALD ARCHER HOLDEN (1972)  
*Chairman, Newport News Shipbuilding and  
 Dry Dock Company*

H. I. ROMNES (1972)  
*Chairman of the Board,  
 American Telephone and Telegraph Company*

WILLIAM EDWARD HARTMANN (1973)  
*General Partner, Skidmore, Owings & Merrill*

FRANK ROSCOE MILLIKEN (1973)  
*President, Kennecott Copper Corporation*

HENRY EARL SINGLETON (1973)  
*Chairman of the Board and Chief Executive Officer,  
 Teledyne, Inc.*

GREGORY SMITH (1973)  
*President and General Manager,  
 Eastman Gelatine Corporation*

THORNTON ARNOLD WILSON (1973)  
*President, The Boeing Company*

JAMES ANTHONY CHAMPY (1974)  
*Attorney at Law,  
 Lawrence, Massachusetts*

ELISHA GRAY II (1974)  
*Chairman of the Board,  
 Whirlpool Corporation*

WILLIAM REDE HAWTHORNE (1974)  
*Master, Churchill College,  
 Cambridge, England*

JEROME HEARTWELL HOLLAND (1974)  
*President, Hampton Institute*

BREENE MITCHELL KERR (1974)  
*Senior Partner,  
 Resource Analysis and Management Group, Inc.*

CARL MUTH MUELLER (1974)  
*Partner, Loeb, Rhoades & Co.*

HAROLD EUGENE THAYER (1974)  
*Chairman and President, Mallinckrodt Chemical Works*

JEPHTHA HOMER WADE (1974)  
*Partner, Choate, Hall & Stewart*

**PRESIDENT OF THE ALUMNI ASSOCIATION**

PHILIP HOMER PETERS  
*Senior Vice President, John Hancock Mutual  
 Life Insurance Company*

**REPRESENTATIVES OF THE COMMONWEALTH**

HIS EXCELLENCY, FRANCIS WILLIAMS SARGENT  
*Governor*

HONORABLE RAYMOND SANGER WILKINS  
*Chief Justice of the Supreme Judicial Court*

NEIL VINCENT SULLIVAN  
*Commissioner of Education*

**LIFE MEMBERS, EMERITI**

WALTER HUMPHREYS  
*Honorary Secretary of the M.I.T. Corporation*

ALFRED LEE LOOMIS  
*President,  
 Loomis Institute for Scientific Research, Incorporated*

HARLOW SHAPLEY  
*Paine Professor of Practical Astronomy, Emeritus,  
 and former Director of the Observatory,  
 Harvard University*

RALPH EDWARD FLANDERS  
*Former United States Senator from Vermont*

HORACE SAYFORD FORD  
*Treasurer Emeritus,  
 Massachusetts Institute of Technology*

WALTER JAY BEADLE  
*Director,  
 E.I. du Pont de Nemours & Company, Inc.*

DUNCAN ROBERTSON LINSLEY  
*Director, The First Boston Corporation*

IRVING WHITE WILSON  
*Director and Former Chairman,  
 Aluminum Company of America*

HAROLD BOURS RICHMOND  
*Former Chairman,  
 General Radio Company*

MERVIN J. KELLY  
*Former President, Bell Telephone Laboratories, Inc.*

RALPH LOWELL  
*Chairman,  
 Boston Safe Deposit and Trust Company*

GWILYM ALEXANDER PRICE  
*Retired Industrialist*

GEORGE MAGOFFIN HUMPHREY  
*Director, National Steel Corporation*

JAMES HAROLD DOOLITTLE  
*Corporate Director*

**OFFICE OF THE CHAIRMAN OF THE CORPORATION**

JAMES RHYNE KILLIAN, JR., LL.D., SC.D., D.ENG.,  
 D.APPL.SCI., ED.D., HH.D.  
*Chairman of the Corporation*

WALTER LING MILNE, A.M.  
*Assistant to the Chairman of the Corporation*

ELIZABETH AILEEN PIGOTT  
*Administrative Assistant*

**PRINCIPAL ACADEMIC OFFICERS, DEANS, HEADS OF DEPARTMENTS, AND  
INSTITUTE PROFESSORS**

HOWARD WESLEY JOHNSON, LL.D., D.H.L., SC.D.	<i>President</i>	<i>Department of Metallurgy and Materials Science</i>	THOMAS BURNES KING, PH.D.	<i>Head</i>
JEROME BERT WIESNER, PH.D.	<i>Provost</i>	<i>Department of Naval Architecture and Marine Engineering</i>	ALFRED ADOLF HEINRICH KEIL, DR. RER. NAT.	<i>Head</i>
WALTER ALTER ROSENBLITH, ING. RAD.	<i>Associate Provost</i>	<i>Department of Nuclear Engineering</i>	MANSON BENEDICT, PH.D.	<i>Head</i>
PAUL EDWARD GRAY, SC.D.	<i>Associate Provost</i>			
<b>SCHOOL OF ARCHITECTURE AND PLANNING</b>		<b>SCHOOL OF HUMANITIES AND SOCIAL SCIENCE</b>		
LAWRENCE BERNHART ANDERSON, M.ARCH.	<i>Dean</i>	ROBERT LYLE BISHOP, PH.D.		<i>Dean</i>
<i>Department of Architecture</i>	<i>Head</i>	<i>Department of Economics</i>	EDGAR CARY BROWN, PH.D.	<i>Head</i>
DONLYN LYNDON, M.F.A.		<i>Department of Foreign Literatures and Linguistics</i>	WILLIAM FILBERT BOTTIGLIA, PH.D.	<i>Head</i>
<i>Department of Urban Studies and Planning</i>	<i>Head</i>	<i>Department of Humanities</i>	RICHARD MATEER DOUGLAS, PH.D.	<i>Head</i>
JOHN TASKER HOWARD, M.C.P.		<i>Department of Political Science</i>	ROBERT COLDWELL WOOD, PH.D.	<i>Head</i>
<b>SCHOOL OF ENGINEERING</b>			LOUIS MENAND III, PH.D.	<i>Head</i>
RAYMOND LEWIS BISPLINGHOFF, DR. SCI. TECHN., SC.D., ENG.D.	<i>Dean</i>	<i>Department of Psychology</i>	HANS-LUKAS TEUBER, PH.D.	<i>Head</i>
ROBERT HUGH SCOTT, S.R.	<i>Assistant Dean, Administration</i>	<b>ALFRED P. SLOAN SCHOOL OF MANAGEMENT</b>	WILLIAM FRANK POUNDS, PH.D.	<i>Dean</i>
<i>Department of Aeronautics and Astronautics</i>	<i>Head</i>		ABRAHAM J. SIEGEL, PH.D.	<i>Associate Dean</i>
RENE HARCOURT MILLER, M.A.			PETER PAUL GIL, PH.D.	<i>Associate Dean for Executive Programs</i>
ROBERT LOUIS HALFMAN, S.M.	<i>Deputy Head</i>	<b>SCHOOL OF SCIENCE</b>	ROBERT ARNOLD ALBERTY, PH.D., SC.D.	<i>Dean</i>
JOSEPH BICKNELL, S.M. ( <i>Absent</i> )	<i>Executive Officer</i>		JOEL ORLEN, M.A.	<i>Administrative Officer</i>
<i>Department of Chemical Engineering</i>		<i>Department of Biology</i>	BORIS MAGASANIK, PH.D.	<i>Head</i>
RAYMOND FREDERICK BADDOUR, SC.D.	<i>Head</i>		GENE MONTE BROWN, PH.D.	<i>Executive Officer</i>
<i>Department of Civil Engineering</i>	<i>Head</i>			
CHARLES LESLIE MILLER, S.M.				
<i>Department of Electrical Engineering</i>	<i>Head</i>			
LOUIS DIJOUR SMULLIN, S.M.				
JAMES DONALD BRUCE, SC.D.	<i>Executive Officer</i>			
<i>Department of Mechanical Engineering</i>	<i>Head</i>			
ASCHER HERMAN SHAPIRO, SC.D.				
WILLIAM MACGREGOR MURRAY, SC.D.	<i>Executive Officer</i>			

**Department of Chemistry**

JOHN ROSS, PH.D.

*Head*

JOHN WITHERS IRVINE, JR., PH.D., SC.D.

*Executive Officer*

**Department of Earth and Planetary Sciences**

FRANK PRESS, PH.D.

*Head*

**Department of Mathematics**

NORMAN LEVINSON, SC.D.

*Head*

DANIEL BURRILL RAY, PH.D.

*Executive Officer*

**Department of Meteorology**

HENRY GARRETT HOUGHTON, SC.D.

*Head*

**Department of Nutrition and Food Science**

NEVIN STEWART SCRIMSHAW, PH.D., M.D., D.P.S.

*Head*

SAMUEL ABRAHAM GOLDBLITH, PH.D.

*Deputy Head*

**Department of Physics**

VICTOR FREDERICK WEISSKOPF, PH.D., SC.D.

*Head*

GEORGE GRAHAM HARVEY, PH.D.

*Executive Officer*

**OTHER DEPARTMENTS**

**Department of Aerospace Studies**

GERALD PERSELAY, M.B.A.

*Lieutenant Colonel, U.S. Air Force*

*Head*

**Athletic Department**

ROSS HAROLD SMITH, B.S., M.ED.

*Head*

**Medical Department**

ALBERT OTTO SEELER, M.D.

*Head*

**Department of Military Science**

MARSHALL OWEN BECKER, M.A.

*Colonel, U.S. Army*

*Head*

**Department of Naval Science**

DEAN ALLEN HORN, NAV.E.

*Captain, U.S. Navy*

*Head*

**THE GRADUATE SCHOOL**

IRWIN WHITING SIZER, PH.D.

*Dean*

SANBORN CONNER BROWN, PH.D.

*Associate Dean*

ROBERT KAREL WEATHERALL, M.A.

*Assistant Dean*

MICHAEL SAMPSON BARAM, B.S., LL.B.

*Executive Officer*

**THE LIBRARIES**

WILLIAM NASH LOCKE, PH.D.

*Director*

NATALIE NEILL NICHOLSON, S.B.

*Associate Director*

MYER MICHAEL KESSLER, PH.D.

*Associate Director*

**INSTITUTE PROFESSORS**

MANSON BENEDICT, PH.D.

KENNETH B. CLARK (*Visiting*)

ARTHUR ROBERT KANTROWITZ, PH.D. (*Visiting*)

EDWIN HERBERT LAND, LL.D., SC.D. (*Visiting*)

CHIA-CHIAO LIN, PH.D.

BRUNO BENEDETTO ROSSI, PH.D.

PAUL ANTHONY SAMUELSON, PH.D., LL.D.,

D.LITT., SC.D.

VICTOR FREDERICK WEISSKOPF, PH.D., SC.D.

JEROME BERT WIESNER, PH.D.

JERROLD REINACH ZACHARIAS, PH.D., L.H.D.,

SC.D.

**Institute Professors, Emeriti**

MARTIN JULIAN BUERGER, PH.D.

CHARLES STARK DRAPER, SC.D.

HAROLD EUGENE EDGERTON, SC.D., D.ENG.

ROMAN JAKOBSON, PH.D.

FRANCIS OTTO SCHMITT, PH.D., SC.D.

JOHN CLARKE SLATER, PH.D., SC.D.

CYRIL STANLEY SMITH, SC.D.

CARL RICHARD SODERBERG, TEKN.D., D.ENG.

ARTHUR ROBERT VON HIPPEL, PH.D.

## The Faculty

### SCHOOL OF ARCHITECTURE AND PLANNING

#### ARCHITECTURE

DONLYN LYNDON, M.F.A.  
*Professor of Architecture; Head of the Department*

LAWRENCE BERNHART ANDERSON, M.ARCH.  
*Professor of Architecture;*  
*Dean of the School of Architecture and Planning*

JOHN ELY BURCHARD, L.H.D., D.ARCH.  
*Professor of Humanities Emeritus;*  
*Dean of the School of Humanities and Social Science Emeritus;*  
*Senior Lecturer*

HORACIO CAMINOS, ARQ.  
*Professor of Architecture*

EDUARDO FERNANDO CATALANO, M.ARCH.  
*Professor of Architecture*

ALBERT GEORGE HENRY DIETZ, SC.D.  
*Professor of Building Engineering*

GYORGY KEPES, M.A.  
*Professor of Visual Design;*  
*Director of the Center for Advanced Visual Studies*

ELIAHU EDUARD TRAU, SC.D.  
*Professor of Structures (Visiting)*

MINOR WHITE  
*Professor of Photography*

WACLAW PIOTR ZALEWSKI, D.TECH.SCI.  
*Professor of Structures*

WAYNE VESTI ANDERSEN, PH.D.  
*Associate Professor of the History of Art;*  
*Director of Exhibitions*

STANFORD ANDERSON, M.A.  
*Associate Professor of the History of Architecture*

WILLIAM HOSKINS BROWN, M.ARCH.  
*Associate Professor of Architecture*

RICHARD FILIPOWSKI, B.A.  
*Associate Professor of Visual Design*

SPIRO KOSTOF, PH.D.  
*Associate Professor of Architecture (Visiting)*

TED KRAYNIK, M.F.A.  
*Associate Professor of Visual Design (Visiting)*

KARL LINN, M.A.  
*Associate Professor of Architecture and City Planning*

HENRY ARMAND MILLON, PH.D.  
*Associate Professor of the History of Architecture*

JOHN RANDOLPH MYER, B.ARCH.  
*Associate Professor of Architecture*

ROBERT BRADFORD NEWMAN, SC.D.  
*Associate Professor of Architecture*

ROBERT ORMEROD PREUSSER (Absent)  
*Associate Professor of Visual Design*

MAURICE KEITH SMITH, B.ARCH.  
*Associate Professor of Architecture*

CHESTER LEE SPRAGUE, M.ARCH.  
*Associate Professor of Architecture*

EDWARD BLAIR ALLEN, M.ARCH.  
*Assistant Professor of Architecture*

ROBERT GOODMAN, B.ARCH.  
*Assistant Professor of Architecture*

JONATHAN WILLIAM GREEN, M.A.  
*Assistant Professor of Photography*

LEON BENNETT GROISSER, A.B., B.S., M.B.A.  
*Assistant Professor of Structures*

ROSALIND EPSTEIN KRAUSS, M.A.  
*Assistant Professor of the History of Art*

PATRICK MORREAU, B.A.  
*Assistant Professor of Structures*

NICHOLAS PETER NEGROPONTE, M.ARCH.  
*Assistant Professor of Architecture*

WILLIAM LYMAN PORTER, B.A., B.ARCH.  
*Assistant Professor of Urban Design*

JOHN AMES STEFFIAN, M.ARCH.  
*Assistant Professor of Architecture*

GEORGE CULBRETH THOMAS, II, M.F.A.  
*Assistant Professor of Photography*

#### Lecturers

HANS H. HARMS, M.U.R.P.  
EDWARD PINCUS, A.B.

#### Instructors

HENRY ELLIOTT FOLEY, JR., A.B.  
RICHARD CHESTER TREMAGLIO, B.ARCH.

#### Technical Instructor

NISHAN BICHAJIAN

#### Research Associates

IGNACIO HIPOLITO GARABIETA-ORUETA, DIPL.  
MARVIN EDWARD GOODY, M.ARCH., M.C.P.  
TIMOTHY EDWARD JOHNSON, S.M.  
CALVIN FRED OPITZ, M.ARCH.  
ROBERT JOSEPH PELLETIER, B.ARCH., BLDG.E.

#### Professors Emeriti

PIETRO BELLUSCHI, DOTT.ING., LL.D., SC.D., D.F.A.  
*Professor of Architecture, Emeritus;*  
*Dean of the School of Architecture and Planning,*  
*Emeritus*

HERBERT LYNES BECKWITH, M.ARCH.  
*Professor of Architecture, Emeritus*

HENRY LATIMER SEAVER, A.M.  
*Professor of History, Emeritus*

## URBAN STUDIES AND PLANNING

- JOHN TASKER HOWARD, M.C.P.  
*Professor of City Planning; Head of the Department*
- FREDERICK JOHNSTONE ADAMS, B.ARCH.  
*Professor of City Planning, Emeritus; Senior Lecturer*
- AARON FLEISHER, SC.D.  
*Professor of Urban and Regional Studies*
- BERNARD JOEL FRIEDEN, PH.D.  
*Professor of City Planning*
- HERBERT J. GANS, PH.D.  
*Professor of Sociology and Planning*
- ROLAND BRADFORD GREELEY, M.C.P.  
*Professor of Regional Planning; Director of Admissions*
- KEVIN ANDREW LYNCH, B.C.P.  
*Professor of City Planning*
- FRANK ISAAC MICHELMAN  
*Professor of Law (Visiting)*
- LLOYD RODWIN, PH.D.  
*Professor of Land Economics*
- JEROME ROTHENBERG, PH.D.  
*Professor of Economics*
- DONALD ALLEN SCHON, PH.D.  
*Professor of Urban Studies (Visiting)*
- ROBERT M. FOGELSON  
*Associate Professor of History and City Planning*
- RALPH A. GAKENHEIMER, PH.D.  
*Associate Professor of Urban Studies (Visiting)*
- KARL LINN, M.A.  
*Associate Professor of Architecture and City Planning*
- LISA REDFIELD PEATTIE, PH.D.  
*Associate Professor of Anthropology*
- STEPHEN CARR, M. ARCH.  
*Assistant Professor of Urban Design*
- LANGLEY CARLETON KEYES, PH.D.  
*Assistant Professor of City Planning*
- WILLIAM LYMAN PORTER, B.A., B.ARCH.  
*Assistant Professor of Urban Design*
- RONALD A. WALTER, PH.D.  
*Assistant Professor of Urban Studies*
- DANIEL WEISBERG, B.S.  
*Assistant Professor of Real Estate Economics (Visiting)*
- Senior Lecturers**
- MORRIS AXELFOD, PH.D.
- CHRISTOPHER D. FOSTER, M.A.
- Lecturers**
- ALEXANDER GANZ, B.A.
- PHILIP BARNARD HERR, M.C.P.
- MARY C. POTTER, PH.D.
- JOHN FRANCIS CHARLEWOOD TURNER, DIPL.ARCH.
- ROBERT S. WEISS, PH.D.
- Instructor**
- WREN MEYER McMANS, S.B.
- Research Associate**
- MAY B. HIPSHMAN, M.C.P.
- Professor Emeritus**
- FREDERICK JOHNSTONE ADAMS, B.ARCH.  
*Professor of City Planning, Emeritus; Senior Lecturer*

## SCHOOL OF ENGINEERING

- RAYMOND LEWIS BISPLINGHOFF, DR.SCI. TECHN.,  
SC.D., ENG.D.  
*Dean*
- ROBERT HUGH SCOTT, S.B.  
*Assistant Dean, Administration*
- ROBERT PAUL GREENE, S.B.  
*Administrative Assistant*
- ENGINEERING COUNCIL**
- RENE HARCOURT MILLER, M.A.  
*Head, Department of Aeronautics and Astronautics*
- RAYMOND FREDERICK BADDOUR, SC.D.  
*Head, Department of Chemical Engineering*
- CHARLES LESLIE MILLER, S.M.  
*Head, Department of Civil Engineering*
- LOUIS DIJOUR SMULLIN, S.M.  
*Head, Department of Electrical Engineering*
- ASCHER HERMAN SHAPIRO, SC.D.  
*Head, Department of Mechanical Engineering*
- THOMAS BURNES KING, PH.D.  
*Head, Department of Metallurgy and Materials Science*
- ALFRED ADOLF HEINRICH KEIL, DR.RER.NAT.  
*Head, Department of Naval Architecture  
and Marine Engineering*
- MANSON BENEDICT, PH.D.  
*Head, Department of Nuclear Engineering*
- ROBERT GRAY GALLAGER, SC.D.  
*School Representative on the Faculty Committee on  
Educational Policy*
- HAROLD SOMERS MICKLEY, SC.D.  
*Director, Center for Advanced Engineering Study*
- SCHOOL PROFESSORS**
- CARL F. J. OVERHAGE, PH.D.  
*Professor of Engineering*
- JOHN BENSON WILBUR, SC.D.  
*Consulting Professor of Engineering*

FACULTY

AERONAUTICS AND ASTRONAUTICS

- RENE HARCOURT MILLER, M.A.  
*H. N. Slater Professor of Flight Transportation;  
Head of the Department*
- ROBERT LOUIS HALFMAN, S.M.  
*Professor of Aeronautics and Astronautics;  
Deputy Head of the Department*
- JOSEPH BICKNELL, S.M. (*Absent*)  
*Professor of Aeronautics and Astronautics;  
Executive Officer*
- JUDSON RICHARD BARON, SC.D.  
*Professor of Aeronautics and Astronautics*
- RAYMOND LEWIS BISPLINGHOFF, DR.SCI.TECHN.,  
SC.D., ENG.D.  
*Professor of Aeronautics and Astronautics;  
Dean of the School of Engineering*
- MILTON URE CLAUSER, PH.D.  
*Professor of Aeronautics and Astronautics;  
Director of Lincoln Laboratory*
- EUGENE EDZARDS COVERT, SC.D.  
*Professor of Aeronautics and Astronautics*
- CHARLES STARK DRAPER, SC.D.  
*Institute Professor, Emeritus; Professor of Aeronautics and  
Astronautics, Emeritus; Director of the Instrumentation  
Laboratory*
- MORTON FINSTON, PH.D.  
*Professor of Aeronautics and Astronautics*
- JOHN VINCENT HARRINGTON, SC.D.  
*Professor of Aeronautics and Astronautics;  
Director of the Center for Space Research*
- JEROME CLARKE HUNSAKER, SC.D., ENG.D.  
*Professor of Aeronautical Engineering, Emeritus*
- JACK LEO KERREBROCK, PH.D.  
*Professor of Aeronautics and Astronautics*
- OTTO CARL KOPPEN, S.B.  
*Professor of Flight Vehicle Engineering, Emeritus;  
Senior Lecturer*
- MARTEN TEODOR LANDAHL, TEKN.D. (*Absent*)  
*Professor of Aeronautics and Astronautics*
- YAO TZU LI, SC.D.  
*Professor of Aeronautics and Astronautics*
- JAMES WAH MAR, SC.D. (*Absent*)  
*Professor of Aeronautics and Astronautics*
- WINSTON ROSCOE MARKEY, SC.D.  
*Professor of Aeronautics and Astronautics*
- JAMES ELLIOT McCUNE, PH.D.  
*Professor of Aeronautics and Astronautics*
- WALTER MCKAY, S.M.  
*Professor of Aeronautics and Astronautics*
- THEODORE HSUEH-HUANG PIAN, SC.D.  
*Professor of Aeronautics and Astronautics*
- PAUL EDWIN SANDORFF, S.B.  
*Professor of Aeronautics and Astronautics (Visiting)*
- EDWARD STORY TAYLOR, S.R.  
*Professor of Flight Propulsion, Emeritus;  
Senior Lecturer*
- LEON TRILLING, PH.D.  
*Professor of Aeronautics and Astronautics*
- WALLACE EARL VANDER VELDE, SC.D.  
*Professor of Aeronautics and Astronautics*
- HAROLD YEHUDA WACHMAN, PH.D.  
*Professor of Aeronautics and Astronautics*
- HENRY PHILIP WHITAKER, S.M.  
*Professor of Aeronautics and Astronautics*
- EMMETT ATLEE WITMER, SC.D.  
*Professor of Aeronautics and Astronautics*
- WALTER WRIGLEY, SC.D.  
*Professor of Instrumentation and Astronautics*
- JOHN DUGUNDJI, SC.D.  
*Associate Professor of Aeronautics and Astronautics*
- NORMAN DOUGLAS HAM, SC.D.  
*Associate Professor of Aeronautics and Astronautics*
- WALTER MARK HOLLISTER, SC.D.  
*Associate Professor of Aeronautics and Astronautics*
- ELMER EUGENE LARRABEE, S.M.  
*Associate Professor of Aeronautics and Astronautics*
- WILLIAM STEPHEN LEWELLEN, PH.D.  
*Associate Professor of Aeronautics and Astronautics*
- JEAN FRANCOIS LOUIS, PH.D.  
*Associate Professor of Aeronautics and Astronautics*
- ROBERT KARL MUELLER, SC.D.  
*Associate Professor of Aeronautics and Astronautics*
- JAMES EMERSON POTTER, PH.D.  
*Associate Professor of Aeronautics and Astronautics*
- ROBERT WARREN SIMPSON, SC.D.  
*Associate Professor of Aeronautics and Astronautics*
- ALBERT SOLBES, PH.D.  
*Associate Professor of Aeronautics and Astronautics*
- LAURENCE RETMAN YOUNG, SC.D.  
*Associate Professor of Aeronautics and Astronautics*
- FRANK KINGSLEY BENTLEY  
*Assistant Professor of Aeronautics and Astronautics, Emeritus;  
Senior Lecturer*
- LOUIS LAWRENCE BUCCIARELLI, JR., PH.D.  
*Assistant Professor of Aeronautics and Astronautics*
- JAMES DONALD CALLEN, PH.D.  
*Assistant Professor of Aeronautics and Astronautics*
- RENWICK EUGENE CURRY, SC.D.  
*Assistant Professor of Aeronautics and Astronautics*
- JOHN JACOB DEYST, JR., SC.D.  
*Assistant Professor of Aeronautics and Astronautics*
- SHAOL EZEKIEL, SC.D.  
*Assistant Professor of Aeronautics and Astronautics*
- AMOS LEVIN, PH.D.  
*Assistant Professor of Aeronautics and Astronautics*
- JACOB LEON MEIRY, SC.D.  
*Assistant Professor of Aeronautics and Astronautics*
- JAMES PATRICK MORAN, PH.D.  
*Assistant Professor of Aeronautics and Astronautics*
- DAVID ANTHONY OLIVER, PH.D.  
*Assistant Professor of Aeronautics and Astronautics*
- DAVID BRUCE STICKLER, PH.D.  
*Assistant Professor of Aeronautics and Astronautics*

CHRISTOPHER KWONG WAH TAM, PH.D.  
*Assistant Professor of Aeronautics and Astronautics;  
 Postdoctoral Fellow in Engineering*

PIN TONG, PH.D.  
*Assistant Professor of Aeronautics and Astronautics*

SHEILA EVANS WIDNALL, SC.D.  
*Assistant Professor of Aeronautics and Astronautics*

**Administrative Officer**

JOHN RONALD MARTUCCELLI, S.M.

**Lecturers**

MICHAEL SAMPSON BARAM, B.S., LL.B.

RICHARD HORACE BATTIN, PH.D.

ELMER JACOB FREY, PH.D.

JOHN HOVORKA, SC.D.

ANDREW JAMES LINCOLN, PH.D.

ROBERT GOTTLIEB STERN, PH.D.

**Technical Instructors**

JOHN BARLEY

ALLAN RALPH SHAW

**Research Associates**

CHARLES WALDO HALDEMAN, SC.D.

ALFRED DAVID WEISS, M.D.

**Professors Emeriti**

FRANK KINGSLEY BENTLEY

*Assistant Professor of Aeronautics and Astronautics, Emeritus;  
 Senior Lecturer*

CHARLES STARK DRAPER, SC.D.

*Institute Professor, Emeritus; Professor of Aeronautics and Astronautics, Emeritus; Director of the Instrumentation Laboratory*

JEROME CLARKE HUNSAKER, SC.D., ENG.D.

*Professor of Aeronautical Engineering, Emeritus*

OTTO CARL KOPPEN, S.B.

*Professor of Flight Vehicle Engineering, Emeritus;  
 Senior Lecturer*

JOHN RAYMOND MARKHAM

*Professor of Aeronautical Engineering, Emeritus*

SHATSWELL OBER, S.B.

*Professor of Aeronautical Engineering, Emeritus*

EDWARD STORY TAYLOR, S.B.

*Professor of Flight Propulsion, Emeritus;  
 Senior Lecturer*

**CHEMICAL ENGINEERING**

RAYMOND FREDERICK BADDOUR, SC.D.

*Professor of Chemical Engineering; Head of the Department*

PIERRE LEONCE THIBAUT BRIAN, SC.D. (Absent)

*Professor of Chemical Engineering*

EDWIN RICHARD GILLILAND, SC.D., D.ENG.

*Warren K. Lewis Professor of Chemical Engineering*

HOYT CLARKE HOTTEL, A.B., S.M.

*Professor of Chemical Engineering, Emeritus;  
 Senior Lecturer*

WARREN KENDALL LEWIS, PH.D., D.SC., D.ENG.

*Professor of Chemical Engineering, Emeritus*

HERMAN PAUL MEISSNER, D.SC.

*Professor of Chemical Engineering*

EDWARD WILSON MERRILL, SC.D. (Absent)

*Professor of Chemical Engineering*

HAROLD SOMERS MICKLEY, SC.D.

*Ford Professor of Chemical Engineering;  
 Director of the Center for Advanced Engineering Study*

ROBERT CLARK REID, SC.D.

*Professor of Chemical Engineering*

CHARLES NELSON SATTERFIELD, SC.D.

*Professor of Chemical Engineering*

THOMAS KILGORE SHERWOOD, SC.D., ENG.D.

*Professor of Chemical Engineering, Emeritus; Senior Lecturer*

JOHNSON EDWARD VIVIAN, SC.D.

*Professor of Chemical Engineering*

GLENN CARBER WILLIAMS, SC.D.

*Professor of Chemical Engineering*

SAMUEL WRIGHT BODMAN, III, SC.D.

*Associate Professor of Chemical Engineering*

LAWRENCE BOYD EVANS, PH.D.

*Associate Professor of Chemical Engineering*

ALLAN SACHS HOFFMAN, SC.D.

*Associate Professor of Chemical Engineering*

ADEL FARES SAROFIM, SC.D.

*Associate Professor of Chemical Engineering*

KENNETH ALAN SMITH, SC.D.

*Associate Professor of Chemical Engineering*

CLARK KENNETH COLTON, PH.D.

*Assistant Professor of Chemical Engineering;  
 Postdoctoral Fellow in Engineering*

FRANCIS RICHARD COTTRELL, SC.D.

*Assistant Professor of Chemical Engineering*

WILLIAM HOWARD DALZEL, SC.D.

*Assistant Professor of Chemical Engineering*

JOHN THOMAS DAY, SC.D.

*Assistant Professor of Chemical Engineering;  
 Director of the Bound Brook Station, School of  
 Chemical Engineering Practice*

MAX CURTIS DEIBERT, SC.D.

*Assistant Professor of Chemical Engineering*

HUGH BRADLEY HALES, SC.D.

*Assistant Professor of Chemical Engineering*

JACK BENNEY HOWARD, PH.D.

*Assistant Professor of Chemical Engineering*

## FACULTY

GEOFFREY MARGOLIS, SC.D.  
*Assistant Professor of Chemical Engineering*

ROBERT HOUSKA MAYER, SC.D.  
*Assistant Professor of Chemical Engineering;*  
*Director of the Oak Ridge Station, School of*  
*Chemical Engineering Practice*

MICHAEL MODELL, SC.D.  
*Assistant Professor of Chemical Engineering*

JAMES JEFFREY NOBLE, PH.D.  
*Assistant Professor of Chemical Engineering*

PREETINDER SINGH VIRK, PH.D.  
*Assistant Professor of Chemical Engineering*

### *Administrative Officer*

MARGARET SCHULER BARRETT

### *Instructor*

SAMUEL McCLAIN FLEMING, S.M.

### *Technical Instructors*

HAROLD HAVNER CARTER  
REED CAMPBELL FULTON  
STANLEY ROBERT MITCHELL

### *Senior Research Associates*

W. GERALD AUSTEN, M.D.  
EDWIN W. SALZMAN, M.D.

## STATIONS OF THE SCHOOL OF CHEMICAL ENGINEERING PRACTICE

### *Directors*

ROBERT HOUSKA MAYER, SC.D. *Oak Ridge*  
JOHN THOMAS DAY, SC.D. *Bound Brook*

### *Assistant Directors and Instructors*

NIGEL WILLIAM ERSKINE CURLET, S.M.  
*Bound Brook*

MICHAEL SYLVESTER BAUTISTA, B.S.  
*Oak Ridge*

### *Professors Emeriti*

THOMAS BRADFORD DREW, S.M.  
*Professor of Chemical Engineering, Emeritus*

HOYT CLARKE HOTTEL, A.B., S.M.  
*Professor of Chemical Engineering, Emeritus;*  
*Senior Lecturer*

WARREN KENDALL LEWIS, PH.D., D.SC., D.ENG.  
*Professor of Chemical Engineering, Emeritus*

WILLIAM HENRY McADAMS, D.SC.  
*Professor of Chemical Engineering, Emeritus*

THOMAS KILGORE SHERWOOD, SC.D., ENG.D.  
*Professor of Chemical Engineering, Emeritus; Senior Lecturer*

HAROLD CHRISTIAN WEBER, D.SC.  
*Professor of Chemical Engineering, Emeritus*

WALTER GORDON WHITMAN, SC.D.  
*Professor of Chemical Engineering, Emeritus*

## CIVIL ENGINEERING

CHARLES LESLIE MILLER, S.M.  
*Professor of Civil Engineering;*  
*Head of the Department;*  
*Director of the Urban Systems Laboratory*

ERNST BASLER, PH.D.  
*Professor of Civil Engineering (Visiting)*

JOHN MELVIN BIGGS, S.M.  
*Professor of Civil Engineering*

JOHN CLARKESON, SC.D.  
*Professor of Civil Engineering (Visiting)*

JOHN FREDERICK COLLINS, PH.D., D.C.L.  
*Professor of Urban Affairs (Visiting)*

PETER STURGES EAGLESON, SC.D.  
*Professor of Civil Engineering*

ROBERT JOSEPH HANSEN, SC.D.  
*Professor of Civil Engineering*

DONALD ROBERT FERGUSSON HARLEMAN, SC.D.  
*Professor of Civil Engineering*

MYLE JOSEPH HOLLEY, JR., S.M.  
*Professor of Civil Engineering*

ARTHUR THOMAS IPPEN, PH.D.  
*Ford Professor of Civil Engineering*

FRANK SIDNEY JONES, M.B.A.  
*Professor of Urban Affairs; Executive Director of The*  
*Urban Systems Laboratory*

THOMAS WILLIAM LAMBE, SC.D.  
*Edmund K. Turner Professor of Civil Engineering*

ALBERT SCHEFFER LANG, S.M.  
*Professor of Civil Engineering (Visiting)*

WILLIAM WALTHER SEIFERT, SC.D.  
*Professor of Engineering*

ROBERT VAN DUYNE WHITMAN, SC.D. (*Absent*)  
*Professor of Civil Engineering*

ALEXANDER JAMIESON BONE, S.M.  
*Associate Professor of Civil Engineering, Emeritus;*  
*Senior Lecturer*

JEROME JOSEPH CONNOR, JR., SC.D.  
*Associate Professor of Civil Engineering*

CARL ALLIN CORNELL, PH.D.  
*Associate Professor of Civil Engineering*

HERMANN FLESSNER, DR.ING.  
*Associate Professor of Civil Engineering (Visiting)*

LYNN WALTER GELHAR, PH.D.  
*Associate Professor of Civil Engineering*

RONALD COLMAN HIRSCHFELD, PH.D.  
*Associate Professor of Civil Engineering*

RUSSEL CAMERON JONES, PH.D.  
*Associate Professor of Civil Engineering*

CHARLES CUSHING LADD, SC.D.  
*Associate Professor of Civil Engineering*

WILLIAM ALBERT LITTLE, SC.D.  
*Associate Professor of Civil Engineering*

ROBERT DANIEL LOGCHER, SC.D. (*Absent*)  
*Associate Professor of Civil Engineering*

MARVIN LEE MANHEIM, PH.D.  
*Associate Professor of Civil Engineering*

CHIANG CHUNG MEI, PH.D.  
*Associate Professor of Civil Engineering*

FRED MOAVENZADEH, PH.D.  
*Associate Professor of Civil Engineering*

PETER JAN PAHL, SC.D.  
*Associate Professor of Civil Engineering*

FRANK EDWARD PERKINS, SC.D.  
*Associate Professor of Civil Engineering*

JOSE MANUEL ROESSET VINUESA, SC.D.  
*Associate Professor of Civil Engineering*

SURENDA POONAMCHAND SHAH, PH.D.  
*Associate Professor of Civil Engineering (Visiting)*

ANWAR ERNEST ZAKI WISSA, SC.D.  
*Associate Professor of Civil Engineering*

LESLIE GLENN BROMWELL, SC.D.  
*Assistant Professor of Civil Engineering*

JOHN THOMAS CHRISTIAN, PH.D.  
*Assistant Professor of Civil Engineering*

RALPH HERBERT CROSS, III, PH.D.  
*Assistant Professor of Civil Engineering*

DAVID JOHN D'APPOLONIA, PH.D.  
*Assistant Professor of Civil Engineering*

RICHARD LAWRENCE DENEUFVILLE, PH.D.  
*Assistant Professor of Civil Engineering*

MICHAEL BICK GODFREY, SC.D.  
*Assistant Professor of Civil Engineering; Postdoctoral  
Fellow in Engineering*

ALAN MARTIN HERSHDORFER, PH.D.  
*Assistant Professor of Civil Engineering*

RALPH LYONS KEENEY, PH.D.  
*Assistant Professor of Civil Engineering;  
Postdoctoral Fellow in Engineering*

DAVID CECIL MAJOR, PH.D.  
*Assistant Professor of Civil Engineering*

DAVID HUNTER MARKS, PH.D.  
*Assistant Professor of Civil Engineering*

MARK FREDERICK NELSON, PH.D.  
*Assistant Professor of Civil Engineering*

KENNETH FRANK REINSCHMIDT, PH.D.  
*Assistant Professor of Civil Engineering*

DANIEL ROOS, PH.D.  
*Assistant Professor of Civil Engineering*

JOHN CHRISTIAN SCHAAKE, JR., PH.D.  
*Assistant Professor of Civil Engineering*

JOSEPH HOOVER STAFFORD, PH.D.  
*Assistant Professor of Civil Engineering*

JOSEPH MARTIN SUSSMAN, PH.D.  
*Assistant Professor of Civil Engineering*

**Administrative Officer**

TROND HANS KAALSTAD, S.M.

**Senior Lecturers**

HERBERT IRVING GROSS, B.S.  
EDWARD EMMET NEWMAN, S.M.

**Lecturers**

DANIEL BRAND, S.M.  
HENRY WOLFGANG BRUCK, A.M.  
GOIN NEIL HARPER, PH.D. (*Visiting*)  
HARRY GEORGE POULOS, PH.D. (*Visiting*)  
MARY ELIZABETH SCHUMACKER, S.B.

**Instructors**

JAMES ELVIN DAILEY, S.M.  
JOHN FAYI ELLIOTT, M.S.  
WAYNE MARTIN PECKNOLD, S.M.  
MORRIS LEWELLYN THATCHER, S.M.

**Technical Instructors**

JAMES THOMAS KING  
ALBERT JOSEPH O'NEILL, S.B.

**Administrative Assistant**

MICHAEL VINCENT SOLOMITA, B.B.A.

**Senior Research Associate**

LOWELL K. BRIDWELL

**Research Associates**

HERBERT HEINRICH EINSTEIN, SC.D.  
ODD ERIK GJORV, C.E.  
WILLIAM ROGER JOBIN, S.M.  
ROBERT TORRENCE MARTIN, PH.D.  
WILLIAM TERRANCE O'BRIEN, PH.D.  
EARL ROGER RUITER, M.S.  
CETIN SOYDEMIR, M.E.  
JOHN HOWARD SUHRBIER, S.M.  
LYLE ANTHONY WOLFSKILL, PH.D.

**Professors Emeriti**

JOHN BRAZER BABCOCK, 3D, S.B.  
*Professor of Railway Engineering, Emeritus*  
ALEXANDER JAMIESON BONE, S.M.  
*Associate Professor of Civil Engineering, Emeritus;  
Senior Lecturer*  
EUGENE MIRABELLI, S.B.  
*Associate Professor of Civil Engineering, Emeritus*  
WILLIAM EDWARD STANLEY, C.E.  
*Professor of Sanitary Engineering, Emeritus*

## ELECTRICAL ENGINEERING

- LOUIS DIJOUR SMULLIN, S.M.  
*Professor of Electrical Engineering;  
Head of the Department*
- JAMES DONALD BRUCE, SC.D.  
*Associate Professor of Electrical Engineering;  
Executive Officer*
- RICHARD BROOKS ADLER, SC.D.  
*Professor of Electrical Engineering*
- AMAR GOPAL BOSE, SC.D.  
*Clarence Joseph LeBel Professor of Electrical Engineering*
- GORDON STANLEY BROWN, SC.D., D.ENG., TEKN.D.  
*Dugald C. Jackson Professor of Electrical Engineering*
- LAN JEN CHU, SC.D.  
*Edwin Sibley Webster Professor of Electrical Engineering*
- FERNANDO JOSÉ CORBATÓ, PH.D.  
*Professor of Electrical Engineering*
- WILBUR BAYLEY DAVENPORT, JR., SC.D.  
*Professor of Electrical Engineering*
- JACK BONNELL DENNIS, SC.D.  
*Professor of Electrical Engineering*
- MILDRED S. DRESSELHAUS, PH.D.  
*Professor of Electrical Engineering*
- MURRAY EDEN, PH.D.  
*Professor of Electrical Engineering*
- HAROLD EUGENE EDGERTON, SC.D., D.ENG.  
*Institute Professor, Emeritus;  
Professor of Electrical Measurements, Emeritus*
- PETER ELIAS, PH.D.  
*Professor of Electrical Engineering*
- DAVID JACOB EPSTEIN, SC.D.  
*Professor of Electrical Engineering*
- ROBERT MARIO FANO, SC.D.  
*Ford Professor of Engineering*
- RICHARD HENRY FRAZIER, S.M.  
*Professor of Electromechanics, Emeritus; Senior Lecturer*
- LAWRENCE SAMUEL FRISHKOPF, PH.D.  
*Professor of Electrical Engineering*
- ROBERT GRAY GALLAGER, SC.D.  
*Professor of Electrical Engineering*
- HARRY CONSTANTINE GATOS, PH.D.  
*Professor of Molecular Engineering; Associate Director  
of the Center for Materials Science and Engineering*
- LEONARD ABRAHAM GOULD, SC.D.  
*Professor of Electrical Engineering*
- PAUL EDWARD GRAY, SC.D.  
*Class of 1922 Professor of Electrical Engineering;  
Assistant Provost*
- TRUMAN STRETCHER GRAY, SC.D.  
*Professor of Engineering Electronics*
- JOHN VINCENT HARRINGTON, SC.D.  
*Professor of Electrical Engineering;  
Director of the Center for Space Research*
- HERMANN ANTON HAUS, SC.D.  
*Professor of Electrical Engineering*
- HAROLD LOCKE HAZEN, SC.D.  
*Professor of Electrical Engineering, Emeritus;  
Dean of the Graduate School, Emeritus;  
Foreign Study Adviser*
- FREDERICK CLAIR HENNIE, III, SC.D.  
*Professor of Electrical Engineering*
- ROBERT LOUIS KYHL, PH.D.  
*Professor of Electrical Engineering*
- FRANCIS FAN LEE, PH.D.  
*Professor of Electrical Engineering*
- YUK-WING LEE, SC.D.  
*Professor of Electrical Engineering  
Emeritus; Senior Lecturer*
- JEROME YSRAEL LETTVIN, M.D.  
*Professor of Communications Physiology*
- JOSEPH CARL ROBNETT LICKLIDER, PH.D.  
*Professor of Electrical Engineering*
- SAMUEL JEFFERSON MASON, SC.D.  
*Professor of Electrical Engineering;  
Associate Director of the Research Laboratory of Electronics*
- ALAN LOUIS McWHORTER, SC.D.  
*Professor of Electrical Engineering;  
Head of the Solid State Division, Lincoln Laboratory*
- JAMES RUSSELL MELCHER, PH.D.  
*Professor of Electrical Engineering*
- MARVIN LEE MINSKY, PH.D.  
*Professor of Electrical Engineering*
- FREDERIC RICHARD MORGENTHAUER, PH.D. (*Absent*)  
*Professor of Electrical Engineering*
- GEORGE CHENEY NEWTON, JR., SC.D.  
*Professor of Electrical Engineering*
- PAUL LIVINGSTONE PENFIELD, JR., SC.D.  
*Professor of Electrical Engineering*
- GEORGE WOODMAN PRATT, JR., PH.D.  
*Professor of Electrical Engineering*
- ROBERT HARMON REDIKER, PH.D.  
*Professor of Electrical Engineering*
- JOHN FRANCIS REINTJES, M.E.E.  
*Professor of Electrical Engineering*
- WALTER ALTER ROSENBLITH, ING. RAD.  
*Professor of Communications Biophysics*
- JACK PHILIP RUINA, D.E.E.  
*Professor of Electrical Engineering;  
Vice President for Special Laboratories*
- WILLIAM FRANCIS SCHREIBER, PH.D.  
*Professor of Electrical Engineering*
- CAMPBELL LEACH SEARLE, S.M.  
*Professor of Electrical Engineering*
- WILLIAM WALTHER SEIFERT, SC.D.  
*Professor of Electrical Engineering*
- CLAUDE ELWOOD SHANNON, PH.D.  
*Donner Professor of Science*
- WILLIAM MCGONWAY SIEBERT, SC.D. (*Absent*)  
*Professor of Electrical Engineering*
- ALEXANDER SMAKULA, PH.D.  
*Professor of Crystal Physics, Emeritus; Senior Lecturer*
- ARTHUR CLARKE SMITH, PH.D. (*Absent*)  
*Professor of Electrical Engineering*
- KENNETH NOBLE STEVENS, SC.D. (*Absent*)  
*Professor of Electrical Engineering*

- RICHARD DOUGLAS THORNTON, SC.D.  
*Professor of Electrical Engineering*
- JOHN GEORGE TRUMP, SC.D.  
*Professor of Electrical Engineering*
- HARRY LESLIE VAN TREES, JR., SC.D. (*Absent*)  
*Professor of Electrical Engineering*
- DAVID CALVIN WHITE, PH.D. (*Absent*)  
*Ford Professor of Engineering*
- JEROME BERT WIESNER, PH.D.  
*Institute Professor;*  
*Professor of Electrical Engineering; Provost*
- HEREERT HORACE WOODSON, SC.D.  
*Philip Sporn Professor of Energy Processing*
- JOHN McREYNOLDS WOZENCRAFT, SC.D.  
*Professor of Electrical Engineering*
- HENRY JOSEPH ZIMMERMANN, S.M.  
*Professor of Electrical Engineering;*  
*Director of the Research Laboratory of Electronics*
- DAVID ADLER, PH.D.  
*Associate Professor of Electrical Engineering*
- MICHAEL ATHANS, PH.D.  
*Associate Professor of Electrical Engineering*
- ABRAHAM BERS, SC.D.  
*Associate Professor of Electrical Communications*
- RICHARD JULIAN BRIGGS, PH.D.  
*Associate Professor of Electrical Engineering*
- CHARLES KIMBALL CRAWFORD, SC.D. (*Absent*)  
*Associate Professor of Electrical Engineering*
- MICHAEL LEONIDAS DERTOUZOS, PH.D.  
*Associate Professor of Electrical Engineering*
- ALVIN WILLIAM DRAKE, SC.D.  
*Associate Professor of Electrical Engineering;*  
*Associate Director of the Operations Research Center*
- ROBERT MONTROSE GRAHAM, M.A.  
*Associate Professor of Electrical Engineering*
- ESTIL VERNON HOVERSTEN, PH.D.  
*Associate Professor of Electrical Engineering*
- THOMAS SHI-TAO HUANG, SC.D.  
*Associate Professor of Electrical Engineering*
- ROBERT SPAYDE KENNEDY, SC.D.  
*Associate Professor of Electrical Engineering*
- CHARLES KINGSLEY, JR., S.M.  
*Associate Professor of Electrical Engineering*
- CHUNG LAUNG LIU, SC.D.  
*Associate Professor of Electrical Engineering*
- ALAN VICTOR OPPENHEIM, SC.D.  
*Associate Professor of Electrical Engineering*
- WILLIAM TOWER PEAKE, SC.D.  
*Associate Professor of Electrical Engineering*
- ROBERT PENDLETON RAFUSE, SC.D.  
*Associate Professor of Electrical Engineering*
- FRED CHARLES SCHWEPPE, PH.D.  
*Associate Professor of Electrical Engineering*
- DAVID HUDSON STAELIN, SC.D.  
*Associate Professor of Electrical Engineering*
- KEITH I. THOMASSEN, PH.D.  
*Associate Professor of Electrical Engineering*
- DONALD EUGENE TROXEL, PH.D.  
*Associate Professor of Electrical Engineering*
- BRUCE DANIELS WEDLOCK, SC.D.  
*Associate Professor of Electrical Engineering*
- THOMAS FISCHER WEISS, PH.D.  
*Associate Professor of Electrical Engineering*
- JOSEPH WEIZENBAUM, S.M.  
*Associate Professor of Electrical Engineering*
- JONATHAN ALLEN, PH.D.  
*Assistant Professor of Electrical Engineering*
- FLOYD OLAF ARNTZ, PH.D.  
*Assistant Professor of Electrical Engineering*
- ARTHUR BERNARD BAGGEROER, SC.D.  
*Assistant Professor of Electrical Engineering*
- BARRY ALLEN BLESSER, PH.D.  
*Assistant Professor of Electrical Engineering;*  
*Postdoctoral Fellow in Engineering*
- LOUIS BENJAMIN DANIEL BRAIDA, PH.D.  
*Assistant Professor of Electrical Engineering;*  
*Postdoctoral Fellow in Engineering*
- STEPHEN KENT BURNS, PH.D.  
*Assistant Professor of Electrical Engineering*
- THOMAS GENE DAVIS, PH.D.  
*Assistant Professor of Electrical Engineering*
- JOHN JOSEPH DONOVAN, PH.D.  
*Assistant Professor of Electrical Engineering*
- ARTHUR EVANS, JR., PH.D.  
*Assistant Professor of Electrical Engineering*
- ROBERT ROSS FENICHEL, PH.D.  
*Assistant Professor of Electrical Engineering*
- JEROME IRA GLASER, PH.D.  
*Assistant Professor of Electrical Engineering*
- JULIUS L. GOLDSTEIN, PH.D.  
*Assistant Professor of Electrical Engineering*
- LEONARD WILLIAM GRUENBERG, PH.D.  
*Assistant Professor of Electrical Engineering*
- JOHN JOSEPH GUINAN, JR., PH.D.  
*Assistant Professor of Electrical Engineering*
- ADOLFO GUZMAN ARENAS, PH.D.  
*Assistant Professor of Electrical Engineering*
- MARTIN EDWARD HELLMAN, PH.D.  
*Assistant Professor of Electrical Engineering;*  
*Postdoctoral Fellow in Engineering*
- WILLIAM L. HENKE, PH.D.  
*Assistant Professor of Electrical Engineering*
- WILLIAM JOHN INCE, PH.D.  
*Assistant Professor of Electrical Engineering*
- ZVI KOHAVI, PH.D. (*Absent*)  
*Assistant Professor of Electrical Engineering*
- JIN-AU KONG, PH.D.  
*Assistant Professor of Electrical Engineering;*  
*Postdoctoral Fellow in Engineering*
- WILLIAM BENJAMIN LENOIR, PH.D. (*Absent*)  
*Assistant Professor of Electrical Engineering*
- FRED LOUIS LUCONI, PH.D.  
*Assistant Professor of Electrical Engineering*
- ROGER GREENWOOD MARK, M.D., PH.D.  
*Assistant Professor of Electrical Engineering*
- ALBERT R. MEYER, PH.D.  
*Assistant Professor of Electrical Engineering*

**FACULTY**

JOHN SYLVESTER MOORE, PH.D.  
*Assistant Professor of Electrical Engineering*

JOEL MOSES, PH.D.  
*Assistant Professor of Electrical Engineering*

DONALD EDWARD NELSEN, PH.D.  
*Assistant Professor of Electrical Engineering*

RONALD RICHARD PARKER, SC.D.  
*Assistant Professor of Electrical Engineering*

IAN BURTON RHODES, PH.D.  
*Assistant Professor of Electrical Engineering*

JAMES KERR ROBERGE, SC.D.  
*Assistant Professor of Electrical Engineering*

JEROME HOWARD SALTZER, SC.D.  
*Assistant Professor of Electrical Engineering*

STEPHEN DAVID SENTURIA, PH.D.  
*Assistant Professor of Electrical Engineering*

DANIEL LAFAYETTE SMYTHE, JR., PH.D.  
*Assistant Professor of Electrical Engineering*

DONALD LEE SNYDER, SC.D. (*Absent*)  
*Assistant Professor of Electrical Engineering*

RICHARD NELSON SPANN, PH.D. (*Absent*)  
*Assistant Professor of Electrical Engineering*

JAMES NEWMAN WALPOLE, PH.D.  
*Assistant Professor of Electrical Engineering*

JAN CAMIEL WILLEMS, PH.D.  
*Assistant Professor of Electrical Engineering*

GERALD LOOMIS WILSON, SC.D.  
*Assistant Professor of Electrical Engineering*

IAN THEODORE YOUNG, PH.D.  
*Assistant Professor of Electrical Engineering;*  
*Postdoctoral Fellow in Engineering*

**Executive Officer for Student Affairs**

JOHN AVERY TUCKER, M.ENG.

**Administrative Officer**

HARMON EUGENE BRAMMER, B.B.A.

**Lecturers**

SAUL ARONOW, PH.D.

RICHARD HARRISON BAKER, S.M.

JORDAN JAY BARUCH, SC.D.

LEO LEROY FERANEK, SC.D.

GODFREY THOMAS COATE, M.S.

NATHANIEL I. DURLACH, M.A.

STANLEY A. FORWARD, M.D.

CHARLES FREED, S.M.

BERNARD GOLD, D.E.E.

ROBERT DILWYN HALL, PH.D.

JESSE CLOPTON JAMES, PH.D.

WILLIAM F. KELLEY, B.B.A.

NELSON YUAN-SHENG KIANG, PH.D.

ALEXANDER KUSKO, SC.D.

RICHARD GWYN MILLS, S.M.

ROBERT HARVEY RINES, S.B., LL.B.

ALLAN CARTER SCHELL, SC.D.

WILLIAM ROBERT SUTHERLAND, PH.D.

HERBERT MARTIN TEAGER, SC.D.

OLEH JOHN TRETIK, SC.D.

JOHN ERWIN WARD, S.M.

**Instructors**

WALTER HENRY BERNINGER, S.M.

HARRY STEVEN COLBURN, S.M.

EDMUND BOOTH DEVITT, S.M.

RICHARD JAMES DIEPHUIS, S.M.

ADRIAN EMMANUEL ECKBERG, JR.

MURRAY EDELBERG, S.M.

LANSING HATFIELD, E.E.

THOMAS BYRON JONES, JR., S.M.

LESLIE CRAIG KRAMER, S.M.

RICHARD CHARLES LARSON, E.E.

SUHAS SHRIKRISHNA PATIL, S.M.

GREGORY FRANCIS PFISTER, S.M.

JAMES ALAN ROME, E.E.

CHARLES LEWIS SEITZ, III, S.M.

ALTON PARKER TRIPP, JR., E.E.

MARKUS ZAHN, S.M.

**Administrative Assistants**

MAX MORTON BYER

HORACE MCNUTT SMITH, JR., B.A.

DOROTHY YOUNG

**Non-Resident Instructors**

JOSEPH FRANCIS BALCEWICZ, S.M.

LAWRENCE RICHARD RABINER, PH.D.

LEONARD RABINS, M.S.

**Research Associates**

KENNETH RUSSELL INGHAM, M.A.

ARTHUR LINZ, PH.D.

DEAN ARNOLD POWERS, E.E.

FRIEDRICH GUENTER RUFDENAUER, PH.D.

DONALD HARLEY STEINBRECHER, PH.D.

**Professors Emeriti**

HERBERT BRISTOL DWIGHT, D.SC.  
*Professor of Electrical Machinery, Emeritus*

MARCY EAGER, S.B.  
*Associate Professor of Electrical Engineering, Emeritus*

HAROLD EUGENE EDGERTON, SC.D., D.ENG.  
*Institute Professor, Emeritus;*  
*Professor of Electrical Measurements, Emeritus*

RICHARD HENRY FRAZIER, S.M.  
*Professor of Electromechanics, Emeritus; Senior Lecturer*

MURRAY FRANK GARDNER, S.M.  
*Professor of Electrical Engineering, Emeritus*

ERNST ADOLPH GUILLEMIN, PH.D.  
*Professor of Electrical Engineering, Emeritus*

HAROLD LOCKE HAZEN, SC.D.  
*Professor of Electrical Engineering, Emeritus;*  
*Dean of the Graduate School, Emeritus;*  
*Foreign Study Adviser*

YUK-WING LEE, SC.D.  
*Professor of Electrical Engineering, Emeritus;*  
*Senior Lecturer*

PARRY MOON, S.M.  
*Associate Professor of Electrical Engineering, Emeritus*

ALEXANDER SMAKULA, PH.D.  
*Professor of Crystal Physics, Emeritus;*  
*Senior Lecturer*

ARTHUR ROBERT VON HIPPEL, PH.D.  
*Institute Professor, Emeritus;*  
*Professor of Electrophysics, Emeritus*

KARL LELAND WILDES, S.M.  
*Professor of Electrical Engineering, Emeritus*

## MECHANICAL ENGINEERING

- ASCHER HERMAN SHAPIRO, SC.D.  
*Ford Professor of Engineering;  
Head of the Department*
- WILLIAM MACGREGOR MURRAY, SC.D.  
*Professor of Mechanical Engineering; Executive Officer*
- DOUGLAS PAYNE ADAMS, S.B., A.M.  
*Professor of Mechanical Engineering*
- ALI SUPHI ARGON, SC.D.  
*Professor of Mechanical Engineering*
- STANLEY BACKER, SC.D.  
*Professor of Mechanical Engineering*
- NATHAN HENRY COOK, SC.D.  
*Professor of Mechanical Engineering*
- STEPHEN HARRY CRANDALL, PH.D.  
*Professor of Mechanical Engineering*
- JACOB PIETER DEN HARTOG, PH.D., D.ENG.,  
D.APPL.SC., D.TECH.SC.  
*Professor of Mechanical Engineering, Emeritus;  
Senior Lecturer*
- JAMES ALAN FAY, PH.D.  
*Professor of Mechanical Engineering*
- PETER GRIFFITH, SC.D. (*Absent*)  
*Professor of Mechanical Engineering*
- AUGUST LUDWIG HESSELSCHWERDT, JR., S.M.  
*Professor of Mechanical Engineering*
- JAMES COLLYER KECK, PH.D.  
*Ford Professor of Engineering*
- JOSEPH HENRY KEENAN, LL.D.  
*Professor of Mechanical Engineering, Emeritus;  
Senior Lecturer*
- SHIH-YING LEE, SC.D.  
*Professor of Mechanical Engineering*
- PATRICK LEEHEY, PH.D.  
*Professor of Naval Architecture*
- DEANE LENT, A.B. (*Absent*)  
*Professor of Mechanical Engineering*
- ROBERT WELLESLEY MANN, SC.D.  
*Professor of Mechanical Engineering*
- FRANK AMBROSE MCCLINTOCK, PH.D.  
*Professor of Mechanical Engineering*
- EGON OROWAN, D.ENG.  
*Professor of Mechanical Engineering, Emeritus;  
Senior Lecturer*
- HENRY MARTYN PAYNTER, SC.D.  
*Professor of Mechanical Engineering*
- RONALD FILMORE PROBSTEIN, PH.D.  
*Professor of Mechanical Engineering*
- ERNEST RABINOWICZ, PH.D.  
*Professor of Mechanical Engineering*
- HERBERT HEATH RICHARDSON, SC.D.  
*Professor of Mechanical Engineering*
- BRANDON GARNER RIGHTMIRE, SC.D.  
*Professor of Mechanical Engineering*
- AUGUSTUS RUDOLPH ROGOWSKI, S.M.  
*Professor of Mechanical Engineering*
- WARREN MAX ROHSENOW, D.ENG.  
*Professor of Mechanical Engineering*
- JOSEPH LECONTE SMITH, JR., SC.D.  
*Professor of Mechanical Engineering*
- PRESCOTT ARTHUR SMITH, S.B.  
*Professor of Mechanical Engineering;  
Assistant Secretary of the Faculty;  
Executive Officer, Committee on Academic Performance*
- TAU-YI TOONG, SC.D.  
*Professor of Mechanical Engineering*
- KENNETH ROBERT WADLEIGH, SC.D.  
*Professor of Mechanical Engineering; Vice President*
- HERBERT HORACE WOODSON, SC.D.  
*Philip Sporn Professor of Energy Processing*
- JOHN PATRICK APPLETON, PH.D.  
*Associate Professor of Mechanical Engineering*
- DWIGHT MAYLON BILLY BAUMANN, SC.D.  
*Associate Professor of Mechanical Engineering*
- CHARLES ADOLPH BERG, SC.D.  
*Associate Professor of Mechanical Engineering*
- ARTHUR EDWARD BERGLES, PH.D.  
*Associate Professor of Mechanical Engineering*
- FORBES TAYLOR BROWN, SC.D.  
*Associate Professor of Mechanical Engineering*
- CLARENCE FORBES DEWEY, JR., PH.D.  
*Associate Professor of Mechanical Engineering*
- DAVID PARKS HOULT, PH.D.  
*Associate Professor of Mechanical Engineering*
- THOMAS JOSEPH LARDNER, PH.D.  
*Associate Professor of Mechanical Engineering*
- PADMAKAR PRATEP LELE, M.D., PH.D.  
*Associate Professor of Experimental Medicine*
- BORIVOJE BUDIMIRA MIKIC, SC.D.  
*Associate Professor of Mechanical Engineering*
- IGOR PAUL, SC.D.  
*Associate Professor of Mechanical Engineering*
- ALLAN DALE PIERCE, PH.D.  
*Associate Professor of Mechanical Engineering*
- THOMAS BROWN SHERIDAN, SC.D.  
*Associate Professor of Mechanical Engineering*
- AIN AN'IS SONIN, PH.D.  
*Associate Professor of Mechanical Engineering*
- ROBERT ERWIN STICKNEY, PH.D.  
*Associate Professor of Mechanical Engineering*
- DAVID GORDON WILSON, PH.D.  
*Associate Professor of Mechanical Engineering*
- IOANNIS VASSILIOU YANNAS, PH.D.  
*Associate Professor of Mechanical Engineering*
- ERNEST GEORGE CRAVALHO, PH.D.  
*Assistant Professor of Mechanical Engineering*
- HUW GRIFFITH DAVIES, PH.D.  
*Assistant Professor of Mechanical Engineering*
- LEON ROBERT GLICKSMAN, PH.D.  
*Assistant Professor of Mechanical Engineering*
- JOHN BENJAMIN HEYWOOD, PH.D.  
*Assistant Professor of Mechanical Engineering*
- MICHEL YVES JAFFRIN, PH.D.  
*Assistant Professor of Mechanical Engineering*
- RICHARD ALAN MOSS, PH.D.  
*Du Pont Assistant Professor of Mechanical Engineering*

## FACULTY

RICHARD FRANK SALANT, SC.D.  
*Assistant Professor of Mechanical Engineering*

WILLIAM JOHN SHACK, PH.D.  
*Assistant Professor of Mechanical Engineering;*  
*Postdoctoral Fellow in Engineering*

WALTER DAN SYNIUTA, SC.D.  
*Assistant Professor of Mechanical Engineering*

PHILIP THULLEN, PH.D.  
*Assistant Professor of Mechanical Engineering*

ARTHUR P. L. TURNER, PH.D.  
*Assistant Professor of Mechanical Engineering*

DANIEL EUGENE WHITNEY, SC.D.  
*Assistant Professor of Mechanical Engineering*

GERALD LOOMIS WILSON, SC.D.  
*Assistant Professor of Electrical Engineering*

DAVID NEAL WORMLEY, PH.D.  
*Assistant Professor of Mechanical Engineering*

### **Administrative Officer**

CHARLES EBERHARD BARRINGER, B.A.

### **Senior Lecturer**

GEORGE NICHOLAS HATSOPOULOS, SC.D.

### **Lecturers**

MICHAEL SAMPSON BARAM, B.S., LL.B.

PHILIP ALDRICH DRINKER, PH.D.

RICHARD PAINE PARMELEE, PH.D.

### **Instructors**

WOODIE CLAUDE FLOWERS

ROBERT CHARLES SHELDON, M.E.

RICHARD STEVENSON SIDELL, S.B.

WILLIAM LAWRENCE VERPLANK, S.M.

### **Administrative Assistant**

GRACE HAHN KELLY, B.A.

### **Technical Instructors**

FREDERICK HAROLD ANDERSON

RALPH JOHN BOWLEY

CLARENCE WILLIAM CHRISTIANSEN

JOHN LEACH

### **Senior Research Associate**

EMERY IMRE VALKO, PH.D.

### **Research Associates**

JOHN STEWART MAULBETSCH, SC.D.

THOMAS IAN MCLAREN, PH.D.

VITO ANTHONY PROSCIA, E.E.

SAMUEL WILSON RADCLIFFE, PH.D.

THOMAS CHARLES ROBINSON, PH.D.

SHOBU SHIBATA, PH.D.

### **Professors Emeriti**

EARLE BUCKINGHAM

*Professor of Mechanical Engineering, Emeritus*

SAMUEL CORNETTE COLLINS, PH.D., SC.D.

*Professor of Mechanical Engineering, Emeritus*

JACOB PIETER DEN HARTOG, PH.D., D.ENG.,

D.APPL.SC., D.TECH.SC.

*Professor of Mechanical Engineering, Emeritus;*  
*Senior Lecturer*

WALTER CARL EBERHARD, S.B.

*Assistant Professor of Engineering Graphics, Emeritus*

JAMES HOLT, S.B.

*Professor of Mechanical Engineering, Emeritus*

JOSEPH HENRY KEENAN, LL.D.

*Professor of Mechanical Engineering, Emeritus;*  
*Senior Lecturer*

EGON OROWAN, D.ENG.

*Professor of Mechanical Engineering, Emeritus;*  
*Senior Lecturer*

JOSEPH CAINS RILEY, S.B.

*Professor of Heat Engineering, Emeritus*

JOHN THOMAS RULE, S.B.

*Professor of Engineering Graphics, Emeritus*

CARL RICHARD SODERBERG, TEKN.D., D.ENG.

*Institute Professor, Emeritus;*

*Professor of Mechanical Engineering, Emeritus*

CARL LOUIS SVENSON, S.M.

*Professor of Mechanical Engineering, Emeritus*

CHARLES FAYETTE TAYLOR, PH.B., M.E.

*Professor of Automotive Engineering, Emeritus*

GORDON BALL WILKES, S.B.

*Professor of Heat Engineering, Emeritus*

## METALLURGY AND MATERIALS SCIENCE

THOMAS BURNES KING, PH.D.  
*Professor of Metallurgy; Head of the Department*

BENJAMIN LEWIS AVEREACH, SC.D.  
*Professor of Metallurgy*

WALTER ALAN BACKOFEN, SC.D.  
*Professor of Metallurgy*

MICHAEL BERLINER BEVER, DR. IUR., SC.D.  
*Professor of Metallurgy*

JOHN WERNER CAHN, PH.D.  
*Professor of Metallurgy*

ROBERT LOUIS COBLE, SC.D.  
*Professor of Ceramics*

MORRIS COHEN, SC.D.  
*Ford Professor of Materials Science and Engineering*

PHILIP LOUIS DE BRUYN, SC.D. (*Absent*)  
*Professor of Metallurgy*

JOHN FRANK ELLIOTT, SC.D.  
*Professor of Metallurgy*

MERTON CORSON FLEMINGS, SC.D.  
*ABEX Professor of Metallurgy*

CARL FREDERICK FLOE, SC.D.  
*Professor of Metallurgy; Vice President, Research Administration*

HARRY CONSTANTINE GATOS, PH.D.  
*Professor of Electronic Materials; Associate Director of the Center for Materials Science and Engineering*

ANTOINE MARC GAUDIN, SC.D.  
*Richards Professor of Mineral Engineering, Emeritus; Senior Lecturer*

NICHOLAS JOHN GRANT, SC.D.  
*Professor of Metallurgy; Director of Center for Materials Science and Engineering*

WILLIAM DAVID KINGERY, SC.D.  
*Professor of Ceramics*

ROBERT EDWARD OGILVIE, SC.D.  
*Professor of Metallurgy*

CYRIL STANLEY SMITH, SC.D.  
*Institute Professor, Emeritus; Professor of Metallurgy, Emeritus*

HERBERT HENRY UHLIG, PH.D.  
*Professor of Metallurgy*

JOHN WULFF, D.SC.  
*Professor of Metallurgy, Emeritus; Senior Lecturer*

JOHN FRANK BREEDIS, D.ENG.  
*Associate Professor of Metallurgy*

ROY KAPLOW, SC.D.  
*Associate Professor of Metallurgy*

SIMON CHARLES MOSS, SC.D. (*Absent*)  
*Associate Professor of Metallurgy*

REGIS MARC NOEL PELLOUX, SC.D.  
*Associate Professor of Metallurgy*

ROBERT MICHAEL ROSE, SC.D.  
*Associate Professor of Metallurgy*

KENNETH CALVIN RUSSELL, PH.D.  
*Associate Professor of Metallurgy*

DONALD ROBERT UHLMANN, PH.D.  
*Associate Professor of Ceramics*

AUGUST FERDINAND WITT, PH.D.  
*Associate Professor of Metallurgy*

BERNHARDT JOHN WUENSCH, PH.D.  
*Associate Professor of Ceramics*

THOMAS OWENS ZIEBOLD, PH.D.  
*Associate Professor of Nuclear Materials*

DAVID LEWIS HOLT, SC.D.  
*Assistant Professor of Metallurgy*

KEITH HUBER JOHNSON, PH.D.  
*Assistant Professor of Metallurgy*

CYRIL JOSEPH MOGAB, SC.D.  
*Assistant Professor of Ceramics*

BARRY HAROLD ROSOF, SC.D.  
*Assistant Professor of Metallurgy*

DAVID JULIAN SELLMYER, PH.D.  
*Assistant Professor of Metallurgy*

**Administrative Officer**

DOUGLAS CRAIG JOHNSTON, S.M.

**Lecturer**

JOSEPH TIBOR BLUCHER, SC.D. (*Visiting*)

**Technical Instructors**

ARTHUR JEREMIAH GREGOR  
PAUL FREDERICK HUGHES

**Research Associates**

JOHN WASHBURN BRACKETT, PH.D.  
JOSEF FRANCISZEK GRACZYK, PH.D.  
ROBERT MEHRABIAN, SC.D.

**Professors Emeriti**

JOHN CHIPMAN, PH.D., SC.D.  
*Professor of Metallurgy, Emeritus*

ANTOINE MARC GAUDIN, SC.D.  
*Richards Professor of Mineral Engineering, Emeritus; Senior Lecturer*

VICTOR OLIVER HOMERBERG, SC.D.  
*Professor of Physical Metallurgy, Emeritus*

FREDERICK HARWOOD NORTON, SC.D.  
*Professor of Ceramics, Emeritus*

JOHN TORREY NORTON, SC.D.  
*Professor of the Physics of Metals, Emeritus*

CYRIL STANLEY SMITH, SC.D.  
*Institute Professor, Emeritus; Professor of Metallurgy, Emeritus*

JOHN WULFF, D.SC.  
*Professor of Metallurgy, Emeritus; Senior Lecturer*

**FACULTY**

**NAVAL ARCHITECTURE AND  
MARINE ENGINEERING**

ALFRED ADOLF HEINRICH KEIL, DR. RER. NAT.  
*Professor of Naval Architecture; Head of the Department*  
MARTIN AARON ABKOWITZ, PH.D.

*Professor of Naval Architecture*

JOHN P. CRAVEN, PH.D.

*Professor of Ocean Engineering (Visiting)*

JACOB PIETER DEN HARTOG, PH.D., D.ENG.,

D.APPL.SC., D.TECH.SC.

*Professor of Mechanical Engineering, Emeritus; Senior Lecturer*

JOHN HARVEY EVANS, B.ENG.

*Professor of Naval Architecture*

ERNST GABRIEL FRANKEL, MAR.MECH.E.

*Professor of Marine Engineering*

DEAN ALDEN HORN, NAV.E.

*Captain, U. S. Navy;*

*Professor of Naval Construction*

JUSTIN ELLIOT KERWIN, PH.D.

*Professor of Naval Architecture*

PATRICK LEEHEY, PH.D.

*Professor of Naval Architecture*

FRANK MENDELL LEWIS

*Professor of Marine Engineering, Emeritus; Senior Lecturer*

PHILIP MANDEL, B.S.

*Professor of Naval Architecture*

NORMAN JUDSON PADELFORD, PH.D., LL.D.

*Professor of Political Science*

KOICHI MASUBUCHI, D.ENG.

*Associate Professor of Naval Architecture*

JOHN NICHOLAS NEWMAN, SC.D.

*Associate Professor of Naval Architecture*

SHANNON CURTIS POWELL, DOTT.ING.

*Associate Professor of Marine Engineering*

SHERMAN CLARK REED, NAV.E.

*Commander, U. S. Navy*

*Associate Professor of Naval Engineering*

DAMON ELLIS CUMMINGS, PH.D.

*Assistant Professor of Naval Architecture;*

*Postdoctoral Fellow in Engineering*

JOHN W. DEVANNEY, II, PH.D.

*Assistant Professor of Naval Architecture*

NORMAN JONES, PH.D.

*Assistant Professor of Naval Architecture*

ALAA EL-'DIN MANSOUR, PH.D.

*Assistant Professor of Naval Architecture;*

*Postdoctoral Fellow in Engineering*

JEROME H. MILGRAM, PH.D.

*Assistant Professor of Naval Architecture*

**Administrative Officer**

KEATINGE KEAYS, NAV.E.

**Senior Lecturers**

MIGUEL CHAPERO JUNGER, SC.D. (*Visiting*)

WILLIAM S. PELLINI, B.S.

**Lecturers**

WILLIAM AVERY BAKER, S.B.

FRANZ A. P. FRISCH, M.S. (*Visiting*)

BERNHARD WALTER ROMBERG, PH.D. (*Visiting*)

**Instructors**

CHRYSSOSTOMOS CHRYSSOSTOMIDIS, M.S. NAV.ARCH.

BRUCE DENTON COX, S.M.

**Professors Emeriti**

EVERS BURTNER, S.B.

*Associate Professor of Naval Architecture*

*and Marine Engineering, Emeritus*

JACOB PIETER DEN HARTOG, PH.D., D.ENG.,

D.APPL.SC., D.TECH.SC.

*Professor of Mechanical Engineering, Emeritus; Senior Lecturer*

FRANK MENDELL LEWIS

*Professor of Marine Engineering, Emeritus;*

*Senior Lecturer*

## NUCLEAR ENGINEERING

- MANSON BENEDICT, PH.D.  
*Institute Professor; Professor of Nuclear Engineering;  
Head of the Department*
- THOMAS HENDERSON DUPREE, PH.D.  
*Professor of Nuclear Engineering*
- ELIAS PANAYIOTIS GYFTOPOULOS, SC.D.  
*Professor of Nuclear Engineering*
- KENT FORREST HANSEN, SC.D.  
*Professor of Nuclear Engineering*
- ALLAN FRANCIS HENRY, PH.D.  
*Professor of Nuclear Engineering*
- IRVING KAPLAN, PH.D.  
*Professor of Nuclear Engineering*
- DAVID DAYTON LANNING, PH.D.  
*Professor of Nuclear Engineering*
- EDWARD ARCHIBALD MASON, SC.D.  
*Professor of Nuclear Engineering*
- NORMAN CARL RASMUSSEN, PH.D.  
*Professor of Nuclear Engineering*
- DAVID JOHN ROSE, PH.D. (*Absent*)  
*Professor of Nuclear Engineering*
- THEOS JARDIN THOMPSON, PH.D. (*Absent*)  
*Professor of Nuclear Engineering*
- GORDON LEE BROWNELL, PH.D.  
*Associate Professor of Nuclear Engineering*
- FRANKLYN MILES CLIKEMAN, PH.D.  
*Associate Professor of Nuclear Engineering*
- MICHAEL JOHN DRISCOLL, SC.D.  
*Associate Professor of Nuclear Engineering*
- HANS WOLFGANG LEVI, DR.ING.  
*Associate Professor of Nuclear Engineering (Visiting)*
- LAWRENCE MARK LIDSKY, PH.D.  
*Associate Professor of Nuclear Engineering*
- SIDNEY YIP, PH.D.  
*Associate Professor of Nuclear Engineering*
- THOMAS OWENS ZIEBOLD, PH.D.  
*Associate Professor of Nuclear Materials*
- RONALD ALFRED BLANKEN, PH.D.  
*Assistant Professor of Nuclear Engineering*
- SOW-HSIN CHEN, PH.D.  
*Assistant Professor of Nuclear Engineering*
- JAMES WATERBURY GOSNELL, PH.D.  
*Assistant Professor of Nuclear Engineering*
- N. THOMAS OLSON, PH.D.  
*Assistant Professor of Nuclear Engineering*

**Lecturers**

- LEON EDWARD BEGHIAN, PH.D.  
SAMUEL LEVIN, S.B.

**Research Associate**

- LINCOLN CLARK, JR., A.B., S.M.  
*Director of the M.I.T. Reactor*

CENTER FOR ADVANCED  
ENGINEERING STUDY

- HAROLD SOMERS MICKLEY, SC.D.  
*Ford Professor of Chemical Engineering;  
Director of the Center for Advanced Engineering Study*
- PAUL EDWARD BROWN, SC.D.  
*Executive Officer of the Center for Advanced Engineering Study*
- JOHN TOWNSEND FITCH, S.B.  
*Manager, Self-Study Subject Development*
- CHARLES DEAN PATON, B.S.  
*Chief Audio-Visual Engineer*
- WILBUR BAYLEY DAVENPORT, JR., SC.D.  
*Professor of Electrical Engineering*
- HERBERT IRVING GROSS, B.S.  
*Senior Lecturer in Civil Engineering*
- WILLIAM WEED KAUFMANN, PH.D.  
*Professor of Political Science*
- HARRY LESLIE VAN TREES, JR., SC.D.  
*Professor of Electrical Engineering*
- RICHARD LAWRENCE DENEUFVILLE, PH.D.  
*Assistant Professor of Civil Engineering*
- JOSEPH MARTIN SUSSMAN, PH.D.  
*Assistant Professor of Civil Engineering*
- RICHARD CHARLES LARSON, E.E.  
*Instructor in Electrical Engineering*
- STEVEN DAVID ROSENBERG, E.E.  
*Instructor in Political Science*
- FACULTY ADVISORY COMMITTEE**
- JUDSON RICHARD BARON, SC.D.  
*Professor of Aeronautics and Astronautics*
- MYLE JOSEPH HOLLEY, JR., S.M.  
*Professor of Civil Engineering*
- LOUIS DIJOUR SMULLIN, S.M.  
*Professor of Electrical Engineering;  
Head of the Department of Electrical Engineering*
- HENRY MARTYN PAYNTER, SC.D.  
*Professor of Mechanical Engineering*
- IRVING KAPLAN, PH.D.  
*Professor of Nuclear Engineering*
- GEORGE EDWARD VALLEY, JR., PH.D.  
*Professor of Physics*

**SCHOOL OF HUMANITIES AND  
SOCIAL SCIENCE**

**ECONOMICS**

EDGAR CARY BROWN, PH.D.  
*Professor of Economics; Head of the Department*

MORRIS ALBERT ADELMAN, PH.D.  
*Professor of Economics*

SIDNEY STUART ALEXANDER, PH.D. (*Absent*)  
*Professor of Economics*

JAGDISH NATWARLAL BHAGWATI, PH.D.  
*Professor of Economics*

ROBERT LYLE BISHOP, PH.D.  
*Professor of Economics;*  
*Dean of the School of Humanities and Social Science*

EVSEY DAVID DOMAR, PH.D.  
*Professor of Economics*

RICHARD SAMUEL ECKAUS, PH.D.  
*Professor of Economics*

FRANKLIN MARVIN FISHER, PH.D.  
*Professor of Economics*

HAROLD ADOLPH FREEMAN, S.B.  
*Professor of Statistics*

EVERETT EINAR HAGEN, PH.D.  
*Professor of Economics*

CHARLES POOR KINDLEBERGER, PH.D., D.H.C.  
*Professor of Economics*

EDWIN KUH, PH.D.  
*Professor of Economics*

MAX FRANKLIN MILLIKAN, PH.D.  
*Professor of Economics;*  
*Director of the Center for International Studies*

FRANCO MODIGLIANI, D.JUR., D.SOC.SCI., LL.D.  
*Professor of Economics*

CHARLES ANDREW MYERS, PH.D.  
*Professor of Industrial Relations*

PAUL NARCYZ ROSENSTEIN-RODAN, DR. RER. POL.  
*Professor of Economics, Emeritus;*  
*Senior Lecturer*

JEROME ROTHENBERG, PH.D.  
*Professor of Economics*

PAUL ANTHONY SAMUELSON, PH.D., LL.D., D.LITT.,  
SC.D.  
*Institute Professor; Professor of Economics*

ABRAHAM J. SIEGEL, PH.D.  
*Professor of Industrial Relations;*  
*Associate Dean, Alfred P. Sloan School of Management*

ROBERT MERTON SOLOW, PH.D., LL.D.  
*Professor of Economics*

CARL CHRISTIAN VON WEIZSÄCKER, PH.D.  
*Professor of Economics (Visiting)*

PETER ARTHUR DIAMOND, PH.D.  
*Associate Professor of Economics*

DUNCAN KARL FOLEY, PH.D.  
*Associate Professor of Economics*

PETER TEMIN, PH.D.  
*Associate Professor of Economic History*

LESTER CARL THUROW, PH.D.  
*Associate Professor of Economics*

ROBERT WARREN GRANDALL, PH.D.  
*Assistant Professor of Economics*

MATTHEW DAVID EDEL, PH.D.  
*Assistant Professor of Economics*

ROBERT FRY ENGLE, III, PH.D.  
*Assistant Professor of Economics*

RONALD EDWARD GRIESON, PH.D.  
*Assistant Professor of Economics*

JOHN REES HARRIS, PH.D. (*Absent*)  
*Assistant Professor of Economics*

MICHAEL JOSEPH PIORE, PH.D.  
*Assistant Professor of Economics*

*Administrative Officer*

IDELLA LYMAN TAPLEY, A.B.

*Professors Emeriti*

PAUL PIGORS, PH.D.  
*Professor of Industrial Relations, Emeritus*

PAUL NARCYZ ROSENSTEIN-RODAN, DR. RER. POL.  
*Professor of Economics, Emeritus; Senior Lecturer*

DONALD SKEELE TUCKER, PH.D.  
*Professor of Economics, Emeritus*

## FOREIGN LITERATURES AND LINGUISTICS

- WILLIAM FILBERT BOTTIGLIA, PH.D.  
*Professor of Foreign Literatures and Humanities;*  
*Head of the Department*
- NOAM AVRAM CHOMSKY, PH.D.  
*Ferrari P. Ward Professor of Modern Languages*  
*and Linguistics*
- MARTIN DYCK, PH.D. (*Absent*)  
*Professor of German and Humanities*
- RICHARD CARL EXNER, PH.D.  
*Professor of German and Humanities (Visiting)*
- MORRIS HALLE, PH.D.  
*Professor of Modern Languages*
- ROMAN JAKOBSON, PH.D.  
*Institute Professor, Emeritus*
- WILLIAM NASH LOCKE, PH.D.  
*Professor of Modern Languages*
- GEORGE HUBERT MATTHEWS, PH.D.  
*Professor of Modern Languages*
- KENNETH L. HALE, PH.D.  
*Associate Professor of Linguistics*
- PATRICK W. HOHEPA, PH.D.  
*Associate Professor of Linguistics (Visiting)*
- ROBERT EMMET JONES, PH.D.  
*Associate Professor of French and Humanities*
- RENÉ PAUL VIKTOR KIPARSKY, PH.D.  
*Associate Professor of Linguistics*
- KRYSZYNA POMORSKA, PH.D.  
*Associate Professor of Russian*
- JAMES WESLEY HARRIS, PH.D.  
*Assistant Professor of Spanish*
- GORDON EUGENE NELSON, PH.D.  
*Assistant Professor of German*
- JOHN ROBERT ROSS, PH.D.  
*Assistant Professor of Linguistics*
- Lecturers**
- PRIMUS BENEDICT BON, B.S., M.A.
- MARGARET ZARODNY FREEMAN, S.M.
- Instructors**
- KRISTINE FORSTER BRECHT, M.A.
- RENATA HOFMAN BRIGGS
- MAGDA BUKA, B.A.
- ROBERT CHARLES CHANNON, M.A.
- CATHERINE VAKAR CHVANY, A.B.
- STELLA BERGER GREENFIELD, M.A.
- CHRISTA LOUISE JOHNS, PH.D. (*Absent*)
- CLAIRE JEANNE KRAMSCH, M.A.
- ILONA RICARDO, M.A.
- Administrative Assistant**
- WARREN ARTHUR SEAMANS, B.S.
- Professors Emeriti**
- ROMAN JAKOBSON, PH.D.  
*Institute Professor, Emeritus*
- HERMAN KLUGMAN, PH.D.  
*Assistant Professor of Modern Languages, Emeritus*
- RICHARD FELIX KOCH, A.M.  
*Assistant Professor of Modern Languages, Emeritus*
- GEORGE ALEXANDROVICH ZNAMENSKY, B.D., ED.M.  
*Assistant Professor of Russian, Emeritus*

## HUMANITIES

- RICHARD MATEER DOUGLAS, PH.D.  
*Professor of History; Head of the Department*
- HOWARD RUSSELL BARTLETT, B.S., A.M.  
*Professor of History, Emeritus; Senior Lecturer*
- SYLVAIN BROMBERGER, PH.D.  
*Professor of Philosophy*
- LYNWOOD SILVESTER BRYANT, A.M.  
*Professor of History*
- JOHN ELY BURCHARD, L.H.D., D.ARCH  
*Professor of Humanities, Emeritus; Dean of the School of*  
*Humanities and Social Science, Emeritus; Senior Lecturer*
- RICHARD LEE CARTWRIGHT, PH.D.  
*Professor of Philosophy*
- GIORGIO DIAZ DE SANTILLANA, PH.D.  
*Professor of the History and Philosophy of Science, Emeritus;*  
*Senior Lecturer*
- JOSEPH DEE EVERINGHAM, A.M.  
*Professor of Literature; Director of Drama*
- JERRY ALAN FODOR, PH.D.  
*Professor of Philosophy*
- CHARLES FRIED, LL.B.  
*Professor of Philosophy (Visiting)*
- WILLIAM CHACE GREENE, M.A.  
*Professor of Literature, Emeritus; Senior Lecturer*
- EDWARD NEAL HARTLEY, A.M.  
*Professor of History;*  
*Secretary of the Faculty; Institute Archivist*
- JERROLD JACOB KATZ, PH.D.  
*Professor of Philosophy*
- ROY LAMSON, PH.D.  
*Professor of Literature*
- DENISE LEVERTOV  
*Professor of Literature (Visiting)*
- KLAUS LIEPMANN  
*Professor of Music; Director of Music*
- ROBERT ELLSWORTH MACMASTER, PH.D.  
*Professor of History and Literature*
- THOMAS HENRY DONALD MAHONEY, PH.D.  
*Professor of History*
- BRUCE MAZLISH, PH.D.  
*Professor of History*
- WAYNE O'NEIL, PH.D.  
*Professor of Literature*
- ROBERT REYNOLDS RATHBONE, A.M.  
*Professor of Literature*
- HARALD ANTON THRAP OLSEN REICHE, PH.D.  
*Professor of Classics and Philosophy*
- IRVING SINGER, PH.D.  
*Professor of Philosophy*
- CYRIL STANLEY SMITH, SC.D.  
*Institute Professor, Emeritus;*  
*Professor of the History of Science and Technology, Emeritus*
- HUSTON CUMMINGS SMITH, PH.D. (*Absent*)  
*Professor of Philosophy*
- JAMES FREDERICK THOMSON, M.A.  
*Professor of Philosophy*

FACULTY

JUDITH JARVIS THOMSON, PH.D.  
*Professor of Philosophy*

GREGORY TUCKER  
*Professor of Music; Director of M.I.T. Humanities Series and Chamber Music of M.I.T.*

ROBERT SMITH WOODBURY, S.B., A.M. (*Absent*)  
*Professor of the History of Technology*

CHARLES THOMAS COLE, A.M.  
*Associate Professor of Literature*

DAVID MAYER EPSTEIN, PH.D.  
*Associate Professor of Music; Conductor of the M.I.T. Symphony Orchestra*

ROBERT M. FOGELSON, PH.D.  
*Associate Professor of History and City Planning*

EUGENE GOODHEART, PH.D.  
*Associate Professor of Literature*

ALBERT RAMSDELL GURNEY, JR., M.F.A.  
*Associate Professor of Literature*

ARTHUR DANIEL KALEDIN, PH.D.  
*Associate Professor of History*

LOUIS KAMPF, B.A.  
*Associate Professor of Literature*

ALVIN CHARLES KIBEL, PH.D.  
*Associate Professor of Literature*

TRAVIS RHODES MERRITT, PH.D.  
*Associate Professor of Literature*

DAVID BIRD RALSTON, PH.D.  
*Associate Professor of History*

ROBERT I. ROTBERG, PH.D.  
*Associate Professor of History and Political Science*

NATHAN SIVIN, PH.D.  
*Associate Professor of the History of Science*

BARRY BERNARD SPACKS, M.A. (*Absent*)  
*Associate Professor of Literature*

WILLIAM BRAASCH WATSON, PH.D.  
*Associate Professor of History*

THEODORE WOOD, JR., S.B., A.M.  
*Associate Professor of Literature*

STUART MARK BLUMIN, PH.D.  
*Assistant Professor of History*

GEORGE STEPHEN BOLOS, PH.D.  
*Assistant Professor of Philosophy*

BORUCH ALTER BRODY, PH.D.  
*Assistant Professor of Philosophy*

JOHN BUTTRICK, M.S.  
*Assistant Professor of Music*

DIANE SHAVER CLEMENS, PH.D.  
*Assistant Professor of History*

MARTIN DISKIN, PH.D.  
*Assistant Professor of Anthropology*

GERALD BOB DWORCKIN, PH.D.  
*Assistant Professor of Philosophy*

NANCY ZILBOORG DWORSKY, PH.D.  
*Assistant Professor of Literature*

PETER HENRY ELBOW, PH.D.  
*Assistant Professor of Literature*

ROBERT SCHOFIELD FREEMAN, PH.D.  
*Assistant Professor of Music*

JOHN COWPERTHWAIT GRAVES, A.M.  
*Assistant Professor of Philosophy*

JOHN HARBISON, M.F.A.  
*Assistant Professor of Music*

ANDREW RICHARD HAWLEY, PH.D.  
*Assistant Professor of Literature*

ROBERT EDWIN HERZSTEIN, PH.D.  
*Assistant Professor of History*

JAMES V. KOHL, PH.D.  
*Assistant Professor of History*

MARK ALAN LEVENSKY, PH.D.  
*Assistant Professor of Philosophy*

DAVID MICHAEL LEVIN, PH.D.  
*Assistant Professor of Philosophy*

ARTHUR RICHARD STEINBERG, PH.D.  
*Assistant Professor of History and Archaeology*

RICHARD WAYNE WERTZ, PH.D.  
*Assistant Professor of History*

DAN SELIGSBERGER WHITE, PH.D.  
*Assistant Professor of History*

FRANK DOMINIC ZINGRONE, PH.D.  
*Assistant Professor of Literature*

**Administrative Officer**  
RUTH ELEANOR DUBOIS, A.B., S.B.

**Lecturers**  
FLOYD BARRINGTON BARBOUR, A.B.  
PAUL BONTEMPS, B.A.  
MYRA BRENNER, B.A.  
JOSEPH STANLEY BROWN, M.A.  
JOHN COOK, MUS.B. *Organist*  
WILLIAM RAYMOND CROUT, M.A.  
HAYWART HENRY, JR., M.A.  
SANFORD KAYE, M.A.  
EDWARD PINCUS, A.B.

**Instructors**  
DONALD HOWARD BELL, M.A.  
ALAN BERGER, M.A.  
PETER S. DONALDSON, M.A.  
MICHAEL BREWSTER FOLSOM, M.A.  
ALLEN GRAUBARD, B.A. (*Absent*)  
HELEN L. HOROWITZ, PH.D.  
SUSAN JHIRAD, M.A.  
RICHARD M. KOFFLER, M.A.  
ROBERT SOLIN LEIKEN, A.B.  
JOHN MCNEES, M.A.  
MICHAEL VINCENT MILLER, B.S., M.A.  
LILLIAN S. ROBINSON, M.A.  
THOMAS WEISBUCH, B.A.  
LEWIS D. WURGAFT, B.A.

**Administrative Assistant**  
WARREN ARTHUR SEAMANS, B.S.

**Professors Emeriti**  
HOWARD RUSSELL BARTLETT, B.S., A.M.  
*Professor of History, Emeritus; Senior Lecturer*  
JOHN ELY BURCHARD, L.H.D., D.ARCH.  
*Professor of Humanities, Emeritus; Dean of the School of Humanities and Social Science, Emeritus; Senior Lecturer*  
GIORGIO DIAZ DE SANTILLANA, PH.D.  
*Professor of the History and Philosophy of Science, Emeritus; Senior Lecturer*  
WILLIAM CHACE GREENE, M.A.  
*Professor of Literature, Emeritus; Senior Lecturer*

## POLITICAL SCIENCE

- ROBERT COLDWELL WOOD, PH.D.  
*Professor of Political Science;*  
*Head of the Department; Director of the Joint Center for*  
*Urban Studies of M.I.T. and Harvard*
- HAYWARD ROSE ALKER, PH.D.  
*Professor of Political Science*
- ALAN ANTHONY ALTSHULER, PH.D.  
*Professor of Political Science*
- LINCOLN PALMER BLOOMFIELD, PH.D.  
*Professor of Political Science*
- WILLIAM P. BUNDY  
*Professor of Political Science (Visiting)*
- JOHN FREDERICK COLLINS, PH.D., D.C.L.  
*Professor of Urban Affairs (Visiting)*
- JOHN P. CRAVEN, PH.D.  
*Professor of Ocean Engineering (Visiting)*
- FREDERICK WARD FREY, PH.D.  
*Professor of Political Science*
- WILLIAM EDGAR GRIFFITH, PH.D.  
*Professor of Political Science*
- EVERETT EINAR HAGEN, PH.D.  
*Professor of Economics and Political Science*
- ERNST HALPERIN, PH.D.  
*Professor of Political Science (Visiting)*
- HAROLD ROBERT ISAACS, A.B.  
*Professor of Political Science*
- WILLIAM WEED KAUFMANN, PH.D.  
*Professor of Political Science*
- PAUL KECSKEMETI  
*Professor of Political Science (Visiting)*
- DANIEL LERNER, PH.D.  
*Professor of Sociology*
- MAX FRANKLIN MILLIKAN, PH.D.  
*Professor of Economics,*  
*Director of the Center for International Studies*
- NORMAN JUDSON PADEFORD, PH.D., LL.D.  
*Professor of Political Science, Emeritus; Senior Lecturer*
- ITHIEL DE SOLA POOL, PH.D.  
*Professor of Political Science*
- LUCIAN WILMOT PYE, PH.D.  
*Professor of Political Science*
- GEORGE WILLIAM RATHJENS, PH.D.  
*Professor of Political Science (Visiting)*
- EUGENE BERTRAM SKOLNIKOFF, PH.D.  
*Professor of Political Science*
- MYRON WEINER, PH.D.  
*Professor of Political Science*
- DONALD LAWRENCE MORTON BLACKMER, PH.D.  
*Associate Professor of Political Science;*  
*Assistant Director of the Center for International Studies*
- LEONARD J. FEIN, PH.D.  
*Associate Professor of Political Science*
- WILLARD RAYMOND JOHNSON, PH.D. (*Absent*)  
*Associate Professor of Political Science*
- MICHAEL LIPSKY, PH.D.  
*Associate Professor of Political Science*
- JOAN MARIE NELSON, PH.D.  
*Associate Professor of Political Science (Visiting)*
- ROBERT I. ROTBERG, D.PHIL.  
*Associate Professor of History and Political Science*
- JOHN SELIM SALOMA, III, PH.D.  
*Associate Professor of Political Science*
- JOSEPH WEIZENBAUM, S.M.  
*Associate Professor of Computer Science*
- SUZANNE BERGER, PH.D.  
*Assistant Professor of Political Science*
- ROY ELIOT FELDMAN, PH.D.  
*Assistant Professor of Political Science*
- NAZLI CHOUCRI FIELD, PH.D.  
*Assistant Professor of Political Science*
- JACKSON ALFRED GIDDENS, PH.D.  
*Assistant Professor of Political Science*
- ROSEMARIE STRÄUSSNIG ROGERS, PH.D.  
*Assistant Professor of Political Science*
- NORALOU PRESTON ROOS, PH.D.  
*Assistant Professor of Political Science*
- HARVEY MORTON SAPOLSKY, PH.D.  
*Assistant Professor of Political Science*
- CHRISTOPHER SCHAEFER, M.A.L.D.  
*Assistant Professor of Political Science*
- Executive Officer**  
LOUIS MENAND, III, PH.D.
- Lecturer**  
*Administrative Officer*  
ELIZABETH ANNA MARIA TERLINGEN, PHARM.
- Lecturers**  
ALBERT GORDON HILL, PH.D.  
JAMES RHYNE KILLIAN, JR., LL.D., SC.D., D.ENG.,  
D.APPL.SCI., ED.D., HH.D.  
THOMAS ANDREW LEHRER, A.M.  
STUART D. MCINTOSH, M.S.
- Instructors**  
L. WALLACE CLAUSEN, M.A.  
DAVID MYRON GRIFFEL, B.S.  
STEVEN DAVID ROSENBERG, E.E.
- Professor Emeritus**  
NORMAN JUDSON PADEFORD, PH.D., LL.D.  
*Professor of Political Science, Emeritus; Senior Lecturer*

FACULTY

PSYCHOLOGY

HANS-LUKAS TEUBER, PH.D.  
*Professor of Psychology; Head of the Department*  
 STEPHAN LEWIS CHOROVER, PH.D.  
*Professor of Psychology*  
 JERRY ALLEN FODOR, PH.D.  
*Professor of Psycholinguistics*  
 RICHARD MARX HELD, PH.D.  
*Professor of Experimental Psychology*  
 WALLE JETZE HARINX NAUTA, M.D., PH.D.  
*Professor of Neuroanatomy*  
 WAYNE ALLEN WICKELGREN, PH.D.  
*Professor of Psychology*  
 EMILIO BIZZI, M.D.  
*Associate Professor of Neurophysiology*  
 ALAN HEIN, PH.D.  
*Associate Professor of Psychology*  
 WHITMAN ALBIN RICHARDS, PH.D.  
*Associate Professor of Psychology*  
 PETER HARKAI SCHILLER, PH.D.  
*Associate Professor of Psychology*  
 MERRILL FREDERICK GARRETT, PH.D.  
*Assistant Professor of Psychology*  
 GERALD EDWARD SCHNEIDER, PH.D.  
*Assistant Professor of Psychology*

*Administrative Assistant*

ROBERT IRWIN McELROY, B.A.

*Research Associates*

JOSEPH ALOYSIUS BAUER, JR., M.S.  
 SUZANNE HAMMOND CORKIN, PH.D.  
 RHEA MENDOZA DIAMOND, PH.D.  
 LENNART HEIMER, M.D.  
 HARVEY JULES KARTEN, M.D.  
 RITA GILLIS RUDEL, PH.D.  
 THOMAS EVANS TWITCHELL, M.D.

SLOAN SCHOOL OF MANAGEMENT

WILLIAM FRANK POUNDS, PH.D.  
*Professor of Management; Dean*  
 ABRAHAM J. SIEGEL, PH.D.  
*Professor of Industrial Relations; Associate Dean*  
 PETER PAUL GIL, PH.D.  
*Associate Dean for Executive Programs;  
 Senior Lecturer*  
 SIDNEY STUART ALEXANDER, PH.D.  
*Professor of Management*  
 EDWARD HARRY BOWMAN, PH.D.  
*Professor of Management*  
 DOUGLASS VINCENT BROWN, PH.D.  
*Alfred P. Sloan Professor of Management,  
 Emeritus; Senior Lecturer*  
 DONALD CARY CARROLL, PH.D. (*Absent*)  
*Professor of Management*  
 JOHN FREDERICK COLLINS, PH.D., D.C.L.  
*Professor of Urban Affairs (Visiting)*  
 PAUL HAROLD COOTNER, PH.D. (*Absent*)  
*Professor of Finance*  
 DAVID DURAND, PH.D.  
*Professor of Management*  
 JAY WRIGHT FORRESTER, D.ENG.  
*Professor of Management*  
 MASON HAIRE, PH.D.  
*Professor of Organizational Psychology and Management*  
 THOMAS MASON HILL, A.B., M.B.A.  
*Professor of Management*  
 DANIEL MARK HOLLAND, PH.D.  
*Professor of Finance*  
 GORDON MAYER KAUFMAN, D.B.A.  
*Professor of Management*  
 CHARLES POOR KINDLEBERGER, PH.D., D.H.C.  
*Professor of Management*  
 EDWIN KUH, PH.D.  
*Professor of Finance*  
 JOHN DUTTON CONANT LITTLE, PH.D.  
*Professor of Management; Director of Operations  
 Research Center*  
 PAUL WEBSTER MACAVOY, PH.D.  
*Professor of Management*  
 DONALD GEORGE MARQUIS, PH.D.  
*Professor of Organizational Psychology and Management*  
 FRANCO MODIGLIANI, D.JUR., D.SOC.SCI., LL.D.  
*Professor of Finance*  
 LEO BENJAMIN MOORE, S.M.  
*Professor of Management*  
 CHARLES ANDREW MYERS, PH.D.  
*Sloan Fellows Professor of Management*  
 MARVIN SCOTT MYERS, PH.D.  
*Prof. of Organizational Psychology and Management  
 (Visiting)*  
 EDGAR HENRY SCHEIN, PH.D.  
*Professor of Organizational Psychology and Management;  
 Undergraduate Planning Professor*  
 CARROLL LOUIS WILSON, SC.D.  
*Professor of Management*

- ZENON SOTERIOU ZANNETOS, PH.D.  
*Professor of Management*
- THOMAS JOHN ALLEN, JR., PH.D.  
*Associate Professor of Organizational Psychology and Management*
- ARNOLD EVERETT AMSTUTZ, PH.D.  
*Associate Professor of Management*
- WALLACE BRUCE STEWART CROWSTON, PH.D.  
*Associate Professor of Management*
- DAVID BRUCE MONTGOMERY, PH.D. (*Absent*)  
*Associate Professor of Management*
- STEWART CLAY MYERS, PH.D.  
*Associate Professor of Finance*
- EDWARD BAER ROBERTS, PH.D.  
*Associate Professor of Management*
- MICHAEL STEWART SCOTT MORTON, D.B.A.  
*Associate Professor of Management*
- JEREMY FRANK SHAPIRO, PH.D.  
*Associate Professor of Management*
- ALVIN JOHN SILK, PH.D.  
*Associate Professor of Management*
- DAVID PETER TAYLOR, PH.D. (*Absent*)  
*Associate Professor of Industrial Relations*
- LESTER CARL THUROW, PH.D.  
*Associate Professor of Management*
- LEON SELIGSBERGER WHITE, PH.D.  
*Associate Professor of Management*
- JAMES E. ANNABLE, PH.D.  
*Assistant Professor of Industrial Relations*
- MICHAEL JAMES BROWER, PH.D.  
*Assistant Professor of Industrial History (Visiting)*
- GEORGE FRANKLIN FARRIS, PH.D.  
*Assistant Professor of Organizational Psychology and Management*
- JAY ROBERT GALBRAITH, D.B.A.  
*Assistant Professor of Management*
- GEORGE ANTHONY GORRY, JR., PH.D.  
*Assistant Professor of Management*
- JOHN HENIZE, B.A.  
*Assistant Professor of Management*
- MALCOLM MURRAY JONES, PH.D.  
*Assistant Professor of Management*
- PAUL R. KLEINDORFER, PH.D.  
*Assistant Professor of Management*
- DAVID ALLEN KOLB, PH.D.  
*Assistant Professor of Organizational Psychology and Management*
- MILTON LAMPL LAVIN, PH.D.  
*Assistant Professor of Organizational Psychology and Management*
- WILLIAM ARTHUR MARTIN, PH.D.  
*Assistant Professor of Management*
- DENNIS LYNN MEADOWS, PH.D. (*Absent*)  
*Assistant Professor of Management*
- DANIEL QUINN MILLS, PH.D.  
*Assistant Professor of Industrial Relations*
- DAVID NORMAN NESS, B.S.B.A.  
*Assistant Professor of Management*
- ALAN LEE PATZ, PH.D.  
*Assistant Professor of Organizational Psychology and Management*
- GERALD ALBERT POGUE, PH.D.  
*Assistant Professor of Finance*
- JOHN FRALICK ROCKART, PH.D.  
*Assistant Professor of Management*
- IRWIN MARTIN RUBIN, PH.D.  
*Assistant Professor of Organizational Psychology and Management*
- MYRON S. SCHOLES, PH.D.  
*Assistant Professor of Finance*
- CHRISTOPHER REED SPRAGUE, PH.D.  
*Assistant Professor of Management*
- CARL VERNER SWANSON, S.B.  
*Assistant Professor of Management*
- GLEN LEE URBAN, PH.D.  
*Assistant Professor of Management*
- ROY ELMER WELSCH, PH.D.  
*Assistant Professor of Management*
- Administrative Officer**  
GERTRUDE ELIZABETH BURNS
- Senior Lecturers**  
RICHARD BECKHARD, A.B.  
GORDON FALK BLOOM, PH.D.  
HERBERT FRANKLIN GOODWIN, S.B.  
JAMES BARNES HARTGERING, M.D.  
STANLEY MARTIN JACKS, A.M., LL.B.  
*Advisor to Prelaw Students*
- WILLIAM LOUIS LETWIN, PH.D.  
RICHARD STETSON MORSE, D.ENG., D.SC.  
RICHARD DUNLOP ROBINSON, PH.D.  
CHANDLER HARRISON STEVENS, JR., B.E.E. (*Absent*)
- Lecturers**  
MICHAEL SAMPSON BARAM, L.L.B.  
WILLIAM ROY HAMILTON, JR., PH.D.  
GENE MARTIN LYONS, PH.D.  
RICHARD THOMAS MURPHY, JR., A.B., B.S., LL.B.  
DAVID SIROTA, PH.D.  
DOROTHY ENID WEDDERBURN, M.A. (*Visiting*)
- Instructors**  
THOMAS PATRICK GERRITY, JR., M.S.  
ROBERT SHAW GREEN, M.S.E.E.  
RICHARD LEE SCHMALENSEE, S.B.  
JOEL SHWIMER, S.B.  
JARROD WHITFIELD WILCOX, S.M.
- Executive Development Programs**  
PRISCILLA ANN KARB, A.B., M.E.D.  
*Associate Director*
- Assistant for Graduate Programs**  
MIRIAM SHERBURNE, A.B.
- Assistant for Undergraduate Programs**  
ESTHER MERRILL, B.S.

FACULTY

**Research Associates**

JAMES MILLER MCINTYRE, B.S.  
ALEXANDER LE FEVRE PUGH, III, E.E.

**Professors Emeriti**

EDWARD LINDLEY BOWLES, D.SC.  
*Professor of Industrial Management, Emeritus*  
EDWARD PENNELL BROOKS, D.S.C.  
*Professor of Industrial Management, Emeritus;  
Dean Emeritus*  
DOUGLASS VINCENT BROWN, PH.D.  
*Alfred P. Sloan Professor of Management, Emeritus;  
Senior Lecturer*  
BILLY EARL GOETZ, PH.D.  
*Professor of Management, Emeritus*

**SCHOOL OF SCIENCE**

ROBERT ARNOLD ALBERTY, PH.D., SC.D. *Dean*  
JOEL ORLEN, M.A. *Administrative Officer*

**SCIENCE COUNCIL**

BORIS MAGASANIK, PH.D. *Head, Department of Biology*  
JOHN ROSS, PH.D. *Head, Department of Chemistry*  
FRANK PRESS, PH.D. *Head, Department of Earth and Planetary Sciences*  
NORMAN LEVINSON, SC.D. *Head, Department of Mathematics*  
HENRY GARRETT HOUGHTON, SC.D. *Head, Department of Meteorology*  
NEVIN STEWART SCRIMSHAW, PH.D., M.D., D.P.S. *Head, Department of Nutrition and Food Science*  
VICTOR FREDERICK WEISSKOPF, PH.D., SC.D. *Head, Department of Physics*  
ALBERT GORDON HILL, PH.D. *Chairman, Physics Council*

**EXECUTIVE OFFICERS AND DEPUTY HEADS**

GENE MONTE BROWN, PH.D. *Department of Biology*  
JOHN WITHERS IRVINE, JR., PH.D., SC.D. *Department of Chemistry*  
DANIEL BURRILL RAY *Department of Mathematics*  
SAMUEL ABRAHAM GOLDBLITH, PH.D. *Department of Nutrition and Food Science*  
GEORGE GRAHAM HARVEY, PH.D. *Department of Physics*

## BIOLOGY

BORIS MAGASANIK, PH.D.  
*Professor of Microbiology; Head of the Department*

GENE MONTE BROWN, PH.D.  
*Professor of Biochemistry; Executive Officer*

EUGENE BELL, PH.D.  
*Professor of Biology*

JOHN MACHLIN BUCHANAN, PH.D., D.SC.  
*John and Dorothy Wilson Professor of Biochemistry*

MAURICE SANFORD FOX, PH.D.  
*Professor of Genetics*

BERNARD SIDNEY GOULD, PH.D.  
*Professor of Biochemistry*

PAUL RANDOLPH GROSS, PH.D.  
*Professor of Biology*

CECIL EDWIN HALL, PH.D.  
*Professor of Biophysics*

VERNON MARTIN INGRAM, PH.D., D.SC.  
*Professor of Biochemistry*

JEROME YSRAEL LETTVIN, M.D.  
*Professor of Communications Physiology*

KURT SIEGFRIED LION, DR.ING.  
*Professor of Applied Biophysics, Emeritus;  
Senior Lecturer*

IRVING M. LONDON, M.D.  
*Professor of Biology*

SALVADOR EDWARD LURIA, M.D., D.SC.  
*Sedgwick Professor of Biology*

ALEXANDER RICH, M.D.  
*Professor of Biophysics*

PHILLIPS WESLEY ROBBINS, PH.D. (*Absent*)  
*Professor of Biochemistry*

FRANCIS OTTO SCHMITT, PH.D., SC.D.  
*Institute Professor, Emeritus; Professor of Biology, Emeritus*

IRWIN WHITING SIZER, PH.D.  
*Professor of Biochemistry; Dean of the Graduate School*

DAVID FLOYD WAUGH, PH.D.  
*Professor of Biophysics*

CORRADO BAGLIONI, M.D.  
*Associate Professor of Biology*

DAVID BALTIMORE, PH.D.  
*Associate Professor of Biology*

JOEL EDWARD BROWN, PH.D.  
*Associate Professor of Physiology*

CHARLES EDWARD HOLT, III, PH.D.  
*Associate Professor of Biology*

SHELDON PENMAN, PH.D.  
*Associate Professor of Biophysics*

UTTAM LAL RAJBHANDARY, PH.D.  
*Associate Professor of Biochemistry*

ETHAN ROY SIGNER, PH.D.  
*Associate Professor of Microbiology*

DAVID BOTSTEIN, PH.D.  
*Assistant Professor of Genetics*

BOYCE WILLIAM BURGE, PH.D.  
*Assistant Professor of Biology*

HARVEY FRANKLIN LODISH, PH.D.  
*Assistant Professor of Biology*

PAUL REINHARD SCHIMMEL, PH.D.  
*Assistant Professor of Biochemistry*

LISA AMELIA STEINER, M.D.  
*Assistant Professor of Biochemistry*

KENNETH BOIVIN TAYLOR, M.D., PH.D.  
*Assistant Professor of Biochemistry*

*Administrative Officer*

EDWARD JOSEPH GAUDIANO

*Lecturer*

LAURENCE HERBERT KEDES, M.D.

*Instructors*

ELIZABETH WINIFRED JONES, PH.D.  
JOHN CHUNG LEE, PH.D.

*Research Associates*

GERALD MAXWELL FULLER, PH.D.  
ANNAMARIA TORRIANI GORINI, PH.D.  
SONJA KELLER GROSS, PH.D.  
SUNG HOU KIM, PH.D.  
ERNST ADOLPH KUCHLER, PH.D.  
KENNETH JAMES LEMBACH, PH.D.  
HENG-CHUN LI, PH.D.  
HANG HSIN LO, PH.D.  
GEORGE MARINOS MANIATIS, M.D.  
HUGH NICHOLAS, PH.D.  
MIROSLAWA PIECHOWSKA, PH.D.  
JAAKKO PERTTI PISPA, MED. SCI. D.  
JOSEPH PRESSLITZ, PH.D.  
HELEN RUTH REVEL, PH.D.  
VIRGINIA FRANKLIN ROSS, PH.D.  
HISAKO SAKIYAMA, M.D.  
SHIGERU SAKIYAMA, M.D.  
VICTOR EZRA SHASHOUA, PH.D.  
DAVID ANDREW SIRBASKU, PH.D.  
CHARLES WILBUR SLATTERY, PH.D.  
WERNER KARL STEUERNAGEL, E.E.  
TOSHIYA TAKANO, M.D.  
BERT LESTER VALLE, M.D.  
DONALD HERMAN VOET, PH.D.  
WALTER ALAN WOLF, PH.D.  
ESTER AURELIA ZYLBER, PH.D.

*Professors Emeriti*

KURT SIEGFRIED LION, DR.ING.  
*Professor of Applied Biophysics, Emeritus; Senior Lecturer*

FRANCIS OTTO SCHMITT, PH.D., SC.D.  
*Institute Professor, Emeritus; Professor of Biology, Emeritus*

CLAIR ELSMERE TURNER, DR.PH., SC.D.  
*Professor of Public Health, Emeritus*

## CHEMISTRY

JOHN ROSS, PH.D.

*Professor of Chemistry; Head of the Department*

JOHN WITHERS IRVINE, JR., PH.D., SC.D.

*Professor of Chemistry; Executive Officer*

ROBERT ARNOLD ALBERTY, PH.D., SC.D.

*Professor of Chemistry;  
Dean of the School of Science*

ISADORE AMDUR, PH.D.

*Professor of Physical Chemistry*

JOANNES JOSEPH BEENAKKER, PH.D.

*Professor of Chemistry (Visiting)*

GLENN ALLEN BERCHTOLD, PH.D.

*Professor of Chemistry*

KLAUS BIEMANN, PH.D.

*Professor of Chemistry*

GEORGE HERMANN BÜCHI, D.SC.

*Dreyfus Professor of Chemistry*

CHARLES DUBOIS CORYELL, PH.D.

*Professor of Chemistry*

FRANK ALBERT COTTON, PH.D., SC.D.

*Dreyfus Professor of Chemistry*EDMUND LEE GAMBLE, PH.D. (*Absent*)*Professor of Inorganic Chemistry*

CARL WESLEY GARLAND, PH.D.

*Professor of Chemistry*

FREDERICK DAVIS GREENE, II, PH.D.

*Professor of Chemistry*

RICHARD HADLEY HOLM, PH.D.

*Professor of Chemistry*

HERBERT OTIS HOUSE, PH.D.

*Professor of Chemistry*

DAVID NEWTON HUME, PH.D.

*Professor of Chemistry*

RICHARD COLLINS LORD, PH.D., SC.D.

*Professor of Chemistry;**Director of the Spectroscopy Laboratory*

IRWIN OPPENHEIM, PH.D.

*Professor of Chemistry*

DIETMAR SEYFERTH, PH.D.

*Professor of Chemistry*

JOHN CLARK SHEEHAN, PH.D., SC.D.

*Dreyfus Professor of Organic Chemistry*

DAVID POWELL SHOEMAKER, PH.D.

*Professor of Chemistry*

CLARK CONKLING STEPHENSON, PH.D.

*Professor of Chemistry*

CHARLES GARDNER SWAIN, PH.D.

*Professor of Chemistry*

JOHN STEWART WAUGH, PH.D.

*Professor of Chemistry*

ALAN DAVISON, PH.D.

*Associate Professor of Chemistry*

DANIEL SCHAEFFER KEMP, PH.D.

*Associate Professor of Chemistry*JAMES LLOYD KINSEY, PH.D. (*Absent*)*Associate Professor of Chemistry*

WILLIAM ROBERT MOORE, PH.D.

*Associate Professor of Chemistry*

ROBERT JAMES SILBEY, PH.D.

*Associate Professor of Chemistry*

GEORGE MCCLELLAND WHITESIDES, PH.D.

*Associate Professor of Chemistry*

KERRY WOLLING BOWERS, PH.D.

*Assistant Professor of Chemistry*

DAVID MAYER CHIPMAN, PH.D.

*Assistant Professor of Chemistry*

JAMES WILLIAM DUBRIN, PH.D.

*Assistant Professor of Chemistry*

THAYER CARLTON FRENCH, PH.D.

*Assistant Professor of Chemistry*

STEPHEN GEORGE KUKOLICH, SC.D.

*Assistant Professor of Chemistry*

JOHN SIMPSON LEWIS, PH.D.

*Assistant Professor of Chemistry and Geochemistry*

PAUL REINHARD SCHIMMEL, PH.D.

*Assistant Professor of Chemistry and Biology*

JEFFREY IRWIN STEINFELD, PH.D.

*Assistant Professor of Chemistry*

WILLIAM BEN WALTERS, PH.D.

*Assistant Professor of Chemistry***Administrative Officer**

EARLE ARTHUR GOODRICH, M.B.A.

**Lecturer**

DANIEL DOMINICK TRAFICANTE, PH.D.

**Instructors**

PAUL LOUIS BOCK, B.S.

GERALD WAYNE HOLLEMAN, PH.D.

JOSEF TAKATS, PH.D.

**Professors Emeriti**

AVERY ALLEN ASHDOWN, PH.D.

*Associate Professor of Organic Chemistry, Emeritus*

JAMES ALEXANDER BEATTIE, PH.D.

*Professor of Physical Chemistry, Emeritus*

LEICESTER FORSYTH HAMILTON, S.B.

*Professor of Analytical Chemistry, Emeritus*

LOUIS HARRIS, PH.D.

*Associate Professor of Physical Chemistry, Emeritus*

LAWRENCE JOSEPH HEIDT, PH.D.

*Associate Professor of Physical Chemistry, Emeritus*

FREDERICK GEORGE KEYES, PH.D., SC.D.

*Professor of Physical Chemistry, Emeritus*

NICHOLAS ATHANASIOS MILAS, PH.D., D.SC.

*Associate Professor of Organic Chemistry, Emeritus*

EARL BOWMAN MILLARD, PH.D.

*Professor of Physical Chemistry, Emeritus*

AVERY ADRIAN MORTON, PH.D.

*Professor of Organic Chemistry, Emeritus*

GEORGE SCATCHARD, PH.D., SC.D.

*Professor of Physical Chemistry, Emeritus*

STEPHEN GERSHOM SIMPSON, PH.D.

*Associate Professor of Analytical Chemistry, Emeritus*

CHARLES MONTGOMERY WAREHAM, S.B.

*Associate Professor of Inorganic Chemistry, Emeritus*

RALPH CHILLINGWORTH YOUNG, PH.D.

*Associate Professor of Inorganic Chemistry, Emeritus*

## EARTH AND PLANETARY SCIENCES

FRANK PRESS, PH.D.  
*Professor of Geophysics; Head of the Department*

KEIITI AKI, PH.D.  
*Professor of Geophysics*

WILLIAM FRANCIS BRACE, PH.D.  
*Professor of Geology*

MARTIN JULIAN BUERGER, PH.D.  
*Institute Professor, Emeritus;  
 Professor of Mineralogy and Crystallography, Emeritus;*

CHARLES SHEPLEY COX, PH.D.  
*Professor of Oceanography (Visiting)*

HAROLD WILLIAMS FAIRBAIRN, PH.D.  
*Professor of Geology*

PATRICK MASON HURLEY, PH.D.  
*Professor of Geology*

THEODORE RICHARD MADDEN, PH.D.  
*Professor of Geophysics*

IRWIN IRA SHAPIRO, PH.D.  
*Professor of Geophysics and Physics*

ROBERT RAKES SHROCK, PH.D.  
*Professor of Geology*

GENE SIMMONS, PH.D.  
*Professor of Geophysics*

WILLIAM STELLING VON ARX, SC.D.  
*Professor of Physical Oceanography*

HIROO KANAMORI, PH.D.  
*Associate Professor of Geophysics (Visiting)*

WILLIAM HAMET PINSON, JR., PH.D.  
*Associate Professor of Geology*

MEHMET NAFI TOKSÖZ, PH.D.  
*Associate Professor of Geophysics*

DAVID ROBERT WONES, PH.D.  
*Associate Professor of Geology*

SHAWN BIEHLER, PH.D.  
*Assistant Professor of Geophysics*

CHARLES CLAUDE COUNSELMAN, III, PH.D.  
*Assistant Professor of Planetary Science*

FREDERICK AUGUST FREY, PH.D.  
*Assistant Professor of Geochemistry*

JOHN SIMPSON LEWIS, PH.D.  
*Assistant Professor of Geochemistry and Chemistry*

THOMAS BARD McCORD, PH.D.  
*Assistant Professor of Planetary Physics*

THOMAS RICHARD McGETCHIN, PH.D.  
*Assistant Professor of Geology*

RICHARD STEVENS NAYLOR, PH.D.  
*Assistant Professor of Geology*

JOHN BRELSFORD SOUTHARD, PH.D.  
*Assistant Professor of Geology*

CARL ISAAC WUNSCH, PH.D.  
*Assistant Professor of Oceanography*

*Administrative Assistant*

HENRY ADAMS MORSS, JR., PH.D.

*Research Associates*

NEZIHI CANITEZ, PH.D.

DAE-HYUN CHUNG, PH.D.

JOHN SEBRING DERR, PH.D.

TOMOWO HIRASAWA, D.SC.

KI-ITI HORAI, SC.D.

HARRY MACK, PH.D.

HAUSILA PRASAD SINGH, PH.D.

PETER SUSSE, PH.D.

JOSEPH BROUGHTON WALSH, PH.D.

RALPH AMBROSE WIGGINS, PH.D.

CHARLES GODDARD WING, PH.D.

*Professors Emeriti*

MARTIN JULIAN BUERGER, PH.D.

*Institute Professor, Emeritus;*

*Professor of Mineralogy and Crystallography, Emeritus*

ROLAND DANE PARKS, E.M., M.S.

*Associate Professor of Mineral Industry, Emeritus*

WALTER LUCIUS WHITEHEAD, PH.D., D.SC.

*Associate Professor of Geology, Emeritus*

FACULTY

MATHEMATICS

- NORMAN LEVINSON, SC.D.  
*Professor of Mathematics; Head of the Department*
- HARVEY PHILIP GREENSPAN, PH.D.  
*Professor of Applied Mathematics; Chairman, Committee on Applied Mathematics*
- KENNETH MYRON HOFFMAN, PH.D.  
*Professor of Mathematics; Chairman, Committee on Pure Mathematics*
- DANIEL BURRILL RAY, PH.D.  
*Professor of Mathematics; Executive Officer*
- WARREN AMBROSE, PH.D. (Absent)  
*Professor of Mathematics*
- NESMITH CORNETT ANKENY, PH.D.  
*Professor of Mathematics*
- MICHAEL ARTIN, PH.D.  
*Professor of Mathematics*
- AVID JOHN BENNEY, PH.D.  
*Professor of Applied Mathematics*
- ARMAND BOREL, PH.D.  
*Professor of Mathematics (Visiting)*
- PRESCOTT DURAND CROUT, PH.D.  
*Professor of Mathematics*
- SIGURDUR HELGASON, PH.D.  
*Professor of Mathematics*
- FRANCIS BEGNAUD HILDEBRAND, PH.D.  
*Professor of Mathematics*
- LOUIS NORBERG HOWARD, PH.D.  
*Professor of Mathematics*
- DANIEL MARINUS KAN, PH.D.  
*Professor of Mathematics*
- DANIEL J. KLEITMAN, PH.D.  
*Professor of Mathematics*
- BERTRAM KOSTANT, PH.D.  
*Professor of Mathematics*
- TAKESHI KOTAKE, DR.SCI.  
*Professor of Mathematics (Visiting)*
- ELLIOTT HERSHEL LIEB, PH.D.  
*Professor of Applied Mathematics*
- CHIA-CHIAO LIN, PH.D.  
*Institute Professor; Professor of Applied Mathematics*
- WILLEM VAN RENSSELAER MALKUS, PH.D.  
*Professor of Applied Mathematics*
- WILLIAM TED MARTIN, PH.D.  
*Professor of Mathematics; Chairman of the Faculty*
- ARTHUR PAUL MATTUCK, PH.D.  
*Professor of Mathematics*
- JOHN WILLARD MILNOR, PH.D.  
*Alfred P. Sloan Professor of Mathematics*
- JAMES RAYMOND MUNKRES, PH.D.  
*Professor of Mathematics*
- SEYMOUR AUBREY PAPERT, PH.D.  
*Professor of Applied Mathematics*
- FRANKLIN PAUL PETERSON, PH.D.  
*Professor of Mathematics*
- ERIC REISSNER, DR. ING., PH.D.  
*Professor of Applied Mathematics*
- HARTLEY ROGERS, JR., PH.D.  
*Professor of Mathematics*
- GIAN-CARLO ROTA, PH.D.  
*Professor of Mathematics*
- GERALD ENOCH SACKS, PH.D. (Absent)  
*Professor of Mathematics*
- RICHARD DONALD SCHAFFER, PH.D.  
*Professor of Mathematics*
- IRVING EZRA SEGAL, PH.D.  
*Professor of Mathematics*
- CLAUDE ELWOOD SHANNON, PH.D.  
*Donner Professor of Science*
- ISADORE MANUAL SINGER, PH.D.  
*Professor of Mathematics*
- GEORGE BRINTON THOMAS, JR., PH.D. (Absent)  
*Professor of Mathematics*
- GEORGE PROCTOR WADSWORTH, PH.D.  
*Professor of Mathematics*
- GEORGE WILLIAM WHITEHEAD, PH.D.  
*Professor of Mathematics*
- DONALD WERNER ANDERSON, PH.D.  
*Associate Professor of Mathematics*
- HUNG CHENG, PH.D.  
*Associate Professor of Applied Mathematics*
- EDWARD BALDWIN CURTIS, PH.D.  
*Associate Professor of Mathematics*
- RICHARD MANSFIELD DUDLEY, PH.D.  
*Associate Professor of Mathematics*
- STEPHEN GROSSBERG, PH.D. (Absent)  
*Associate Professor of Applied Mathematics*
- VICTOR WILLIAM GUILLEMIN, PH.D. (Absent)  
*Associate Professor of Mathematics*
- CHRISTOPHER HUNTER, PH.D.  
*Associate Professor of Applied Mathematics*
- STEVEN KLEIMAN, PH.D.  
*Associate Professor of Mathematics*
- BERNARD MASKIT, PH.D.  
*Associate Professor of Mathematics*
- DANIEL GRAY QUILLEN, PH.D. (Absent)  
*Associate Professor of Mathematics*
- HAROLD MEAD STARK, PH.D. (Absent)  
*Associate Professor of Mathematics*
- WILLIAM GILBERT STRANG, PH.D.  
*Associate Professor of Mathematics*
- ALAR TOOMRE, PH.D. (Absent)  
*Associate Professor of Applied Mathematics*
- FREDERIC YUI-MING WAN, PH.D.  
*Associate Professor of Applied Mathematics*
- RODNEY JAMES BAXTER, PH.D.  
*Assistant Professor of Applied Mathematics*
- ROE WILLIAM GOODMAN, PH.D.  
*Assistant Professor of Mathematics*
- PHILIP JOEL GREENBERG, PH.D.  
*Assistant Professor of Applied Mathematics*
- STEVEN ALAN ORSZAG, PH.D. (Absent)  
*Assistant Professor of Applied Mathematics*
- MICHAEL STEWART PATTERSON, PH.D.  
*Assistant Professor of Applied Mathematics*

**Lecturers**

WOLF BARTH, PH.D.  
ELIZABETH JEAN O'NEIL, PH.D.

**C. L. E. Moore Instructors**

LAWRENCE SANDOR BREEN, PH.D.  
JOHN TUCKER CANNON, PH.D.  
LAWRENCE JAY CORWIN, PH.D.  
EDWARD BRIAN DAVIES, PH.D.  
HELMUT PAVLOVICH EPP, PH.D.  
DIRK FERUS, PH.D.  
DAVID LEWIS FRANK, PH.D.  
JOHN MOORE FRANKS, PH.D.  
CURTIS GREENE, PH.D.  
BIRGER IVERSEN, PH.D.  
KENNETH DAVID JOHNSON, PH.D.  
BARRY BRUCE MACKICHAN, PH.D.  
JAMES WAI-KEE MARK, PH.D.  
MALAYATTIL RABINDRANATHAN, PH.D.  
BERNARD SHIFFMAN, PH.D.

**Instructors**

DOUGLAS BRUCE ABRAHAM, PH.D.  
MICHAEL FREDERICK BEHRENS, PH.D.  
SIHAM C. BRAIDI, PH.D.  
BRYAN EDMUND CAIN, PH.D.  
HARRIET JANE FELL, PH.D.  
HANS DIETER FÖLLMER, PH.D.  
MICHAEL RALPH FOSTER, PH.D.  
LAWRENCE ALBERT HARRIS, PH.D.  
JAMES RICHARD KING, PH.D.  
EUGENE MEYER KLEINBERG, PH.D.  
MICHAEL MARVIN KRIEGER, PH.D.  
WILLIAM KUNKIN, PH.D.  
MANUEL LERMAN, PH.D.  
CHRISTOPHER LLOYD MORGAN, PH.D.  
ROBERT CUNNINGHAM REILLY, PH.D.  
RONALD AVON SHAPIRO, PH.D.  
DAVID AUREL STONE, PH.D.  
JOHN KEVIN STUTZ, PH.D.  
EDWARD CHARLES TURNER, PH.D.  
BAHMAN VAHIDI, PH.D.  
WILLIBRORDUS INOCENTIVS MARIA WILS, PH.D.

**Administrative Assistants**

JAMES EDWARD DALTON  
JOHN ARTHUR MITCHELL, A.B.

**Research Associate**

LARRY WOLFE BEEFERMAN, PH.D.

**Professors Emeriti**

RAYMOND DONALD DOUGLASS, PH.D., SC.D.  
*Professor of Mathematics, Emeritus*  
HENRY BAYARD PHILLIPS, PH.D., LL.D.  
*Professor of Mathematics, Emeritus*  
DIRK JAN STRUIK, PH.D.  
*Professor of Mathematics, Emeritus*

**METEOROLOGY**

HENRY GARRETT HOUGHTON, SC.D.  
*Professor of Meteorology; Head of the Department*  
JAMES MURDOCH AUSTIN, SC.D.  
*Associate Professor of Meteorology;  
Director of Summer Session*  
JULE GREGORY CHARNEY, PH.D.  
*Alfred P. Sloan Professor of Meteorology*  
EDWARD NORTON LORENZ, SC.D.  
*Professor of Meteorology*  
ERIK LEONARD MOLLÖ-CHRISTENSEN, SC.D.  
*Professor of Meteorology*  
REGINALD EDWARD NEWELL, SC.D.  
*Professor of Meteorology*  
NORMAN ALTON PHILLIPS, PH.D.  
*Professor of Meteorology*  
FREDERICK SANDERS, SC.D.  
*Professor of Meteorology*  
VICTOR PAUL STARR, PH.D.  
*Professor of Meteorology*  
HENRY MELSON STOMMEL, PH.D.  
*Professor of Oceanography*  
HURD CURTIS WILLET, PH.D.  
*Professor of Meteorology, Emeritus; Senior Lecturer*  
DELBAR POULEUR KEILY, S.B.  
*Associate Professor of Meteorology*  
ROBERT CRUCE BEARDSLEY, PH.D.  
*Assistant Professor of Oceanography*  
PETER BROOMELL RHINES, PH.D.  
*Assistant Professor of Oceanography*  
  
**Senior Research Associates**  
PAULINE MORROW AUSTIN, PH.D., SC.D.  
ALAN COGSWELL BEMIS, A.B., S.M.  
  
**Professor Emeritus**  
HURD CURTIS WILLET, PH.D.  
*Professor of Meteorology, Emeritus; Senior Lecturer*

## NUTRITION AND FOOD SCIENCE

NEVIN STEWART SCRIMSHAW, PH.D., M.D., D.P.S.  
*Professor of Nutrition; Head of the Department*

SAMUEL ABRAHAM GOLDBLITH, PH.D.  
*Professor of Food Science; Deputy Head of the Department*

ARNOLD L. DEMAIN, PH.D.  
*Professor of Industrial Microbiology*

LEO FRIEDMAN, PH.D. (*Absent*)  
*Professor of Nutrition and Food Safety*

ROBERT SAMUEL HARRIS, PH.D.  
*Professor of Nutritional Biochemistry, Emeritus;*  
*Senior Lecturer*

MARCUS KAREL, PH.D.  
*Professor of Food Engineering*

HAMISH NISBET MUNRO, M.D., D.SC.  
*General Foods Professor of Physiological Chemistry*

PAUL MEDFORD NEWBERNE, D.V.M., PH.D.  
*Professor of Nutritional Pathology*

JOHN THEODORE ROOSEVELT NICKERSON, PH.D.  
*Professor of Food Technology*

ABRAHAM DANIEL RUBENSTEIN, M.D.  
*Professor of Epidemiology (Visiting)*

JOHN BRUTON STANBURY, M.D.  
*Professor of Experimental Medicine*

EMILY LIPPINCOTT WICK, PH.D.  
*Professor of Food Chemistry;*  
*Associate Dean of Student Affairs*

GERALD NORMAN WOGAN, PH.D.  
*Professor of Food Toxicology*

EDWIN DAGOBERT BRANSOME, JR., M.D.  
*Associate Professor of Endocrinology and Metabolism*

PHILLIP ISSENBERG, PH.D.  
*Associate Professor of Food Science*

ROBERT SPENCER LEES, M.D.  
*Associate Professor of Metabolism and Human Nutrition*

PADAMAKAR PRATEP LELE, PH.D. M.D.  
*Associate Professor of Experimental Medicine*

RICHARD ISAAC MATELES, SC.D. (*Absent*)  
*Associate Professor of Biochemical Engineering*

SANFORD ARTHUR MILLER, PH.D.  
*Associate Professor of Nutritional Biochemistry*

JAMES KENNETH PALMER, PH.D.  
*Associate Professor of Food Biochemistry*

STEVEN ROBERT TANNENBAUM, PH.D.  
*Associate Professor of Food Science*

ROBERT BURTON WILSON, PH.D.  
*Associate Professor of Nutritional Animal Pathology*

GEORGE WOLF, D.PHIL.  
*Associate Professor of Physiological Chemistry*

RICHARD J. WURTMAN, M.D.  
*Associate Professor of Endocrinology and Metabolism*

JAMES F. DRUMMOND, PH.D.  
*Assistant Professor of Nutritional Biochemistry*  
*and Metabolism*

JOHN PIERRE FLATT, PH.D.  
*Assistant Professor of Physiological Chemistry*

SAMSON THEKKEKARA JACOB, PH.D.  
*Assistant Professor of Physiological Chemistry*

THEODORE PETER LABUZA, PH.D.  
*Assistant Professor of Food Engineering*

WILLIAM MEDDEN RAND, PH.D.  
*Assistant Professor of Biostatistics*

RONALD CARLYLE SHANK, PH.D.  
*Assistant Professor of Food Toxicology*

ANTHONY JOHN SINSKEY, SC.D.  
*Assistant Professor of Food Microbiology*

DANIEL I. C. WANG, PH.D.  
*Assistant Professor of Biochemical Engineering*

DAÑA E. WILSON, M.D.  
*Assistant Professor of Metabolism and Human Nutrition*

VERNON ROBERT YOUNG, PH.D.  
*Assistant Professor of Physiological Chemistry*

**Administrative Officer**

CHARLES FREDERICK BENTLEY, II

**Senior Lecturers**

JOHN EVERETT GORDON, PH.D., M.D.  
HUGO MUENCH, JR., D.P.H., M.D.

**Lecturers**

AARON M. ALTSCHUL, PH.D. (*Visiting*)  
RICARDO BRESSANI, PH.D. (*Visiting*)  
DAVID LINCOLN CALL, PH.D. (*Visiting*)  
CHARLEY ELMER GILMORE, D.V.M.  
MIGUEL A. GUZMAN, PH.D. (*Visiting*)  
RONALD DUNCAN HUNT, D.V.M.  
ALLAN KLIMAN, M.D.  
ARNOLD JOHN LEHMAN, PH.D., M.D. (*Visiting*)  
CHARLES MERRITT, JR., PH.D.  
H. A. B. PARPIA, PH.D. (*Visiting*)

**Instructors**

LUIGI MARIA DELUCA, PH.D.  
MICHAEL JONATHAN ZIGMOND, PH.D.

**Research Associates**

MITSUTARO AKAO, PH.D.  
SYED QAMAR ALAM, PH.D.  
CELESTINO JESUS ALVAREZ, D.D.S.  
JANIS Z. GABLIKS, PH.D.  
OTTO GEORGE GLASER, M.D.  
JOHN EVERETT HARRIS, PH.D.  
EVA HONOVA, R.N. DR.  
SHIMON MIZRAHI, D.S.C.  
ABRAHAM EDWARD NIZEL, D.M.D., M.S.D.  
RAYMOND SIUCHUN PONG, S.M.  
PIERGIORGIO RIGHETTI, PH.D.  
ADRIANNE ELLEFSON ROGERS, M.D.  
RAYMOND RUSSO, D.V.M.  
UDO UKWENI UDO, M.B.CH.D.  
GRACE I. CHEN YUAN, M.D.

**Professors Emeriti**

CECIL GORDON DUNN, PH.D.  
*Associate Professor of Industrial Microbiology, Emeritus*

ROBERT SAMUEL HARRIS, PH.D.  
*Professor of Nutritional Biochemistry, Emeritus;*  
*Senior Lecturer*

## PHYSICS

- VICTOR FREDERICK WEISSKOPF, PH.D., SC.D.  
*Institute Professor; Professor of Physics;  
Head of the Department*
- ALBERT GORDON HILL, PH.D.  
*Professor of Physics; Chairman, Physics Council*
- GEORGE GRAHAM HARVEY, PH.D.  
*Professor of Physics; Executive Officer;  
Associate Director of the Research Laboratory of Electronics*
- WILLIAM PHELPS ALLIS, SC.D.  
*Professor of Physics, Emeritus; Senior Lecturer*
- FORTUNATO TITO ARECCHI, PH.D.  
*Professor of Physics (Visiting)*
- MICHEL BARANGER, PH.D.  
*Professor of Physics*
- WALTER CARLISLE BARBER, PH.D.  
*Professor of Physics*
- ALAN HILDRETH BARRETT, PH.D.  
*Professor of Physics*
- GEORGE BEKEFI, PH.D.  
*Professor of Physics*
- GEORGE BERNARD BENEDEK, PH.D.  
*Professor of Physics*
- WILLIAM BERTOZZI, PH.D.  
*Professor of Physics*
- HERBERT SAGE BRIDGE, PH.D.  
*Professor of Physics;  
Associate Director of the Center for Space Research*
- SANBORN CONNER BROWN, PH.D.  
*Professor of Physics;  
Associate Dean of the Graduate School*
- WILLIAM WEBER BUECHNER, PH.D., SC.D.  
*Professor of Physics*
- BERNARD FLOOD BURKE, PH.D.  
*Professor of Physics*
- GEORGE WHIPPLE CLARK, PH.D.  
*Professor of Physics*
- BRUNO COPPI, PH.D.  
*Professor of Physics*
- PETER THEODORE DEMOS, PH.D.  
*Professor of Physics;  
Director of the Laboratory for Nuclear Science*
- MARTIN DEUTSCH, PH.D., SC.D.  
*Professor of Physics*
- THOMAS HENDERSON DUPREE, PH.D.  
*Professor of Physics*
- HARALD ANTON ENGE, DR. PHIL.  
*Professor of Physics*
- ROBLEY DUNGLISON EVANS, PH.D.  
*Professor of Physics*
- BERNARD TAUB FELD, PH.D.  
*Professor of Physics*
- HERMAN FESHBACH, PH.D.  
*Professor of Physics*
- NATHANIEL HERMAN FRANK, SC.D.  
*Professor of Physics, Emeritus; Senior Lecturer*
- ANTHONY PHILIP FRENCH, PH.D.  
*Professor of Physics*
- JEROME ISAAC FRIEDMAN, PH.D.  
*Professor of Physics*
- DAVID HENRY FRISCH, PH.D.  
*Professor of Physics*
- SERGIO PIERO FUBINI, DOTT. IN FIS.  
*Professor of Physics*
- LEE GRODZINS, PH.D.  
*Professor of Physics*
- KERSON HUANG, PH.D.  
*Professor of Physics*
- ROBERT INSLEE HULSIZER, JR., PH.D.  
*Professor of Physics*
- ICKO IBEN, JR., PH.D.  
*Professor of Physics*
- KARL UNO INGARD, PH.D.  
*Professor of Physics*
- ALI JAVAN, PH.D.  
*Professor of Physics*
- KENNETH ALAN JOHNSON, PH.D.  
*Professor of Physics*
- HENRY WAY KENDALL, PH.D.  
*Professor of Physics*
- ARTHUR KENT KERMAN, PH.D.  
*Professor of Physics*
- JOHN GORDON KING, PH.D.  
*Professor of Physics*
- GEORGE FRED KOSTER, PH.D.  
*Professor of Physics*
- BENJAMIN LAX, PH.D.  
*Professor of Physics;  
Director of the National Magnet Laboratory*
- MILTON STANLEY LIVINGSTON, PH.D., SC.D. (*Absent*)  
*Professor of Physics*
- FRANCIS EUGENE LOW, PH.D.  
*Karl Taylor Compton Professor of Physics*
- PHILIP MORRISON, PH.D.  
*Professor of Physics*
- PHILIP MCCORD MORSE, PH.D., SC.D.  
*Professor of Physics, Emeritus; Senior Lecturer*
- STANISLAW OLBERT, PH.D.  
*Professor of Physics*
- LOUIS SHREVE OSBORNE, PH.D.  
*Professor of Physics*
- IRWIN ABRAHAM PLESS, PH.D.  
*Professor of Physics*
- LAWRENCE ROSENSON, PH.D.  
*Professor of Physics*
- BRUNO BENEDETTO ROSSI, PH.D.  
*Institute Professor; Professor of Physics*
- IRWIN IRA SHAPIRO, PH.D.  
*Professor of Geophysics and Physics*
- CLIFFORD GLENWOOD SHULL, PH.D.  
*Professor of Physics*
- JOHN CLARKE SLATER, PH.D., SC.D.  
*Institute Professor, Emeritus;  
Harry B. Higgins Professor of the Solid State, Emeritus*
- MALCOM WOODROW PERSHING STRANDBERG, PH.D.  
*Professor of Physics*
- SAMUEL TING, PH.D.  
*Professor of Physics*

FACULTY

- LASZLO TISZA, PH.D.  
*Professor of Physics*
- GEORGE EDWARD VALLEY, JR., PH.D.  
*Professor of Physics*
- FELIX MARC HERMANN VILLARS, D.SC.  
*Professor of Physics*
- BERTRAM EUGENE WARREN, SC.D.  
*Professor of Physics, Emeritus; Senior Lecturer*
- STEVEN WEINBERG, PH.D.  
*Professor of Physics*
- JERROLD REINACH ZACHARIAS, PH.D., L.H.D., SC.D.  
*Institute Professor; Professor of Physics; Director of the Education Research Center*
- THOMAS ALEXANDER BELOTE, PH.D.  
*Associate Professor of Physics*
- ARON MYRON BERNSTEIN, PH.D.  
*Associate Professor of Physics*
- HALE VAN DORN BRADT, PH.D.  
*Associate Professor of Physics*
- JOHN BRAYTON BRONZAN, PH.D.  
*Associate Professor of Physics*
- IRA STEPHEN GERSTEIN, PH.D.  
*Associate Professor of Physics*
- DANIEL KLEPPNER, PH.D.  
*Associate Professor of Physics*
- WALTER HENDRIK GUSTAV LEWIN, DR.TECH.SCI.  
*Associate Professor of Physics*
- EARLE LEONARD LOMON, PH.D.  
*Associate Professor of Physics*
- LEO SARTORI, PH.D.  
*Associate Professor of Physics*
- HERBERT WILLIAM SCHNOPPER, PH.D.  
*Associate Professor of Physics*
- BRIAN BENJAMIN SCHWARTZ, PH.D.  
*Associate Professor of Physics*
- MARLAN ORVIL SCULLY, PH.D.  
*Associate Professor of Physics*
- CARL MARX SHAKIN, PH.D.  
*Associate Professor of Physics*
- ABRAHAM SZÖKE, PH.D.  
*Associate Professor of Physics*
- RAINER WEISS, PH.D.  
*Associate Professor of Physics*
- RICHARD KUMEO YAMAMOTO, PH.D.  
*Associate Professor of Physics*
- WILLIAM H. BASSICHIS, PH.D.  
*Assistant Professor of Physics*
- WILLIAM KEITH BERTRAM, PH.D.  
*Assistant Professor of Physics*
- GEORGE FREDERICK BERTSCH, PH.D.  
*Assistant Professor of Physics*
- WIT BUSZA, PH.D.  
*Assistant Professor of Physics*
- JAMES RODGERS CLOW, PH.D.  
*Assistant Professor of Physics*
- ERIC RICHARD COSMAN, PH.D.  
*Assistant Professor of Physics*
- PETER DONALD DE CICCO, PH.D.  
*Assistant Professor of Physics*
- MICHAEL STEPHEN FELD, PH.D.  
*Assistant Professor of Physics*
- THOMAS JOHN GREYTAK, PH.D.  
*Assistant Professor of Physics*
- ROMAN WLADIMIR JACKIW, PH.D.  
*Assistant Professor of Physics*
- CECIL EDWARD JONES, PH.D.  
*Assistant Professor of Physics*
- ROBERT JOHN KOLENKOW, PH.D.  
*Assistant Professor of Physics*
- STANLEY BENEDICT KOWALSKI, PH.D.  
*Assistant Professor of Physics*
- RICHARD CHARLES LANZA, PH.D.  
*Assistant Professor of Physics*
- JAMES DAVID LITSTER, PH.D.  
*Assistant Professor of Physics*
- HENRY J. LUBATTI, PH.D.  
*Assistant Professor of Physics*
- WALLACE MILTON MANHEIMER, PH.D.  
*Assistant Professor of Physics*
- DAVID CECIL MILLER, PH.D.  
*Assistant Professor of Physics*
- WILLIAM HENRY MOORE, PH.D.  
*Assistant Professor of Physics*
- RICHARD MARCUS PRICE, PH.D.  
*Assistant Professor of Physics*
- SAUL ALAN RAPPAPORT, PH.D.  
*Assistant Professor of Physics*
- WILLIAM KENNETH ROSE, PH.D.  
*Assistant Professor of Physics*
- ARTHUR JOHN STUART SMITH, PH.D.  
*Assistant Professor of Physics*
- HARRY EUGENE STANLEY, PH.D.  
*Assistant Professor of Physics*
- VIGDOR LOUIS TEPLITZ, PH.D.  
*Assistant Professor of Physics*
- KOSTA MICHAEL TSIPIS, PH.D.  
*Assistant Professor of Physics*
- VYTENIS MARIJA VASYLIUNAS, PH.D.  
*Assistant Professor of Physics*
- GABRIELE VENEZIANO, PH.D.  
*Assistant Professor of Physics (Visiting)*
- TERENCE LESLIE WATTS, PH.D.  
*Assistant Professor of Physics*
- BRADFORD LAWRENCE WRIGHT, PH.D.  
*Assistant Professor of Physics*
- Administrative Officer**  
DANIEL HENRY GOULD
- Lecturers**  
FREDERIC JOHN EPPLING, PH.D.  
*Associate Director of the Laboratory for Nuclear Science*  
PAUL DAVID LUCKEY, JR., PH.D.  
HARRY MORITZ SCHEY, PH.D.
- Senior Research Scientists**  
VERA KISTIAKOWSKY, PH.D.  
ALAN JAY LAZARUS, PH.D.  
CHARLES PHILIP SARGENT, PH.D.  
JUDAH LEON SCHWARTZ, PH.D.  
EDWIN FLORIMAN TAYLOR, PH.D.

WILLIAM ERNEST TURCHINETZ, PH.D.  
WILLIAM UPTON WALTON, M.S.

**Instructors**

JOHN ELMER ELIAS, B.S.  
EDWARD VICTOR GEORGE, B.S.E.E.  
ROBERT GILMORE, PH.D.  
CHARLES THEODORE GRANT, PH.D.  
DAVID SHELDON HYMAN, PH.D.  
DAE MANN KIM, PH.D.  
MARGARET LOVE AGNES MACVICAR, S.C.D.  
DAVID EDWARD PRITCHARD, PH.D.  
MICHAEL REID SOGARD, B.A.  
CHIA-GEE WANG, PH.D.

**Technical Instructors**

ANGELO DELARA LARRAGA  
HAROLD ADOLPH LUNDQUIST  
JAN ORSULA

**Research Associates**

NORMAN ALAN KURNIT, PH.D.  
ROBERT THOMAS ROOD, PH.D.  
WILLIAM DOUGLAS WATSON, PH.D.

**Professors Emeriti**

WILLIAM PHELPS ALLIS, SC.D.  
*Professor of Physics, Emeritus; Senior Lecturer*  
NATHANIEL HERMAN FRANK, SC.D.  
*Professor of Physics, Emeritus; Senior Lecturer*  
ARTHUR COBB HARDY, SC.D.  
*Professor of Optics and Photography, Emeritus*  
GEORGE RUSSELL HARRISON, PH.D., D.SC., LL.D.,  
D.ENG.  
*Professor of Physics, Emeritus;*  
*Dean of the School of Science, Emeritus*  
PHILIP MCCORD MORSE, PH.D., SC.D.  
*Professor of Physics, Emeritus; Senior Lecturer*  
JOHN CLARKE SLATER, PH.D., SC.D.  
*Institute Professor, Emeritus;*  
*Harry B. Higgins Professor of the Solid State, Emeritus*  
BERTRAM EUGENE WARREN, SC.D.  
*Professor of Physics, Emeritus; Senior Lecturer*

## OTHER ACADEMIC DEPARTMENTS AND OFFICES

### INFORMATION PROCESSING SERVICES

RICHARD GWYN MILLS, S.M.

*Director*

### INTERDEPARTMENTAL LABORATORIES *Center for Materials Science and Engineering*

NICHOLAS JOHN GRANT, SC.D.

*Director*

HARRY CONSTANTINE GATOS, PH.D.

*Associate Director*

### *Center for Space Research*

JOHN VINCENT HARRINGTON, SC.D.

*Director*

HERBERT SAGE BRIDGE, PH.D.

*Associate Director*

### *Francis Bitter National Magnet Laboratory*

BENJAMIN LAX, PH.D.

*Director*

DONALD THOMAS STEVENSON, PH.D.

*Assistant Director*

ELMER WILBUR LAURENCE DAVIS, S.B.

*Assistant Director for Administration*

### *Laboratory for Nuclear Science*

PETER THEODORE DEMOS, PH.D.

*Director*

FREDERIC JOHN EPPLING, PH.D.

*Associate Director*

### *Operations Research Center*

JOHN DUTTON CONANT LITTLE, PH.D.

*Director*

ALVIN WILLIAM DRAKE, SC.D.

*Associate Director*

### *Research Laboratory of Electronics*

HENRY JOSEPH ZIMMERMANN, S.M.

*Director*

GEORGE GRAHAM HARVEY, PH.D.

*Associate Director*

SAMUEL JEFFERSON MASON, SC.D.

*Associate Director*

RALPH ALLEN SAYERS

*Assistant Director*

### *Spectroscopy Laboratory*

RICHARD COLLINS LORD, PH.D., SC.D.

*Director*

### *Urban Systems Laboratory*

CHARLES LESLIE MILLER, S.M.

*Director*

FRANK SIDNEY JONES, M.B.A.

*Executive Director*

### CAMBRIDGE ELECTRON ACCELERATOR OF HARVARD UNIVERSITY AND THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

KARL STRAUCH, PH.D.

*Director*

### JOINT CENTER FOR URBAN STUDIES OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY AND HARVARD UNIVERSITY

ROBERT COLDWELL WOOD, PH.D.

*Director*

CHARLES M. HAAR, LL.D.

*Chairman of the Faculty Committee*

### UNIVERSITY INFORMATION TECHNOLOGY CORPORATION

CARL F. J. OVERHAGE, PH.D.

*Executive Director*

### CENTER FOR INTERNATIONAL STUDIES

MAX FRANKLIN MILLIKAN, PH.D.

*Director*

DONALD LAWRENCE MORTON BLACKMER, PH.D.

*Assistant Director*

### DRAMA

JOSEPH DEE EVERINGHAM, A.M.

*Director of Drama*

### MUSIC

KLAUS LIEPMANN

*Director of Music*

JOHN DEAN CORLEY, JR., M.MUS.

*Assistant Director of Music*

GREGORY TUCKER

*Director of M.I.T. Humanities Series and  
Chamber Music at M.I.T.*

DAVID MAYER EPSTEIN, PH.D.  
*Conductor of the M.I.T. Symphony Orchestra*  
 JOHN SANFORD OLIVER, M.MUS.  
*Executive Assistant to the Director of Music*  
 JOHN COOK, MUS.B.  
*Organist*

**VISUAL ARTS**

WAYNE VESTI ANDERSEN, PH.D.  
*Director of Exhibitions*  
 GYORGY KEPES, M.A.  
*Director of the Center for Advanced  
 Visual Studies*

**DEPARTMENT OF AEROSPACE STUDIES**

GERALD PERSELAY, M.B.A.  
*Lieutenant Colonel, U. S. Air Force  
 Professor of Aerospace Studies; Head of the Department*  
 RAYMOND HORACE GRENIER, B.A.  
*Major, U. S. Air Force  
 Assistant Professor of Aerospace Studies*

**Instructors**

GEORGE W. HOAGE  
*Staff Sergeant, U. S. Air Force*  
 WILLIAM ELIAS LEE  
*Technical Sergeant, U. S. Air Force*  
 EARL SYLVESTER RASMUSSEN  
*Technical Sergeant, U. S. Air Force*

**DEPARTMENT OF MILITARY SCIENCE**

MARSHALL OWEN BECKER, M.A.  
*Colonel, Infantry  
 Professor of Military Science; Head of the Department*  
 EUGENE RILEY HUNTON, JR., B.A.  
*Major, Infantry  
 Associate Professor of Military Science*  
 STANLEY HERBERT HYMAN, M.A.  
*Major, Military Intelligence  
 Associate Professor of Military Science*

JOSEPH GRADY MCCOY, JR., B.S.  
*Major, Signal Corps  
 Associate Professor of Military Science*  
 LELAND ERNEST PRENTICE, S.M.  
*Major, Infantry  
 Associate Professor of Military Science*  
 DAVID JOSEPH PAWELSKI, M.ED.  
*Sergeant Major, U.S. Army  
 Assistant Professor of Military Science*

**Instructor**

WILLIAM E. ANDERSON, SR.  
*Master Sergeant, U. S. Army*

**Administrative Assistant**

GREGORY JOHN FALZONE  
*Staff Sergeant, U. S. Army*

**DEPARTMENT OF NAVAL SCIENCE**

DEAN ALDEN HORN, NAV. E.  
*Captain, U. S. Navy  
 Professor of Naval Science; Head of the Department;  
 Professor of Naval Construction*  
 HAROLD O. MCEACHERN, B.A.  
*Commander, U. S. Navy  
 Associate Professor of Naval Science*  
 JOHN HUDSON BEATON, B.A.  
*Lieutenant, U. S. Navy  
 Assistant Professor of Naval Science*

**Instructors**

WILLIAM F. WELCH  
*Chief Yeoman, U. S. Navy*  
 ROBERT GRANT MELLEEN  
*Gunnery Sergeant, U.S. Marine Corps.*  
 MIKE DOUGLAS MONK  
*Chief Storekeeper, U. S. Navy*

**SUMMER SESSION**

JAMES MURDOCH AUSTIN, SC.D.  
*Director of the Summer Session*  
 MARY DALY HOWE, A.M.  
*Assistant to the Director of the Summer Session*

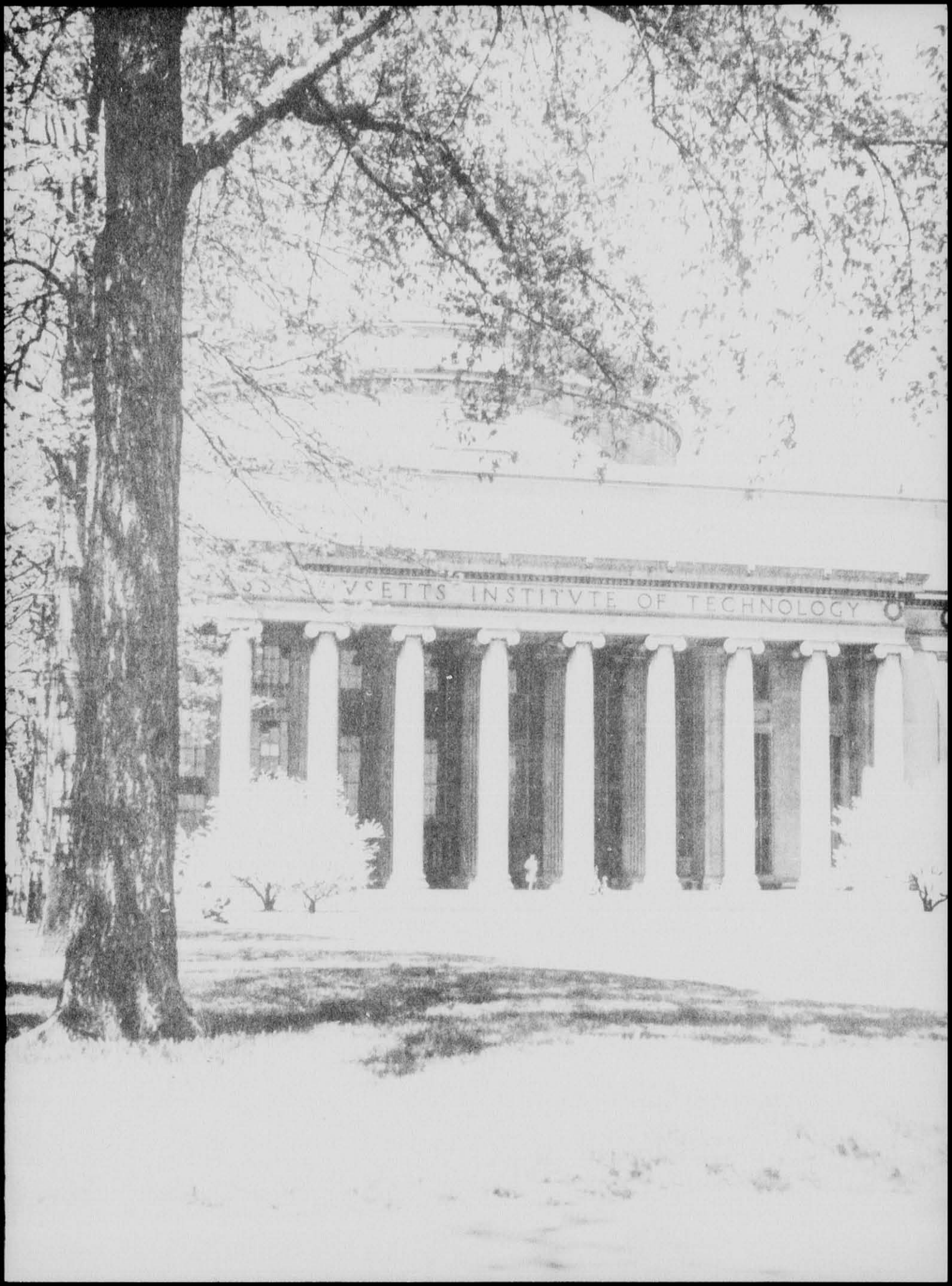
## *An M.I.T. Education for Our Times*

I see the new awareness on the campus among students and faculty, . . . reflecting the whole American society, as a cause for optimism . . . , for I strongly believe that, if we are to succeed in factoring the dilemmas of today's world, science and its applications — modern engineering, if you will — must be more powerfully involved, not less so. I believe, too, that within the science-based learning environment, we can develop a more effective laboratory for leadership than has so far been possible. This combination of increased involvement and opportunity — by the faculty and the students of the Institute — emphasizes for me the meaning of an education in the broadest liberal and scientific sense; an education in which learning with a purpose and a professional approach is accompanied by an abiding concern for the condition of man.

HOWARD W. JOHNSON

*From the Report of the President 1968.*





MASSACHUSETTS INSTITUTE OF TECHNOLOGY



## GENERAL INFORMATION: *A Modern University Centered in Science* 1.



The Massachusetts Institute of Technology is an independent, coeducational, endowed institution committed by charter and plan to the extension of knowledge through teaching and research. It is organized into five academic schools — Architecture and Planning, Engineering, Humanities and Social Science, Management, and Science — and a number of interdisciplinary groups. There are about 7,700 students (including about 450 women), more than 3,900 of them studying for undergraduate degrees; about 1,000 members of the Faculty; and a supporting teaching staff of about 700. The Institute is located on a well-equipped residential campus of 125 acres fronting the Charles River in Cambridge, opposite Boston.

M.I.T. awards Bachelor's, Master's, professional (Engineer), and doctoral degrees in a total of 38 Courses; and it provides important programs of postdoctoral and postgraduate study in management, engineering, and the life sciences. From modest beginnings in 1861 as an institution "where young men could learn exactly and thoroughly the fundamental principles of positive science with their leading applications to the industrial arts," the Institute has grown to embrace teaching and research programs of distinction in engineering and the engineering sciences, the physical sciences, architecture and planning, the life sciences, management, and those of the humanities and social sciences most closely related by method or content to modern developments in engineering, science, and mathematics.

### ***A Powerful Curiosity about Things Not Understood***

The unique educational opportunities which the Institute presents to undergraduate and graduate students stem from concepts which underlie all its teaching programs and from special qualities which M.I.T.'s character imparts to its entire academic community.

Emphasis on fundamentals and on self-reliance are central in M.I.T.'s educational philosophy. Substantially every subject taught here is influenced by the environment of a scientific and technological institution: a strong

# General

A MODERN UNIVERSITY

sense of the quantitative and the analytical, a critical analysis of cause and effect, a demand for precision, and a powerful curiosity about things not understood enter every classroom. The Institute's Faculty holds that this kind of education is relevant to any responsible role which its graduates may assume in a society increasingly influenced by technological progress.

The central purpose of the academic programs is to give students a sound command of basic principles, versatility of mind, insight and perspective concerning natural phenomena, the habit of continued learning, and the power that comes from a thorough and systematic method of attack. From these attributes comes the best assurance against professional obsolescence, especially in today's world of rapid technological change.

M.I.T. is widely known for its contributions to new knowledge, achievements of a remarkable research enterprise which is shared broadly by faculty and students. This interlocking of research and teaching gives to M.I.T. an intellectual climate of extraordinary excitement, a spirit of ferment and creative innovation which every student may share.

The Institute has always sought high professional standards for its teaching and research; there is a traditional and established role of stressing excellence. The continuing search for new methods of teaching, rapid assimilation of new knowledge into teaching programs, and constant emphasis on self-criticism are evidence of the Faculty's commitment to maintain and extend the high quality of an M.I.T. education.

## *Singleness of Method, Diversity of Interest*

The Institute has a single campus and a single Faculty serving both undergraduate and graduate students. Most of its classrooms and laboratories are in an interconnected group of buildings which facilitate informal interchange between departments and disciplines. Members of the Faculty group themselves for teaching and research very largely according to their interests, and there are interdisciplinary laboratories to provide support in many fields which go beyond the traditional boundaries of a single department. Students, too, though they register (except for freshmen and some sophomores) in specific departments, focus their work much according to their interests, sharing the interdisciplinary activities of the faculty with whom they work.

Though registration and academic requirements tend of necessity to emphasize the procedural aspects of an M.I.T. education, it is important to understand that the academic programs of most students — both undergraduate and graduate — are flexible within broad limits, determined each year by each student himself (in collaboration with a faculty advisor) in response to his own interests and preparation.

Most undergraduates study in at least three of M.I.T.'s schools, many in four, and a few in all five during the four years of their undergraduate work. Graduate students frequently study in two or three of M.I.T.'s five academic schools. Advanced undergraduates often register with graduate students for at least one of their classes; and many undergraduates and almost all graduate students participate, often together, in advanced research. M.I.T. students come from every state in the United States and from 80 foreign nations; the proportion of foreign students at the Institute (about 15 per cent) is one of the highest in an American university.

The intermixing of ages, disciplines, and nationalities which is characteristic of the Institute deeply influences the life and experience of every member of this academic community, bringing together students and teachers, metallurgists and physicists, biologists and architects, humanists and engineers, young and old. The result is an academic environment unusual for its singleness of method and purpose and notable for its diversity of interest.

## *To Foster Qualities of Intellect and Character*

The scope of M.I.T. has always been wider than its title, "institute of technology," might suggest, and today the Institute's commitments to the humanities and social sciences are providing an entirely new dimension of scholarship. The increasing impact of science upon our social institutions and upon the conduct of industry and government has been reflected at M.I.T. in the emergence of active teaching and research in fields in which the physical and social sciences most directly interact — fields such as economics, psychology, political science, linguistics, and the history and philosophy of science.

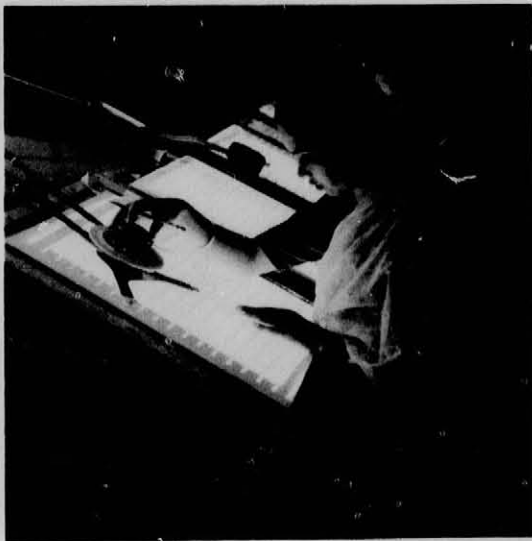
Every M.I.T. undergraduate takes approximately 20 per cent of his undergraduate work in the humanities program, averaging one subject each term. An undergraduate who wants more work in this area may register for a program

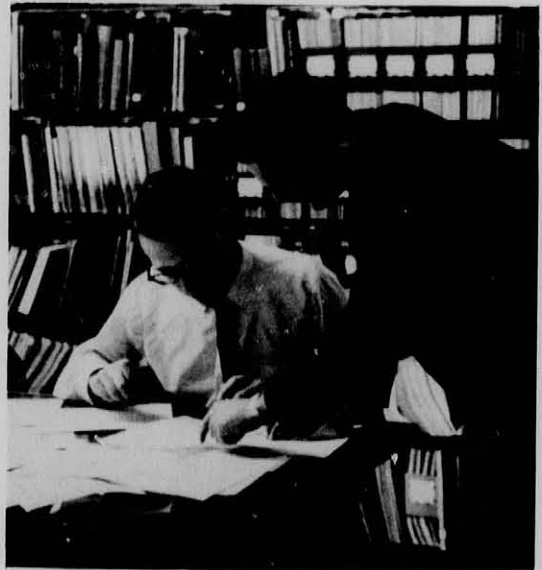
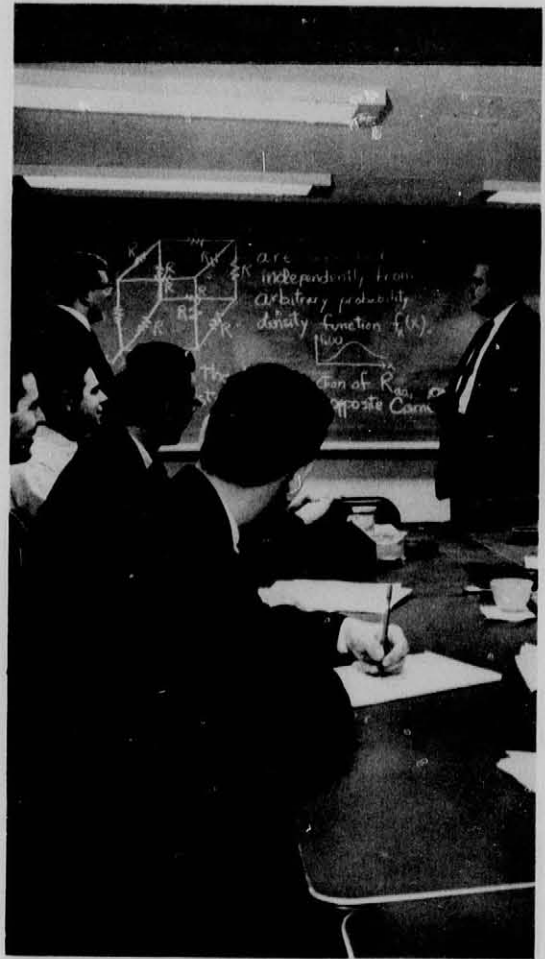
which combines study in one field of humanities or social science with work in one science or engineering discipline, or for a program which permits concentration in humanities alone. Students are eligible for either option after satisfying the Institute requirements in science.

The Institute maintains a commitment to foster for its students those qualities of intellect and character which distinguish truly educated men and women, the qualities of responsibility and ethic which mark the professional estate. In turn, M.I.T. assumes in its students a commit-

ment to adult values which is expressed by extending to them a large measure of responsible self-government and personal freedom.

"As a great educational institution," Dr. Julius Adams Stratton, former President of M.I.T., has said, "we shall be judged not only by the quality of our students' intellectual discipline but by the firmness of their moral fiber, by their attitudes toward the whole of learning, by the manner in which they speak and act, and by their understanding of the obligations of a citizen."





## The Academic Program

The primary organization of the academic program is along the lines of the traditional disciplines. Each of the 23 academic departments offers one or more degree programs, or Courses<sup>1</sup> of study, and every upperclass undergraduate student and every graduate student is registered in one of these Courses. Degrees are awarded on the basis of satisfactory completion of Courses.

But increasing numbers of students choose fields of concentration which cross regular departmental lines. Among these are programs in fields such as planetary and space science, space technology, communications, materials, computer science, operations research, instrumentation, and others. Some of these involve guidance for the student by standing or special committees; some consist of association with one of the interdepartmental activities described below.

Undergraduate Courses at M.I.T. lead to the degree of Bachelor of Science (S.B.). Graduate degrees awarded are Bachelor in Architecture (B.ARCH.), Master of Science (S.M.), Master in

<sup>1</sup> At the Institute the word *Course* refers to an organized curriculum leading to a specified degree. The word *subject*, on the other hand, refers to the individual classes. Each Course is designated by a Roman numeral; individual subjects are given Arabic numerals to correspond with the Course numbers. For example, Civil Engineering is Course I; the number 1.05 indicates a subject given in the Course in Civil Engineering.

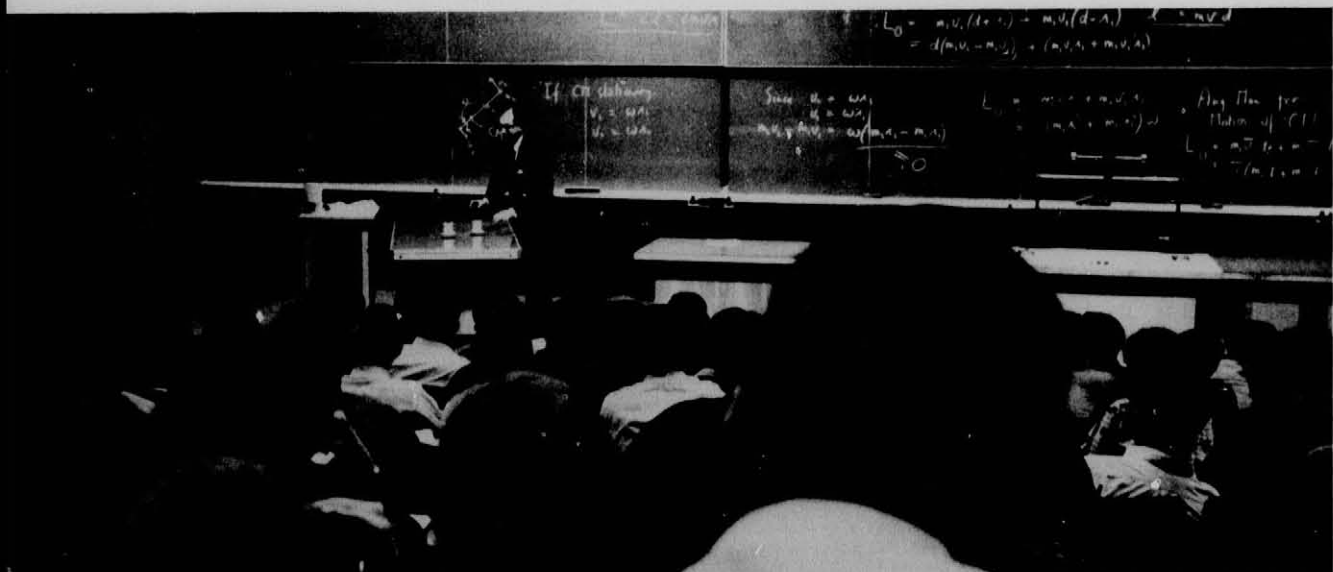
Architecture (M.ARCH.), Master in City Planning (M.C.P.), Engineer (each degree designating the field in which it is awarded),<sup>2</sup> Doctor of Philosophy (PH.D.), and Doctor of Science (SC.D.).

The chart on the following pages shows schools, departments, undergraduate and graduate Courses and degrees, and Course numbers. Undergraduate Courses, including Courses which provide periods of on-the-job experience in industry, require four years of full-time study for the Bachelor of Science degree.

Undergraduate Courses and degree requirements are described in Section 2 of this Catalogue; graduate fields of study and degree requirements, in Section 3. The statements of each department in Sections 4, 5, 6, 7, and 8 should be consulted for detailed information about the degrees offered.

Three departments (Aerospace Studies, Military Science, and Naval Science) offer undergraduate instruction to all eligible students but are not a part of any of the five Institute schools. Their programs are described in Section 2.

<sup>2</sup> The Engineer degrees include Chemical Engineer (CHEM.E.), Civil Engineer (C.E.), Electrical Engineer (E.E.), Engineer in Aeronautics and Astronautics (E.A.A.), Marine Mechanical Engineer (MAR.MECH.E.), Materials Engineer (MAT.E.), Mechanical Engineer (MECH.E.), Metallurgical Engineer (MET.E.), Mineral Engineer (MIN.E.), Naval Architect (NAV.ARCH.), Naval Engineer (NAV.E.), Nuclear Engineer (NUCL.E.), Ocean Engineer (OCEAN E.).



# General

SCHOOLS, DEPARTMENTS, COURSES, DEGREES

## SCHOOLS, DEPARTMENTS, COURSES, AND DEGREES

<i>Schools and Departments</i>	<i>Undergraduate Courses (and Course Numbers)</i>	<i>Bachelor's Degrees</i>	<i>Graduate Courses (and Course Numbers)</i>	<i>Graduate Degrees</i>
<b><i>School of Architecture and Planning</i></b>				
Department of Architecture	ARCHITECTURE <sup>1</sup> (IV)	S.B.	ARCHITECTURE (IV)	B.ARCH.
	ARCHITECTURE <sup>1</sup> (IV-B)	S.B.		M.ARCH.
Department of Urban Studies and Planning			CITY AND REGIONAL PLANNING (XI)	M.C.P. PH.D.
<b><i>School of Engineering</i></b>				
Department of Aeronautics and Astronautics	AERONAUTICS AND ASTRONAUTICS (XVI)	S.B.	AERONAUTICS AND ASTRONAUTICS <sup>2</sup> (XVI)	S.M., E.A.A., SC.D., PH.D.
	COOPERATIVE COURSE <sup>1</sup> (XVI-B)	S.B.		
Department of Chemical Engineering	CHEMICAL ENGINEERING (X)	S.B.	CHEMICAL ENGINEERING <sup>2</sup> (X)	S.M., CHEM.E., SC.D., PH.D.
	CHEMICAL ENGINEERING <sup>1</sup> (X-C)	S.B.		CHEMICAL ENGINEERING PRACTICE (X-A)
Department of Civil Engineering	CIVIL ENGINEERING <sup>1</sup> (I)	S.B.	CIVIL ENGINEERING <sup>2</sup> (I)	S.M., C.E., SC.D., PH.D.
Department of Electrical Engineering	ELECTRICAL ENGINEERING (VI)	S.B.	ELECTRICAL ENGINEERING <sup>2</sup> (VI)	S.M., E.E., SC.D., PH.D.
	ELECTRICAL ENGINEERING (VI-A)	S.B.		ELECTRICAL ENGINEERING S.M. (VI-A)
Department of Mechanical Engineering	MECHANICAL ENGINEERING (II)	S.B.	MECHANICAL ENGINEERING <sup>2</sup> (II)	S.M., MECH.E., SC.D., PH.D.
	MECHANICAL ENGINEERING <sup>1</sup> (II-A)	S.B.		TEXTILE TECHNOLOGY
	COOPERATIVE COURSE <sup>1</sup> (II-B)	S.B.		
Department of Metallurgy and Materials Science	METALLURGY AND MATERIALS SCIENCE (III)	S.B.	METALLURGY (III)	S.M., MET.E., MIN.E., SC.D., PH.D.
	METALLURGY AND MATERIALS SCIENCE <sup>1</sup> (III-A)	S.B.	CERAMICS	S.M.

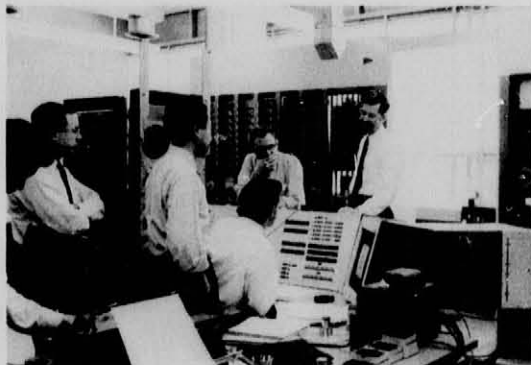
<sup>1</sup> See the Department's statement for complete information about the specific degrees offered.

<sup>2</sup> In the field of Materials Engineering, programs leading to the degrees of Materials Engineer (MAT.E.) or Doctor of Science or Doctor of Philosophy are offered under interdepartmental supervision.

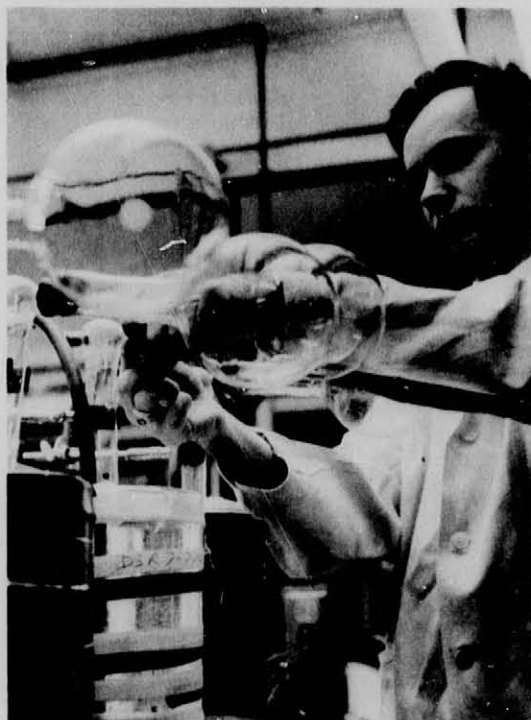
<sup>3</sup> Five-year Course leading to Bachelor of Science and Master of Science degrees awarded simultaneously at the end of the graduate year.

<sup>4</sup> See the statement concerning the specific degrees offered by the Department, as well as the doctor's degrees offered by the Woods Hole Oceanographic Institution and M.I.T. in the Joint Program described at the end of Section 8.

<i>Schools and Departments</i>	<i>Undergraduate Courses (and Course Numbers)</i>	<i>Bachelor's Degrees</i>	<i>Graduate Courses (and Course Numbers)</i>	<i>Graduate Degrees</i>
Department of Naval Architecture and Marine Engineering	NAVAL ARCHITECTURE AND MARINE ENGINEERING (XIII)	S.B.	NAVAL ARCHITECTURE AND MARINE ENGINEERING (XIII)	S.M., NAV. ARCH., MAR. MECH. E., SC.D., PH.D.
			OCEAN ENGINEERING	S.M., OCEAN E.
	SHIPPING AND SHIP- BUILDING MANAGEMENT <sup>1,3</sup> (XIII-B)	S.B.	SHIPPING AND SHIP- BUILDING MANAGEMENT (XIII-B)	S.M.
			NAVAL CONSTRUCTION AND ENGINEERING <sup>1</sup> (XIII-A)	S.M., NAV. E.
Department of Nuclear Engineering			NUCLEAR ENGINEERING (XXII)	S.M., NUCL. E., SC.D., PH.D.
<b><i>School of Humanities and Social Science</i></b>				
Department of Economics	ECONOMICS (XIV)	S.B.	ECONOMICS (XIV)	S.M., PH.D.
Department of Foreign Literatures and Linguistics			LINGUISTICS (XXIII)	PH.D.
Department of Humanities	HUMANITIES AND ENGINEERING (XXI-A)	S.B.	PHILOSOPHY (XXI)	PH.D.
	HUMANITIES AND SCIENCE (XXI-B)	S.B.		
Department of Political Science	POLITICAL SCIENCE (XVII)	S.B.	POLITICAL SCIENCE (XVII)	S.M., PH.D.
Department of Psychology			PSYCHOLOGY (IX)	PH.D.
<b><i>Alfred P. Sloan School of Management</i></b>	MANAGEMENT (XV)	S.B.	MANAGEMENT (XV)	S.M., PH.D.
<b><i>School of Science</i></b>				
Department of Biology	LIFE SCIENCES (VII)	S.B.	BIOLOGY <sup>1</sup> (VII)	S.M., PH.D., SC.D.
Department of Chemistry	CHEMISTRY (V)	S.B.	CHEMISTRY (V)	S.M., PH.D., SC.D.
Department of Earth and Planetary Sciences	EARTH AND PLANETARY SCIENCES (XII)	S.B.	EARTH AND PLANETARY SCIENCES (XII)	S.M., PH.D., SC.D.
	EARTH AND PLANETARY SCIENCES <sup>3</sup> (XII-A)	S.B.	EARTH AND PLANETARY SCIENCES <sup>3</sup> (XII-A)	S.M.
	PHYSICAL SCIENCES <sup>1</sup> (XII-B)	S.B.	OCEANOGRAPHY <sup>4</sup>	S.M., PH.D. SC.D.
Department of Mathematics	MATHEMATICS (XVIII)	S.B.	MATHEMATICS (XVIII)	S.M., PH.D., SC.D.
Department of Meteorology			METEOROLOGY (XIX)	S.M., PH.D., SC.D.
			OCEANOGRAPHY <sup>4</sup>	S.M., PH.D., SC.D.
Department of Nutrition and Food Science			NUTRITION AND FOOD SCIENCE <sup>1</sup> (XX)	S.M., PH.D., SC.D.
Department of Physics	PHYSICS (VIII)	S.B.	PHYSICS (VIII)	S.M., PH.D., SC.D.



THE TX-O DIGITAL COMPUTER



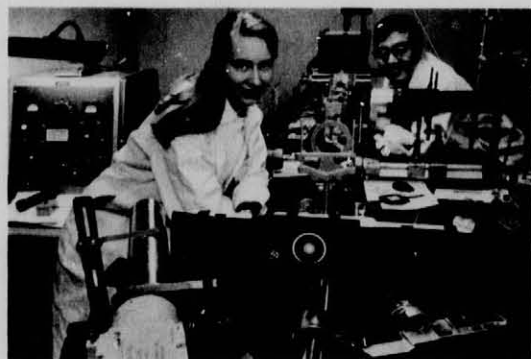
IN THE FOOD SCIENCE LABORATORIES



A COUNTER IN THE RADIOACTIVITY  
CENTER



POWDER METALLURGY IN THE METALS  
PROCESSING LABORATORY



SPECTROSCOPY LABORATORY

### ***Teaching and Research Resources***

Teaching and research both fulfill M.I.T.'s purpose of advancing the frontiers of knowledge, and these activities carried on together have greater power than either performed alone. While advancing human knowledge and understanding, research makes special contributions to the Institute's educational program by providing experience in theory and experiment for both students and faculty and by assuring that classroom teaching is up-to-date; thus research is viewed at M.I.T. as an essential partner with classroom and laboratory instruction.

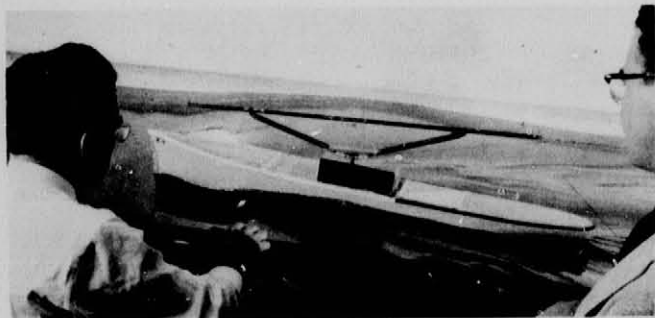
The Institute receives generous grants from both industry and government in support of research activities in which students and faculty participate, and it devotes substantial resources of its own to such undertakings. For this work M.I.T. has facilities unusual — and in some cases unique — among educational institutions. There are more than 70 special laboratories on the campus in Cambridge. In general, the Institute's policy is to make these facilities available to all scholars — undergraduate, graduate, and postdoctoral — whenever they have a legitimate educational need for them, with the result that nearly all of M.I.T.'s laboratories are shared by undergraduates, graduate students, and faculty working together.

Most of these research facilities are described elsewhere in this book by the departments which operate them. Typical are the nuclear reactor (Department of Nuclear Engineering); the supersonic wind tunnels and Instrumentation Laboratory (Department of Aeronautics and Astronautics); the Electronic Systems Laboratory (Department of Electrical Engineering); and several departmental computation facilities operated by the Departments of Civil, Electrical, and Mechanical Engineering, and the Alfred P. Sloan School of Management.

In addition to laboratories and facilities organized within departments, there are an increasing number of laboratories of an interdepartmental nature, established to facilitate work in fields which cross the lines of traditional disciplines. The most important of these interdisciplinary research activities are described below.

#### ***Francis Bitter National Magnet Laboratory***

The Francis Bitter National Magnet Laboratory, sponsored at M.I.T. by the U. S. Air Force Office of Scientific Research, provides magnetic fields of extremely high intensity for research in



THE SHIP MODEL TOWING TANK

# General

## TEACHING AND RESEARCH RESOURCES

solid-state, low-temperature, and plasma physics and in related areas of science. The experimental facilities are available to students and faculty from M.I.T. and to scientists from other academic, government, and industrial laboratories. The resident research staff and students conduct experimental and theoretical studies in solid-state and low-temperature physics. Electromagnetic radiation from radio frequencies to gamma rays and a wide frequency range of acoustic waves are employed to probe the properties of matter in intense magnetic fields. Continuous fields up to 250,000 gauss are produced in a variety of water-cooled magnets powered by a ten-megawatt direct current supply. Superconducting magnets are also in use. A hybrid magnet consisting of both superconducting and water-cooled sections is under construction. Pulsed fields exceeding 500,000 gauss are generated by large currents from a capacitor bank.

### **Cambridge Electron Accelerator**

The Cambridge Electron Accelerator, a 6-BeV synchrotron built and supported by funds from Atomic Energy Commission contracts, is operated jointly by M.I.T. and Harvard for research in particle physics by faculty and students from both institutions and other qualified scientists.

### **Center for Advanced Visual Studies**

The Center for Advanced Visual Studies provides artists of achievement with the opportunity to explore new artistic forms of civic dimensions warranted by the sophisticated technology and complex scale of our urban world. Collaboration through a working dialogue between the artists and the scientists and engineers is of primary importance in the exploration of new creative objectives. This mutually beneficial contact between artist and scientist allows the artist to develop the technical competence to utilize advanced technology and test its applications to new creative challenges.

Some of the distinguished artist-fellows currently working at the Center are Jack Burnham, Charles Frazier, Ted Kraynik, Otto Piene, Takis, Harold Tovish, Wen-Ying Tsai, and Stan Van Der Beek. The Center is currently involved in preparing the American section of the X Bienal de Sao Paulo International Art and Technology exhibition, under the sponsorship of the National Collection of Fine Arts and M.I.T.

A limited amount of work space is available for a small number of research affiliates and

special students, though there is no formal program of study offered and no degrees are granted.

### **Center for International Studies**

The Center for International Studies reflects the strong interest of M.I.T. in the social, political, and economic problems of the contemporary world. Although the Center has no teaching program of its own, most of its senior staff are faculty members of the Departments of Economics or of Political Science; the Center provides research opportunities that are important to the professional development of these departments. There are also opportunities for graduate students to participate in the Center's research programs.

Current research includes studies on economic and political development of nations in Asia, Africa and Latin America; international communications; Communism, revisionism and revolution; arms control; various aspects of American foreign and defense policy; and computer handling of social science data.

### **Center for Materials Science and Engineering**

The aims of the Center for Materials Science and Engineering (C.M.S.E.) are to encourage, promote, and support interdisciplinary research in materials. Associated with the C.M.S.E. are faculties from numerous science and engineering departments; excellent, modern central facilities for the preparation, analysis, testing, and evaluation of various classes of materials; and groups of undergraduate, graduate, and postdoctoral students doing all, or some part, of their research at the Center. The central facilities are available to all students of the Institute.

The materials research activities of the Center as well as those of the entire Institute are described in the Annual Report on Materials Science and Engineering at M.I.T., available through the Center.

The Advanced Research Projects Agency of the Department of Defense provided part of the funds for the construction of this new facility, and provides operating funds to support the Center's materials research effort.

### **Center for Space Research**

The Center for Space Research has been formed to stimulate graduate education and research in space-related disciplines in many departments at M.I.T. The Center administers funds for specific and collaborative space studies and experiments. It also provides facilities and engi-

neering support for the development of space payloads and assists in the reduction and interpretation of astrophysical data.

A new building to house the Center's principal activities recently has been completed on the north campus. Both the building and the research program have been financed in part by the National Aeronautics and Space Administration.

#### ***Center for Theoretical Physics***

In developing a Center for Theoretical Physics at M.I.T., it has been our intention to create an atmosphere in which theoretical physics research and teaching can flourish. Toward this end, a fairly large group of theorists have been brought together and a "home" has been established for them which maximizes the opportunities for communication and collaboration. In addition to the professorial staff, the Center consists of a number of postdoctoral fellows as well as senior visitors. M.I.T. graduate students engaged in research in theory also are housed at the Center. At the present time the major areas of research represented are elementary particles, nuclear physics, and astrophysics. We believe that the lively interaction among the specialists in each of these fields is unique to the M.I.T. group and is one of the major sources of its strength.

#### ***Graduate Studies in Engineering and Living Systems***

Students and faculty in many departments at M.I.T. are conducting research in engineering and living systems. These research interests, arising in the biological, engineering, and social sciences, have led to programs of graduate study for students wishing to pursue careers in these rapidly evolving fields. The spectrum of academic and research programs is extremely broad, ranging from basic physiological studies and the development of new medical and biological techniques with related engineering analysis and design, to problems in urban structure and planning, such as the design of new systems for the delivery of health services. Each of these programs, although strongly interdisciplinary in nature, has grown out of the interests and professional specialties of the participating faculty. Thus, students can enter these programs through various departmental routes.

In addition to the large number of investigations in the biological and medical sciences

being carried out within the Departments of Biology, and Nutrition and Food Sciences, there are active programs of research in Engineering and Living Systems within the following departments: Aeronautics and Astronautics, Chemical Engineering, Chemistry, Urban Studies and Planning, Electrical Engineering, Mechanical Engineering, Metallurgy and Materials Science, Foreign Literatures and Linguistics, Nuclear Engineering, Physics, and Psychology. Virtually all of these studies are collaborative, involving interdepartmental cooperation as well as active support and participation by faculty of the medical schools in the Boston area and the affiliated teaching hospitals.

To serve as an advisory body to students in Engineering and Living Systems, the Dean of the School of Engineering has established a Steering Committee drawn primarily from the Engineering faculty with representatives from other Institute departments and academic centers. In addition to its advisory functions, this Committee provides an effective mechanism for interdepartmental and interorganizational communication through meetings, invited lectures and seminars.

#### ***Information Processing Services***

Computation at M.I.T. touches all aspects of the university: teaching, research, and administration. Drawing upon two decades of experience with digital computers, members of the M.I.T. Faculty, and research and administrative staffs continually seek to develop and exploit computer capabilities in all three areas.

Students, both undergraduate and graduate, are intimately involved in much of this activity. A large majority of students begin to use the computer early in their programs of study and many continue to do so on into graduate work. Specific opportunities to pursue programs oriented toward the computer sciences are described elsewhere in this Bulletin.

The Information Processing Center (I.P.C.) is a large and versatile computer facility whose purpose is to meet the teaching, research and administrative needs for information processing of all members of the Institute community. The Center offers its users a broadening spectrum of information processing services, including high-performance job-stream processing, remote-job-entry processing, experimental and system-development oriented systems, and general purpose, interactive time sharing.

# General

## TEACHING AND RESEARCH RESOURCES

The I.P.C. facility includes an extensive IBM System/360 complex housed in quarters completed in the summer of 1968. Also available is a specially modified IBM 7094 installation, which has been providing general-purpose time sharing to the campus and the New England colleges since mid-1963.

The Center is a key component in the growing, campus-wide information processing capability of M.I.T., which now includes, in addition to the facility described above, ten other computer facilities, each of which meets some specialized information-processing requirement. With this approach, some of the specialized local needs of the community can be met with small or specially tailored computers; these local facilities are then backed up by the large general-purpose installation of the Center. This same concept extends to nearly 70 colleges and universities in New England that are cooperating with M.I.T. in the development of regional computer capabilities.

A number of the smaller computers, both on the M.I.T. campus and on the campuses of other New England colleges, can be connected directly by data-communication circuits to one or more of the other computers in the network. This interconnected, mutually supporting complex is being continually developed in order to provide high quality computer service to all users.

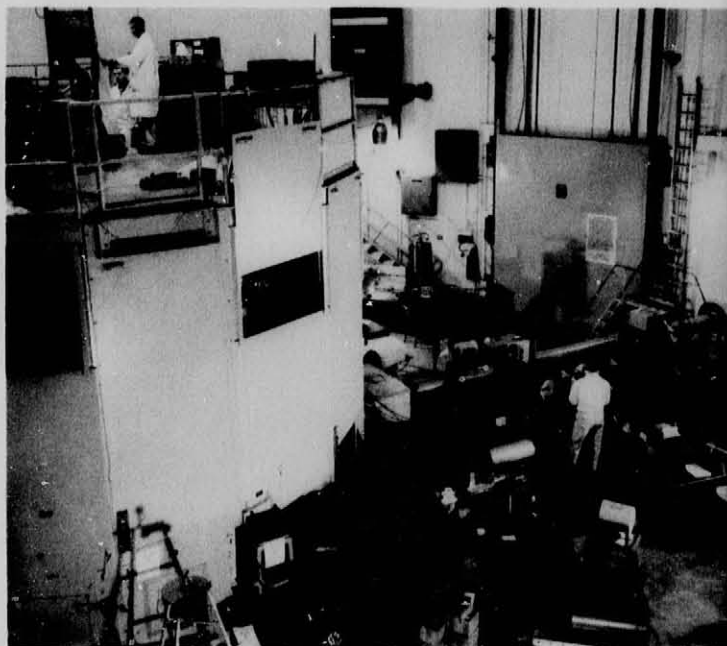
### *Joint Center for Urban Studies of M.I.T. and Harvard University*

The Joint Center was established in 1959 to link urban research activities at M.I.T. with similar activities at Harvard and to develop a new level of interest in urban and regional studies at both institutions. The Center maintains offices at 66 Church Street, Cambridge (02138), encourages basic and applied research on the problems of cities and regions, and sponsors colloquia, seminars, and professional conferences.

The Joint Center provides important research opportunities for faculty members and advanced graduate students at both institutions. Research areas of current interest include problems of transportation, housing, urban design and technology in relation to urban and regional development.

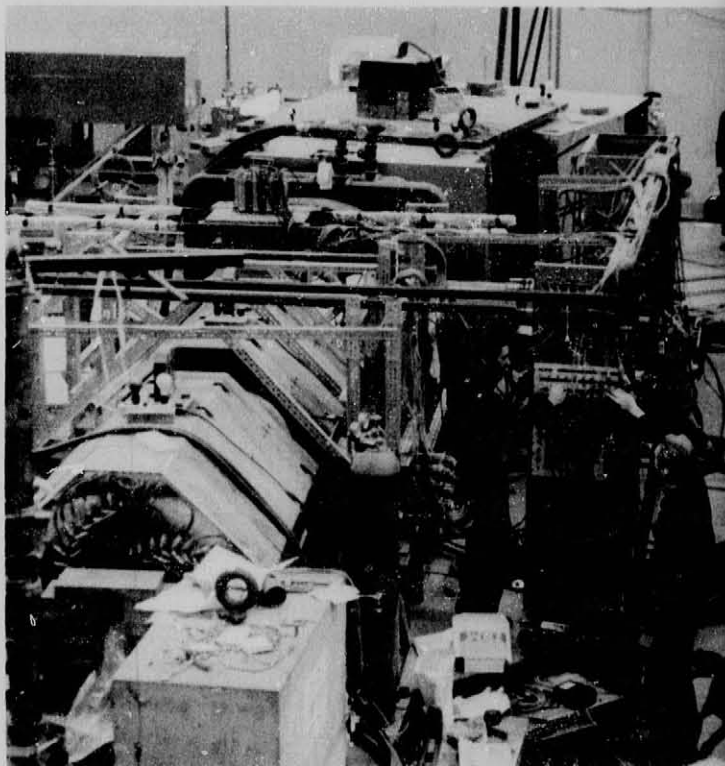
### *Laboratory for Nuclear Science*

The Laboratory for Nuclear Science performs basic research in nuclear physics, supporting research interests of faculty in the Department



THE M.I.T. REACTOR

A LARGE SCINTILLATION COUNTER AT THE  
CAMBRIDGE ELECTRON ACCELERATOR

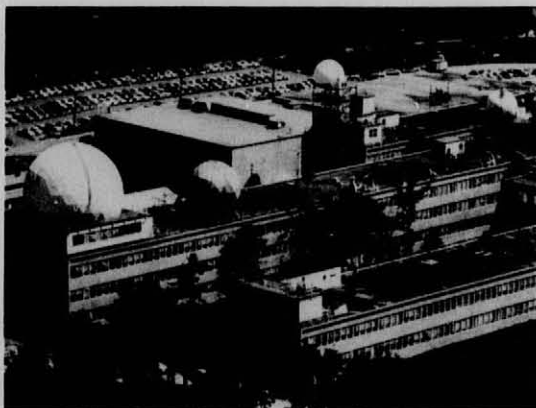


of Physics by maintaining and administering a number of special research facilities. Its major equipment includes a Van de Graaff positive ion accelerator capable of producing particles with energies up to 10 MeV and a number of special experimental facilities adapted to studies in high-energy and nuclear structure physics. A 400-MeV, high-intensity electron linear accelerator is expected to be available for nuclear physics research by 1971. This will extend greatly the Laboratory's capabilities in this field. In addition, the Laboratory operates an IBM 360-65 computer as an open-shop facility available to staff and students. Among many projects are theoretical studies of the atomic nucleus; studies of the photoproduction of mesons and other high-energy phenomena; studies of the new fundamental particles involving broad experimental endeavors using bubble chambers, spark chambers, and complex electronic hodoscopes; studies of cosmic rays, including a program oriented toward the astrophysical aspects of these rays; programs oriented toward the application of high-speed electronic computer techniques to the problems of nuclear and elementary particle data analysis; a broad program of precise nuclear energy level measurements; and programs in medium- and low-energy photo-nuclear and nuclear particle research, and radioactivity. As part of its program, the Laboratory is engaged in experiments in high-energy physics at the Brookhaven and Argonne National Laboratories as well as at the Stanford Linear Accelerator. Experiments are also under way in conjunction with the 6-BeV Cambridge Electron Accelerator and at the German high energy electron synchrotron (DESY) at Hamburg.



COMMUNICATIONS BIOPHYSICS

LINCOLN LABORATORY



### ***The Libraries***

With holdings in excess of one million volumes, the M.I.T. Libraries are a vital resource for the support of both teaching and research. Nearly 9,500 current journals and serials and 1,500 government document series, together with extensive back files, provide comprehensive holdings in all major fields. These are enriched by numerous special collections, including a large group of technical reports, and the Institute archives.

The library system, with headquarters in the Charles Hayden Memorial Library building, includes five school libraries, three branches, and four reading rooms: the Rotch Library of Architecture and Planning; the Dewey Library

# General

## TEACHING AND RESEARCH RESOURCES

(economics, industrial management, industrial relations, and political science); the Engineering Library (with a separate aeronautics and astronautics branch, materials science reading room, and space research reading room); the Humanities Library (with a branch music library and a reserve book room); and the Science Library (with the Lindgren Library branch for the earth sciences); and the Student Center Reading Room.

All the services offered by a fine research library are available: reference and information, interlibrary loans, and microfilms, photoprints, and quick copies of works here or in other libraries.

The libraries serve primarily Institute students, faculty, staff members, and their families. Others wishing to use the facilities may apply to the Director of Libraries for a library privilege card.

### **Lincoln Laboratory**

The Lincoln Laboratory, located in Lexington, Massachusetts, is a Federally sponsored center for research and development in advanced electronics, with special emphasis on applications to national defense. The Laboratory is staffed and operated by M.I.T.

The work of the Laboratory consists of programs undertaken in response to requests of government agencies whose needs coincide with the Laboratory's fields of competence, as well as an underlying program of general research. Two major specific programs are space communications and re-entry studies and technology. Smaller programs include computer graphics, the seismic discrimination and detection of earthquakes and underground nuclear explosions, and the design of a prototype ambulatory health care system. General research is conducted in the fields of data systems, solid state, radio physics and astronomy, radar, and integrated circuits.

In many technical areas, the research facilities of Lincoln Laboratory are available to M.I.T. faculty members and advanced graduate students.

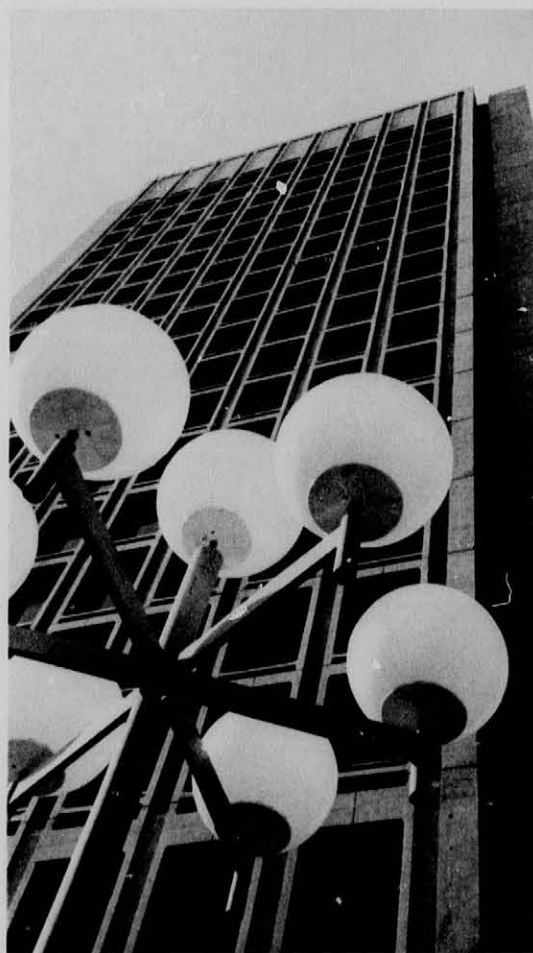
### **Project MAC**

Project MAC is an interdepartmental facility devoted to research in the computer and information sciences. The name MAC is an acronym derived from two titles: machine-aided cognition and multiple-access computer. The broad goal of machine-aided cognition implies

the development of new ways in which on-line use of computers can aid people in their creative work, whether it be research, engineering design, management, or education.

Most of the research activities of Project MAC are carried out by professors, graduate and undergraduate students, and research staff members working together informally in small groups, often with a system of computer hardware and software as a facility or as the object of research. One group, having developed the first general-purpose time-sharing system, is now completing the development of the basic core of an advanced multiple-access information and computing system (MULTICS). During the next two or three years, several groups will create and perfect the user-oriented programs and data

GREEN BUILDING (EARTH SCIENCES)



bases required to make MULTICS a comprehensive computer and information service and others will conduct research on problems in the management and operation of such a service, sometimes called a "computer utility." Several interlocking groups in the field of artificial intelligence are engaged in efforts to program a computer (still another multi-access system) to do things that require "intelligence" when people do them: to solve non-trivial problems and to "perceive" and deal effectively with an environment. One of the programs, said to be the best of its kind in the world, now plays Class C chess; it is improving.

Other groups are active in theory of computation, theory of finite-state automata, design of advanced parallel-processing computers, theory and implementation of programming languages, man-computer interaction, computer graphics, management of information, computer networks, and applications of computers in education, management, and medicine. Examples of their research results that may convey an idea of the nature of their undertakings are, respectively: determination of the limits of capability of the class of elementary parallel-processing machines called "perceptrons"; a way of designing a digital system that makes it possible to set it readily to a known state from which to start tests; the concept of program "segment," now widely used in research on multi-access information processing; programming languages (such as PAL) designed to simplify and clarify the basic ideas of programming; a program (ELIZA) that permits the user to interact with a computer in natural English; the prototype of storage-tube graphical displays currently coming into use in time-sharing computer systems; several on-line data-management and data-analysis systems; systematic standards of format and protocol for intercomputer communication; a program (TEACH) that teaches programming; a program system (OPS) for on-line simulation and modeling; and a program designed to facilitate medical diagnosis.

Research Assistantships are available for work in all aspects of the research program of Project MAC. Also, facilities are provided for thesis research and special projects on the part of both undergraduate and graduate students.

Project MAC is sponsored by the Office of Naval Research on behalf of the Advanced Research Projects Agency. All the work of Project MAC is unclassified and open.

#### ***Operations Research Center***

The Operations Research Center, an interdepartmental activity, affords an opportunity for graduate students to combine work on actual operations research problems with the pursuit of theoretical knowledge in this rapidly developing field. Since its founding in 1953, the Center has sponsored research in the fields of dynamic probabilistic systems, mathematical programming, queuing, inventory and storage systems, and simulation of operational systems; and has carried out field investigations in various areas including transportation, traffic, educational, and municipal services. Present interests are particularly focused on the study of public systems. The research grants and contracts administered by the Center provide support for graduate thesis research, and the Center supervises graduate programs of study in operations research leading to Master's or doctoral degrees. Some graduate students prefer to work mainly in the department of their registration, taking the examinations and subjects required for a graduate degree in that department and obtaining operations research experience by taking elective subjects and conducting their thesis research in this field. Doctoral students who desire to concentrate more heavily in operations research may arrange for interdepartmental supervision of their graduate programs by special faculty committees.

#### ***Research Laboratory of Electronics***

The Research Laboratory of Electronics (R.L.E.) was evolved in 1945 from the Basic Research Group of the M.I.T. Radiation Laboratory to provide a research environment for faculty and students in electrical engineering and physics. The program of the Laboratory has broadened through the years and now includes participants from ten or twelve academic departments. Currently, the activities of the Laboratory fall into three principal categories. These are general physics, plasma dynamics, and communication sciences. Among the research topics in general physics are microwave spectroscopy, radio astronomy, molecular beam studies, atomic resonance and scattering, gravitation research, physical acoustics, electrodynamics, and solid-state microwave electronics. The research in plasma dynamics includes basic studies of plasma physics and gaseous electronics, as well as applications such as controlled fusion

# General

## OTHER TEACHING FACILITIES

for energy conversion, ion propulsion, and microwave devices.

The research in communication sciences involves studies of both man-made and living systems. Work on communication theory and systems studies includes processing and transmission of information, detection and estimation theory, signal processing, circuit theory and computer research. Work related to living systems (communications bio-engineering) includes communications biophysics, neurophysiology, speech communication, cognitive information processing, and linguistics.

Both graduate and undergraduate students participate in the full range of activities mentioned above.

### *Spectroscopy Laboratory*

The Spectroscopy Laboratory has pioneered in the ruling of large, high-performance diffraction gratings and in designing, building and utilizing high-resolution spectrometers throughout the optical range of the spectrum from the vacuum ultraviolet to the far infrared. These instruments are used in studies of molecular geometry, the properties of solids and liquids, and the interactions of molecules of importance to biology. Investigations are in progress in the application of lasers to such problems as excitation of Raman spectra from very small samples of biochemicals and generation of Brillouin scattering in liquid and solid systems of special interest.

### *Urban Systems Laboratory*

The Urban Systems Laboratory was started in 1967 and is evidence of the Institute's intention to organize and bring to bear its resources on the problems of the urban areas. The Laboratory is an interdepartmental and multidisciplinary federation of individuals — students, faculty, and staff members — groups, laboratories, and departments with interests and activities in the area of urban systems. The area of urban systems can be defined as the advancement and utilization of the methods of systems analysis, systems engineering, information systems, and related advanced capabilities and technologies as applied to the facilities required for urban living, including among others transportation, education, communication, environmental quality control, and health.

The Laboratory is developing an environment and mechanism for helping the individual

faculty member and his students pursue their interests in urban systems, is helping the various departments and schools build focal point groups and is helping them become active in the area of urban systems; it is developing urban systems research resources and capabilities that will assist the faculty. The Laboratory is promoting the development of creative interactions with urban organizations that can apply the results of urban systems research and can help in the process of defining needs and problems. The objective of the Laboratory over the intermediate range is to develop an Institute capability for playing a significant role in large-scale, mission-oriented, action-oriented projects in the area of urban systems.

### *Other Interdepartmental Activities*

There are, in addition, other interdepartmental groups which indicate the Institute's growing concern with the interrelationships of the scientific and engineering disciplines. A full list of these Committees on Joint Research Areas, including communication sciences, information processing, operations research, radio astronomy, and solar energy, appears at the back of this Catalogue.

The Institute is one of nine universities operating the Brookhaven National Laboratory at Upton, Long Island, New York; its facilities are available to faculty and qualified students in all M.I.T. departments.

### *Other Teaching Facilities*

The Institute's philosophy of "learning by doing" sometimes carries its teaching program beyond the Cambridge campus. Three departments (Aeronautics and Astronautics, Electrical Engineering, and Mechanical Engineering) have programs of study combining academic work at M.I.T. with on-the-job practice in industry. In chemical engineering, the School of Chemical Engineering Practice operates stations for undergraduates and graduate students at the Bound Brook, New Jersey, plant of the American Cyanamid Company and at the Oak Ridge National Laboratory and it also provides other opportunities for students to obtain practical experience in industry.

In a very real sense, these activities extend the M.I.T. campus into a number of industrial plants throughout the country.

## ***Organization of the Institute***

The governing body of the Institute is a board of trustees known as the Corporation, over which the Chairman presides. Its members include more than 60 distinguished leaders of science, engineering, industry, and education and (*ex officio*) the President and Vice President and Treasurer of the Institute. Between quarterly meetings the Corporation functions through its officers and Executive Committee.

The Corporation appoints Visiting Committees for each department and for certain of the other major activities of the Institute. Members of these Committees, leaders in their respective professions, serve as counselors to the departments and in turn make recommendations to the Corporation concerning departmental activities.

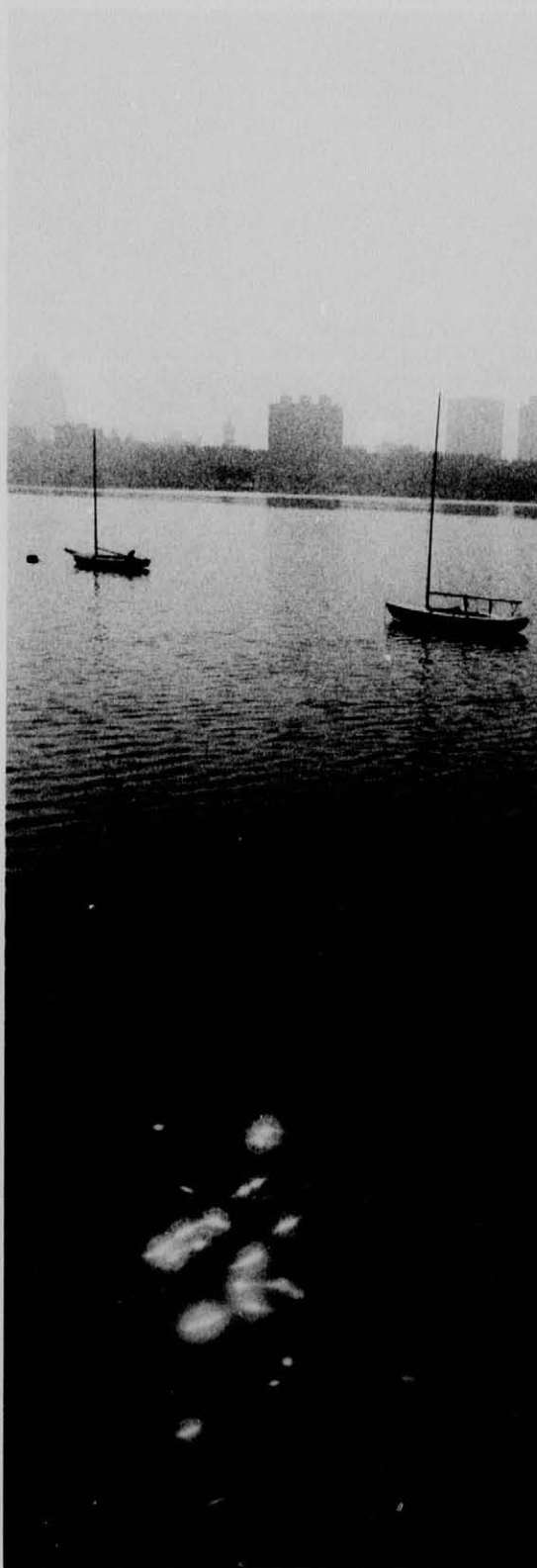
The Institute's chief executive officer is the President. In addition, senior officers include the Provost, the Associate Provosts, the Dean for Institute Relations, and eight Vice Presidents. The academic program is directed by the President, the Provost, and five deans, each responsible for the undergraduate and graduate programs in one of the five academic schools.

The Dean for Student Affairs is directly concerned with all aspects of student life, and the Dean of the Graduate School is concerned with coordinating educational policies of the graduate program. Officers concerned with the administration of academic affairs meet regularly in the Academic Council. Other administrative officers join them to form the Administrative Council.

The management of research activities which are financed through contracts with government and industry is centered in the Division of Sponsored Research. The Industrial Liaison Office and the M.I.T. Associates Office are responsible for fulfilling the contractual obligations of the Institute to a group of leading American companies which make special grants in support of M.I.T.'s program in research and education.

The President presides over the Faculty of the Institute, which consists of all professors, associate professors, assistant professors, certain professors emeriti, certain designated instructors and research associates, and a number of administrative officers (*ex officio*).

The academic staff of the Institute — including instructors, research associates, and graduate, teaching, research, and technical assistants who are not members of the Faculty — totals about 3,000.



# General

THE CAMPUS

## The Campus

M.I.T.'s 125-acre campus extends for more than a mile along the Cambridge side of the broad Charles River Basin facing the city of Boston. Most academic activities are brought together in a group of interconnected buildings designed to permit maximum flexibility and easy communication among the departments and schools. The extensive athletic plant and playing fields are on the campus, as are the recreational buildings, dormitories, and dining halls. This convenient arrangement is an expression of the sense of unity and interdisciplinary involvement that characterizes the Institute.

At the eastern end of the campus are the Alfred P. Sloan Building and the distinctive Grover M. Hermann Building, which house activities in management, economics, international studies, and political science. Adjacent to them is Eastgate, a 30-story apartment tower for married students and faculty.

A commanding feature of East Campus is McDermott Court, in which a great sculpture by Alexander Calder rises in bold contrast against the facade of the 20-story Center for Earth Sciences, the Cecil and Ida Green Building. Surrounding McDermott Court are student residences, Walker Memorial, Hayden Library, and a new building for chemistry.

The Institute's main buildings, enclosing the Great Court, were designed by Welles Bosworth '89 and were dedicated in 1916. Banked by magnificent rhododendrons and lined with tall shade trees, the Great Court opens to a wide prospect of the Charles River, the low brick buildings of old Boston and the concrete and glass towers that rise above them.

Interconnected with these central buildings are the Center for Life Sciences (the Dorrance and the Uncas A. and Helen F. Whitaker Buildings), the Karl Taylor Compton Laboratories (electronics and nuclear science), the Center for Materials Science and Engineering (the Vannevar Bush Building), the Information Processing Center, the Center for Space Research, the Sloan Laboratory, the Guggenheim Laboratory, and the Center for Advanced Engineering Study.

Across Massachusetts Avenue, on West Campus, is the Student Center, the Julius Adams Stratton Building, which contains social rooms, restaurants, offices for student activities, music rooms, a spacious library, and recreational and commercial facilities.



THE DORRANCE LABORATORY FOR BIOLOGY AND FOOD SCIENCE

THE CHARLES HAYDEN MEMORIAL LIBRARY



THE GUGGENHEIM AERONAUTICAL LABORATORY



THE STEIN CLUB MAP ROOM



MUSIC LIBRARY

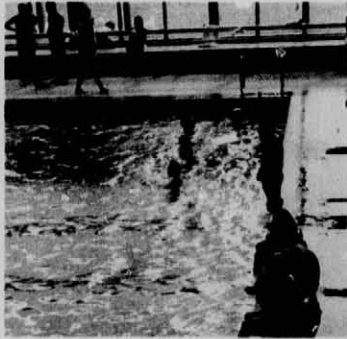




THE HAYDEN GALLERY



ALUMNI SWIMMING POOL



KRESGE AUDITORIUM



M.I.T. CHAPEL



# General

## STUDENT HOUSING

The Student Center plaza, which is the focus of social activities at the Institute, is bounded on the west and south by Kresge Auditorium and the Chapel. Both buildings were designed by Eero Saarinen. The auditorium contains a large concert hall seating 1,200, a little theater, and offices and rehearsal rooms. The Chapel is used regularly for religious services by all faiths and is open throughout the day for meditation. The Chapel's unusual design includes an exterior moat that reflects light in changing patterns on the interior walls.

Along Memorial Drive and facing out on the Charles River are additional student residences, among them the serpentine Baker House, which was designed by the Finnish architect Alvar Aalto. Westgate, an apartment complex for married students, is at the westernmost end of the campus.

Also on West Campus are playing fields for soccer, lacrosse, baseball, softball, touch football, rugby, cricket, track, and tennis. Here, too, are Rockwell Athletic Cage, Briggs Field House, an outdoor skating rink, and the David Flett duPont Athletic Center.

The Charles River Basin, which is two miles long and a third of a mile wide, of course is a major feature of M.I.T.'s physical environment, and the Pierce Boathouse and the Sailing Pavilion provide means for extensive activity in crew and sailing.

### *Endicott House*

Endicott House, a former private estate at 80 Haven Street in Dedham, is M.I.T.'s center for off-campus educational and administrative con-

ferences. Set in spacious grounds, the House has meeting and dining rooms for 75 guests and overnight accommodations for 31.

### *Talbot House*

Near Woodstock, Vermont, Talbot House is an attractive old New England farm home furnished to accommodate groups of students and faculty for conferences and recreational weekends in the Vermont countryside.

## *Student Housing*

### UNDERGRADUATE RESIDENCE

At the undergraduate level, the Massachusetts Institute of Technology is essentially a residential university. Of the total undergraduate student body of about 3,900, about 1,700 single men live in six men's residences on or near the campus; about 200 single undergraduate women live in the women's residence, McCormick Hall, on the campus; and about 1,300 single men live in 29 fraternity chapters and the cooperative M.I.T. Student House. The men's and women's residences are generally called the "Institute Houses."

The central purpose of the residential system is to provide environment and programs conducive to personal development as well as to academic achievements and in this way to extend the experience of higher education which M.I.T. offers its undergraduates. Great reliance is placed by the Institute on the initiative and responsibility of both individual students and student government organizations in the residences.

Faculty families chosen for their understanding of and deep interest in students live in each of

THE HAYDEN LIBRARY



ENDICOTT HOUSE

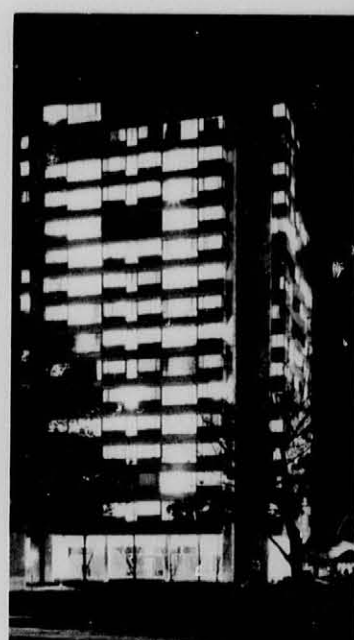




BURTON HOUSE



BAKER HOUSE



WESTGATE

SENIOR HOUSE



MC CORMICK HALL



# General

## STUDENT HOUSING

the Institute Houses. They are not charged with formal academic or operational responsibilities; instead, they welcome informal associations with their fellow residents. In all of the Institute Houses and in many fraternities, resident graduate student tutors also provide personal and academic assistance to undergraduates.

Determination and maintenance of living conditions in the residences are the responsibility of the Dean for Student Affairs and the Office of Campus Housing, in cooperation with student governments and those members of the faculty in residence. Many responsibilities are delegated to student governing groups for establishing and administering House regulations and acceptable standards of community behavior.

Residential student governments also organize a wealth of social, athletic, and intellectual programs for House members. In the Institute House system a House Tax which is included in each resident's rental fee is turned over to the Dormitory Council — a federation of the Institute House governments — to help support these activities. Individual fraternity chapters have similar taxes to support their extracurricular programs.

The Institute believes that it is to the great advantage of all undergraduates who do not live at home to reside "on campus" — that is, to live in an Institute House, one of the 28 recognized fraternities, or the M.I.T. Student House. Freshmen particularly gain from associations with upperclassmen and participation in residence programs. Therefore, insofar as accommodations permit, all unmarried freshmen who cannot commute daily from their own homes or those of close relatives in the Greater Boston area are required to live "on campus."

All unmarried woman members of the freshman class who do not live at home are required to live in McCormick Hall. Exceptions to these "on-campus" living requirements are made only with the specific approval of the Dean for Student Affairs.

### *The Undergraduate Houses for Men*

The Everett Moore Baker House, located on the river front at 362 Memorial Drive, Cambridge, west of Massachusetts Avenue, accommodates some 350 students in single, double, or triple rooms. The House has its own dining facilities, where residents are expected to take commons meals.

The Alfred Edgar Burton House, also on the river front at 410-420 Memorial Drive, Cambridge, west of Baker House, accommodates about 520 students. It consists of five bays, two of which are known as Conner Hall. There are some single and double rooms, but most of the accommodations are suites of rooms designed for larger groups. Burton House has its own dining facilities, where residents are expected to take commons meals.

Bexley Hall, an apartment house at 46-48-50-52 Massachusetts Avenue, directly across from the main entrance to the Institute, has been furnished as an apartment dormitory for men. There are suites for two, three, and four students, each with bath and kitchenette, and a total of 126 men are accommodated. Residents may, if they wish, take their meals at any of the Institute's dining facilities.

Random Hall, located on Massachusetts Avenue three blocks north of the campus, accommodates 100 men in suite-style apartments. A normal suite accommodates 14 men in one- and two-man rooms and contains com-



mon bath, kitchenette, and lounge facilities. Residents may, if they wish, take their meals at any of the Institute's dining facilities.

The Senior House—Ware, Atkinson, Runkle, Holman, Nichols, and Crafts — on Memorial Drive, east of Walker Memorial and adjacent to the President's House, accommodates about 190 undergraduate men in single, double, and triple rooms and suites.

The East Campus Houses — Munroe, Hayden, Wood, Goodale, Bemis, and Walcott—near Walker Memorial have accommodations for about 400 undergraduate men, mostly in single rooms.

Dining facilities for residents of the Senior House and the East Campus Houses are in the Walker Memorial Building. They include a large cafeteria, where both commons meals and a la carte service are provided, and a modern social room and soda bar, where light refreshments are served. The latter, known as Pritchett Lounge, is open during evening hours and has a dance floor and other facilities for entertainment.

Rooms in the Institute Houses for undergraduate men are engaged for the full academic year. For the year 1969-70, the residence fees range from \$200 to \$265 per term. Commons meals for men are served Monday through Friday — 15 meals per week, on an "unlimited seconds" basis. For the academic year 1969-70, the commons fee is \$285 for the fall term and \$269 for the spring term.

#### ***Residence for Undergraduate Women***

Stanley McCormick Hall, the new undergraduate women's residence, located at 320 Memorial Drive overlooking the Charles River, has accommodations for 221 women students in single and double rooms. All unmarried women members of the freshmen class who do not live at home are required to live in McCormick Hall. Unmarried women members of the three upper classes who wish to live in McCormick Hall must contract for residence for periods of a complete academic year, which extends from September to June and includes 15 meals per week during this period (excluding vacations). The residence fee is \$1,114 for the 1969-1970 academic year and includes blankets for the year and fresh bed linen weekly.

#### ***Other Housing Facilities***

##### **FRATERNITIES**

Recognized fraternities at the Massachusetts Institute of Technology include 28 chapters of

national fraternities and one local residential group with no off-campus affiliation. All of the fraternities maintain houses in Cambridge, Boston, or Brookline. Fraternities participate in M.I.T. student government through the Interfraternity Conference. Each house has one or more members of the Institute Faculty or alumni as advisors and several chapters have resident graduate student tutors.

Each fraternity chapter is self-governing and is responsible for management of all its operations and maintenance and for development of its academic, social, membership, recreational and external relations policies and programs. The fraternities provide a unique experience in leadership, community planning, and group interactions.

Approximately 90 per cent of the fraternity freshmen are pledged during "Rush Week," which is held in September just prior to Freshman Weekend. Normally, about 350 freshmen accept invitations to join fraternities. A few upperclassmen, including college transfer students, also pledge fraternities at the beginning of each term.

##### **COOPERATIVE LIVING**

The M.I.T. Student House is an independent, cooperative living group sponsored by a group of House alumni. The 34 undergraduate members maintain the residence and do all the work except for cooking and major repairs. Cooperation by the students extends to the management of the House and to the academic, recreational, and social aspects of student life. Savings per member are about \$400 a year.

##### ***The Non-Resident Student Association***

Those unmarried undergraduate men and women who commute daily from their own homes or off-campus quarters and who are not affiliated with one of the Institute Houses, fraternity chapters, or the M.I.T. Student House are considered members of the Non-Resident Student Association (the N.R.S.A.). A small fee is charged members to help support the social and cultural programs undertaken by this student organization.

The focus for N.R.S.A. activities is a house on the campus which provides social and study facilities for commuting students and limited overnight accommodations. A graduate student tutor is in residence in the house, and the student governing group has responsibilities similar to those of the student governing bodies in the residences.

### **Additional Information**

Additional information on floor plans, fees, regulations in undergraduate housing, and application procedures is contained in the publication *Undergraduate Residence at M.I.T.* Each new first-year student and each new college transfer student is automatically sent a copy of this brochure about three months before registration day of the term for which he has been admitted to M.I.T. Others may request copies from the Campus Housing Office, Room E18-307, M.I.T., Cambridge, Massachusetts 02139. Information on fraternities may also be obtained by writing to Interfraternity Conference, Room W20-413, M.I.T., Cambridge, Massachusetts 02139. Information on the M.I.T. Student House may be obtained by writing to the President, M.I.T. Student House, 111 Bay State Road, Boston, Massachusetts 02215.

### **GRADUATE STUDENT RESIDENCE**

Although the graduate student body numbers about 3,800, a comparatively small number reside on the campus. About 400 single men and 30 single women are accommodated in Ashdown House. Housing for married students and their families is available in two modern apartment complexes, Eastgate and Westgate, at the east and west ends, respectively, of the M.I.T. campus. Westgate accommodates 210 families and Eastgate 204. For graduate students who reside off campus, the M.I.T. Community Housing Service will assist in locating suitable accommodations.

#### ***The Avery Allen Ashdown House***

Ashdown House is the primary graduate residence of the Institute for single graduate students; the House is located on the corner of Massachusetts Avenue and Memorial Drive directly across from the main buildings of M.I.T. and adjacent to the West Campus plaza, which is bounded by Kresge Auditorium, the Chapel, the Stratton Student Center, the Du Pont Athletic Center, and the athletic fields.

A member of the Faculty who is familiar with the aims and problems of graduate students is Master of the House. A student House Executive Committee, acting with the advice and assistance of the Master, plans and operates the activities program. The many facilities for social and cultural activities in Ashdown House make it a center of graduate student activities.

Rooms in Ashdown House are engaged for a full academic year; rents range from \$175 to \$250 per term.

The main dining room provides a la carte cafeteria service Monday through Friday, except during certain vacation periods, and contract meal service for those who may choose to purchase this service. For the academic year 1969-70, the cost of the contract is \$285 for the fall term and \$269 for the spring term.

Cafeteria and restaurant food service is also available seven days a week during the regular academic year at the Student Center.

More complete information is found in *Graduate Residence at M.I.T.*, which is automatically mailed to all entering graduate students.

In general, accommodations in Ashdown House are insufficient to meet the demand at the beginning of each year, and there is usually a waiting list. Priority is granted to graduate students already living in the House whose applications are filed in accordance with instructions distributed each spring. Information on Ashdown House may be obtained by writing the Campus Housing Office, Room E18-307, M.I.T., Cambridge, Massachusetts 02139.

### **MARRIED STUDENT HOUSING**

Two modern apartment complexes, one at either end of the M.I.T. campus, contain a total of 414 family units for married students and faculty couples.

Residence in married student housing is limited to regular undergraduate and graduate married students registered and attending M.I.T. for at least two terms of each year. The summer session is considered a term. Assignments are made on a one-year lease basis. Rents range from \$103 to \$195 per month including utilities and heating.

A nursery school, with one classroom in Westgate and two in Eastgate, is operated by Technology Nursery School, Inc., a non-profit student-faculty organization; it is open to children of students residing off-campus as well as those residing in Westgate and Eastgate.

Married student housing is managed by the Campus Housing Office, Room E18-307, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139. Since accommodations in Eastgate and Westgate are limited, married students are well advised to contact the Community Housing Office regarding off-campus housing.

**Westgate**

Five buildings, completed in 1963 and known as Westgate, are at the west end of the M.I.T. campus; they provide 210 modern unfurnished apartments. The West Campus location near Memorial Drive and the Charles River is within ten minutes' walk of the Institute's main buildings.

The complex includes a 16-story tower with 90 one-room efficiency apartments and 60 one-bedroom units, and four three-story garden-type buildings with a total of 60 two-bedroom apartments. Community facilities are available and free parking is provided for a majority of the residents. Rents in Westgate range from \$103 to \$149 per month.

**Eastgate**

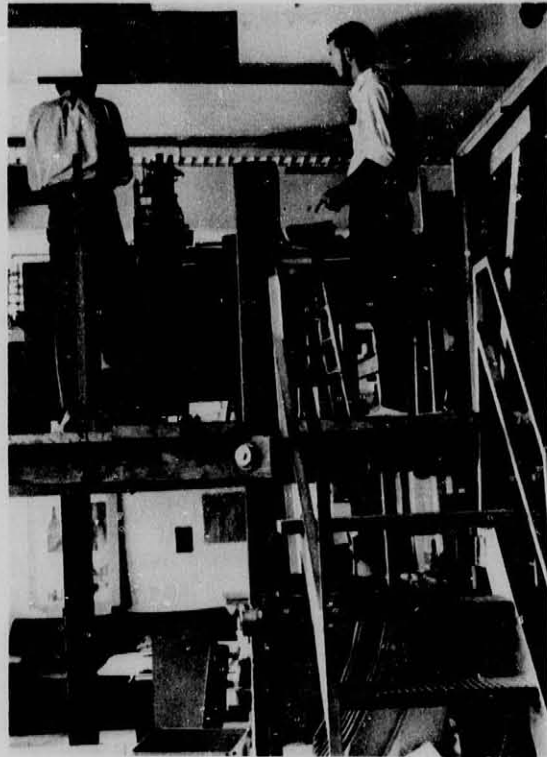
Located adjacent to Kendall Square at the east end of the M.I.T. campus is Eastgate, a new 30-story apartment tower with 204 family units for married students and faculty. The site adjoins the Alfred P. Sloan Campus with the School of Management, and the Departments of Economics and Political Science. It is convenient to the main campus and public transportation.

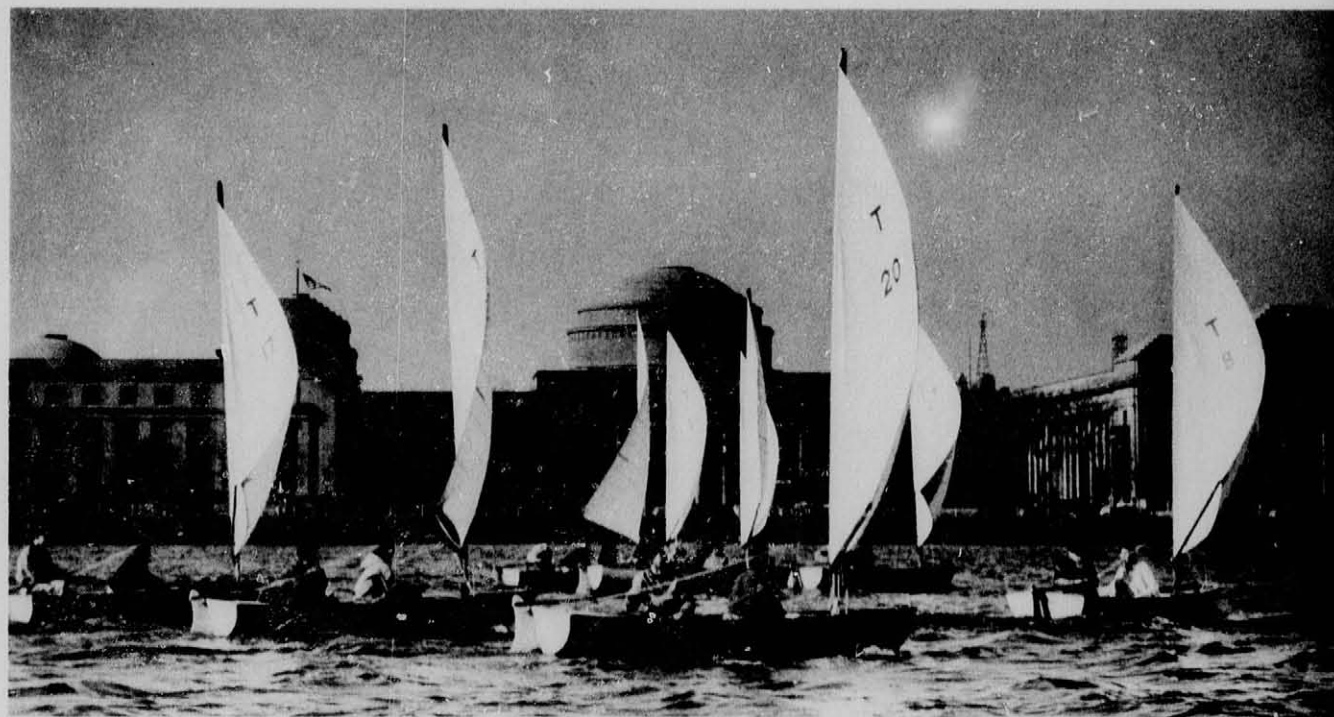
The tower building contains 96 one-bedroom apartments, 84 large one-bedroom apartments, and 24 two-bedroom apartments. About 75 per cent of the apartments are allotted to married students; the remainder are available to faculty members. Rents in Eastgate range from \$120 to \$195 per month. Community facilities are available and free parking is provided for a majority of the residents.

**COMMUNITY HOUSING SERVICE**

Married students, single upperclass men, and single graduate men and women who do not live on campus will find help in locating accommodations in the Community Housing Service. Listings of available rentals in the Greater Boston area are maintained, and the staff attempts, on an individual basis, to help students locate the type of accommodations that will best suit individual preferences and financial resources and to advise on many additional aspects of off-campus living.

The Community Housing Service is located in Building W31 at the corner of Massachusetts Avenue and Vassar Streets. All correspondence should be addressed to Community Housing Service, Box 42, M.I.T. Branch Post Office, Cambridge, Massachusetts 02139.





## *Campus Activities*

M.I.T. is a community with wide extracurricular interests and liberal opportunities to enjoy them. More than one hundred student-directed activities supported by excellent facilities and capable staff provide the student with opportunities to develop his interests, to acquire new skills and talents and most important, to participate actively in the life of the M.I.T. community.

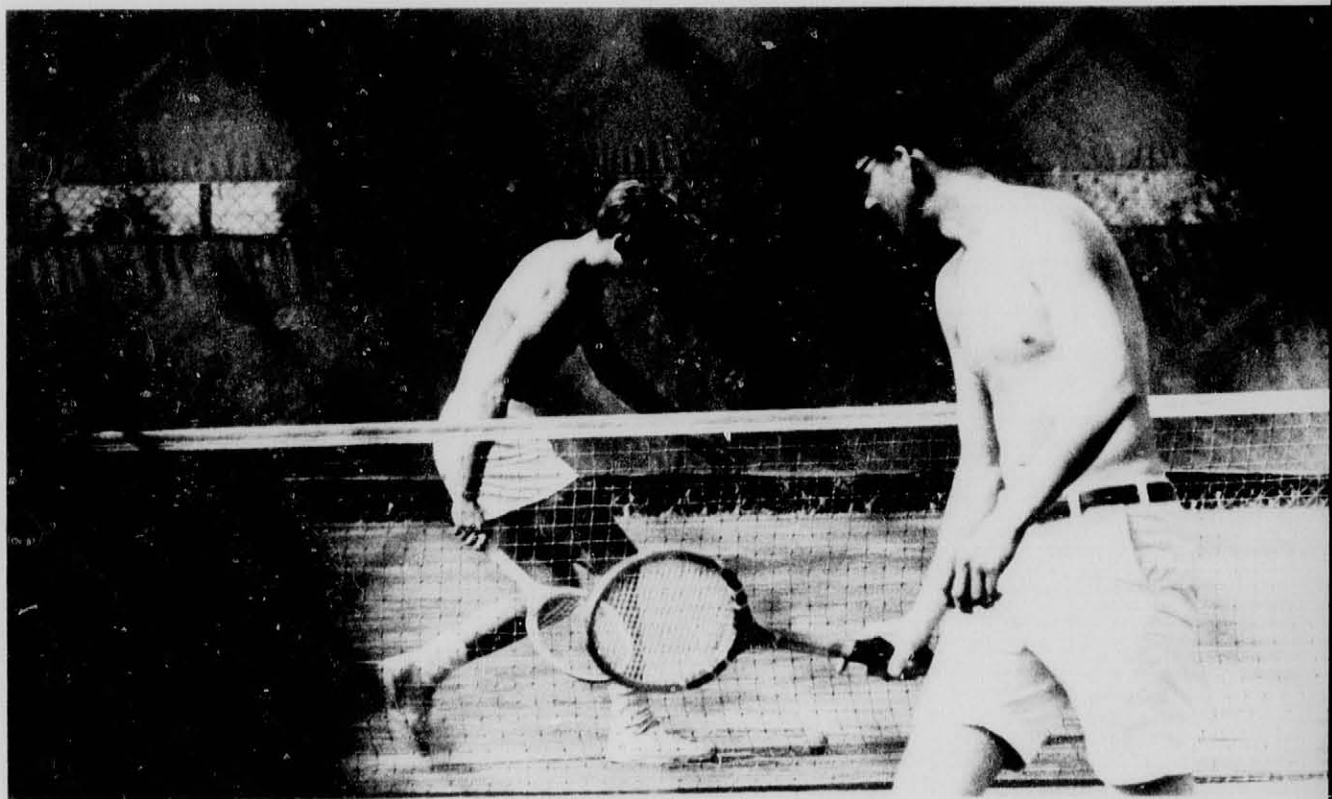
Lectures, music, drama, art, athletics, and hobbies all make for a many-sided and busy campus. Moreover, Greater Boston provides a wide range of cultural activities to enrich further the total college experience.

### *Student Government*

The M.I.T. Undergraduate Association, comprising all undergraduate students, is responsible for major areas of undergraduate life. The core agency of the Association is its elected legislative body, comprised of 75 representatives from the Institute Houses and each of the fraternities, determines association policy and procedures and sponsors a variety of functions and operations. Various subcommittees of the General Assembly deal with specific aspects of these responsibilities. The Student Committee on

Educational Policy makes recommendations to the Faculty concerning academic matters. The Student Center Committee plays a key role in the management of the Student Center. The Student Committee on Environment works to make the campus a pleasant place to live and work. The International Students' Council coordinates the activities of the various national-ity clubs. The Activities Executive Board, an administrative group, represents the interests of more than one hundred student activities and seeks to improve the program and scope of each group. The budgets and expenditures of all student organizations are coordinated by the Finance Board, which annually allocates a budget of over \$100,000 to support both the work of these subcommittees and the programs of the student activities. Other subcommittees are responsible for such special events as all-campus social weekends and intercollegiate conferences.

All living groups, both fraternities and Institute Houses, elect governing councils responsible for the functioning of their houses. In addition to sponsoring social events, these House councils also handle all judicial matters with the respective Houses. To deal with the problems of common concern, the fraternities have joined in



# General

## CAMPUS ACTIVITIES

the Interfraternity Conference (I.F.C.), while the Institute Houses have formed the Dormitory Council. The I.F.C. operates a central food purchasing agency, coordinates and supervises Rush Week, and works to improve relations between fraternities and Boston's Back Bay community by sponsoring an area clean-up and beautification program. The Dormitory Council coordinates such common House activities as freshman orientation, major social events, and intra-House judicial problems.

The elected officers of the Non-Resident Student Association run a program of tutorial, athletic, and social events for commuting students which centers around the N.R.S.A. house on Memorial Drive.

Each class at M.I.T. elects a president and executive committee to handle class affairs such as Field Day, Junior Prom and Graduation. Freshmen participate in class government through the Freshman Council, whose members are elected early in the fall.

The Graduate Student Council, comprised of elected representatives from each department, coordinates departmental activities and runs from its office in Walker Memorial a broad program of athletic, social and cultural events for the entire graduate community. The Ash-down House has its own elected group to conduct House government and activities.

### Athletics

A major purpose of the athletic program at the Institute is to encourage all students to develop interests leading to participation in some form of physical recreation. Instruction is offered in those activities which may be continued in the years following graduation.

The intercollegiate program last year attracted more than 900 students to competition in 20 sports, while 4,000 undergraduates seeking more informal activities joined intramural and club teams. These figures do not include sailing, which is by far the most popular recreational activity.

M.I.T. has varsity and freshman intercollegiate teams in track and field, cross-country, crew, baseball, skiing, gymnastics, hockey, basketball, fencing, golf, lacrosse, rifle, swimming, tennis, soccer, squash, pistol, sailing, and wrestling. Competition includes many New England colleges and Ivy League schools.

The intramural athletic program is noteworthy; last year over two-thirds of M.I.T. undergraduates participated in over 1,500 intra-



CHORAL SOCIETY

DRAMASHOP



OUTING CLUB



TECH SHOW

mural contests. There were league competitions in touch football, cross-country, basketball, cycling, softball, volleyball, swimming, track, tennis, table tennis, sailing, badminton, hockey, golf, squash, water polo, wrestling, rifle, water polo, and bowling. Club sports, with inter-collegiate competition but less formal organization than varsity teams, include badminton, bicycling, rugby, water polo, cricket, judo, white water, and weightlifting. Undergraduate and graduate students participate in both intramural and club programs.

Excellent facilities for these sports are provided by the Du Pont Athletic Center, Rockwell Cage, the Du Pont Gymnasium, Briggs Field, the Alumni Swimming Pool, 14 tennis courts, an outdoor skating rink, and the Sailing Pavilion and Pierce Boathouse on the Charles River.

Through the M.I.T. Athletic Association, undergraduates share with the Athletic Department the responsibility for planning and operating athletic programs.

#### Theater

A variety of theatrical performances is presented on the campus by both student organizations and professional groups.

Dramashop, the student drama group, presents a varied program under the professional supervision of the Director of Drama and his two assistants: a designer and a technical director. This program includes each year at least two major productions of full-length plays and four workshop productions of one-act plays directed, designed, and acted by students. Dramashop, in conjunction with the Department of Humanities, also sponsors a Celebrity Series including lectures by prominent theatrical people, productions of plays by well-known theater groups, and performances by modern dance and ballet groups. Tech Show is an annual musical comedy written and produced by students. The Gilbert and Sullivan Society presents two Gilbert and Sullivan operettas each year.

The M.I.T. Community Players, a group of graduate students and staff and their families, present under professional direction a number of plays each year.

#### Lectures and Seminars

The Lecture Series Committee, an all-student group, brings outstanding and controversial speakers to the campus. Such men as Timothy

Leary, Jacques-Yves Cousteau, Edward Teller, and Isaac Asimov — all have recently delivered talks to the M.I.T. community. In cooperation with the Department of Humanities, the L.S.C. also has presented such entertainment as Max Adrian as George B. Shaw in "By George," and the Pennsylvania Ballet Company in a program of contemporary and classic ballet. In addition to these programs, L.S.C. is responsible for a highly popular weekend movie series of current and classic movies.

The Karl Taylor Compton Seminars, inaugurated in the past year, bring to the campus men and women whose ideas and acts are making major contributions towards solving the problems that beset contemporary American society. The 1968-69 series started with a panel discussion by Mayors Jerome Cavanaugh and Henry Maier, Claude Brown, and Paul Ylvisaker on the topic of "Crises in the Cities." In November, McGeorge Bundy spoke on new alternatives for peace in Vietnam. In the spring, Former Vice President Hubert Humphrey gave his personal view of the current problems facing America and John Gardner, the former Secretary of Health, Education and Welfare, gave a challenging report on health in our nation. The series closed the year with a debate on economic philosophy between Paul Samuelson and Milton Friedman.

#### Music

M.I.T. is a musical community. It has a busy season of musical activities and programs performed by many different musical groups, all of which are open to both undergraduate and graduate students. The Combined Musical Clubs include a Glee Club, Symphony Orchestra, Concert Band, Woodwind and Brass Ensembles, Concert Jazz Band, and a barbershop group — the Logarithms; there is also a Choral Society, which draws its members from the entire M.I.T. community. These organizations give public concerts on the campus, participate in joint concerts on other northeastern college campuses, and take periodic concert tours throughout the East and Midwest. In 1968-69 the Glee Club performed Poulenc's *Gloria* and Haydn's *Missa Cellensis* with the Douglass College Choir, and Barber's *Reincarnations* and Mozart's *Vesperae de Dominica* with the Mount Holyoke College Glee Club. The Concert Band, which specializes in contemporary compositions written for band and which for several

# General

CAMPUS ACTIVITIES



years has commissioned a composer each year to write a new work for the Band, gave concerts in the Boston area and toured the eastern United States and Canada. On its 1969 spring tour the Symphony Orchestra appeared at Amherst College, Brown University and at Carnegie Hall in New York. In 1968 the Concert Jazz Band placed in the finals at both the Villanova and Notre Dame Jazz Festivals, appeared on WGBH television, and held a collegiate invitational jazz festival at M.I.T. The Choral Society has three European concert tours to its credit; the last, in 1962, included appearances in London, Cambridge, Paris, Bonn, Berlin and Munich. Here at home they performed Mendelssohn's *Elijah* with 47 members of the Boston Symphony Orchestra and gave a concert of music set to the poetry of Walt Whitman.

Chamber music groups, symphonic groups, and concert soloists appear at M.I.T. each year as part of the Humanities Series. Other professional musical events are sponsored at the Institute by the Baton Society (the student

musical honorary group) and various campus organizations.

### *Exhibitions and Activities in the Visual Arts*

The Office of Exhibitions presents approximately eight major exhibitions a year in the Hayden Gallery, hallway, and courtyard which appeal to a wide range of interests. Important exhibitions of the year included photography ("Light") and architecture ("Form and Use in Architecture") as well as art ("Takis: Evidence of the Unseen"; "Selections from the Paul Tishman Collection of African Sculpture".)

The Francis Russell Hart Nautical Museum, housed in the Department of Naval Architecture and Marine Engineering, contains a fine collection of ship models and the Allan Forbes and Arthur H. Clark print collections on permanent display.

The Catherine N. Stratton Collection of Original Graphics is offered to students for use in their own living areas. These works may be borrowed at the beginning of each term from the Technology Community Association.

The M.I.T. permanent Art Collection, which now includes nearly 300 paintings, indoor and outdoor sculpture, and graphics, is on view throughout the Institute.

Recent acquisitions include important works by Conrad Marca-Relli, Niel Williams, Jim Huntington, Jasper Johns, Richard Merkin, Tamara Melcher, Robert Rauschenberg, Allan D'Arcangelo and Howard Mehring.

In addition, the Office of Exhibitions sponsors lectures, films, exhibition openings, and informal discussions with artists exhibiting at the Institute.

### **Religious Organizations**

The long-established programs of the several student religious organizations on the campus are focused about the Chapel and the Student Center. Ministers representing the major faiths devote all or a large part of their time to on-campus activities, counseling with individual students, and advising the student religious organizations. The offices of the Religious Counselors are located at 312 Memorial Drive.

Students take an active part in the religious activities of many of the neighboring churches in Boston and Cambridge. In the last few years the new chapel has made it possible for the religious groups to center more of their activity, especially their services of worship, on the campus.

In accordance with the chapel's interdenominational status, the Institute has not appointed an Institute Chaplain or Dean of the Chapel. M.I.T. considers that one of its responsibilities is to maintain an atmosphere of religious freedom for the individual and, within this environment, to provide adequate opportunity for the development of spiritual maturity and the exercise of spiritual interests.

### **Student Publications**

Student publications at M.I.T. include *The Tech*, student newspaper published twice each week; *Technique*, the senior yearbook; *Tech Engineering News*, monthly student magazine of science and engineering; *Tangent*, literary review; *Innisfree*, journal of inquiry; and *Voo Doo*, humor magazine. There are less formal outlets for journalism talents in the newspapers of the Institute Houses and in departmental newsletters of many kinds. The Graduate Student Council sponsors publication of *A Guide to Graduate Life*, and the Technology Community Association prepares an undergraduate guide, *The Social Beaver*.

### **Technology Community Association**

Managed by undergraduates and operated with the help of a permanent staff, T.C.A. conducts a diversified program of year-round services to the M.I.T. community. A handbook for new arrivals on the campus, a theater ticket service, a book exchange, an extensive program of student-taught college level subjects for high school students, duplicating machines for student use, and annual blood donor and charity drives are a few of the activities sponsored by the student members.

### **Special Interest Groups**

There are more than 80 non-athletic student activities and clubs at M.I.T., many of them open to both undergraduate and graduate students. Among the most active are the Outing Club, the White Water Club (canoe and kayak), the Hobby Shop (complete facilities for wood-working, and metal working, photography, and other activities), the Debating Society, the "ham" radio station w1mx, and wrbs (the student-operated FM local broadcasting station).

More than 500 students are actively engaged in social service work in many areas of Greater Boston. Although many of the major projects and over-all coordination is the responsibility of the M.I.T. Urban Action, many other student groups such as the Alpha Phi Omega (the national service fraternity) and the Civil Rights Committee have social service projects as one part of their over-all program.

Political groups have traditionally played a significant role in student affairs at M.I.T. Groups such as the Socialist Club, Students for a Democratic Society, Young Americans for Freedom, the Young Republicans, and the Young Democrats have provided means for student involvement and expression in the larger issues of the day. These groups have sponsored teach-ins, guest lecturers, discussion groups and political rallies.

Technology Student Enterprises, Inc., is a new corporation which provides management facilities under which M.I.T. students develop individual and group entrepreneurial efforts.

The various professional societies invite outside lecturers to discuss topics of professional interest and provide a forum for the presentation of scientific papers by students.

Numerous nationality clubs sponsor programs which bring foreign students of similar backgrounds together for cultural and social occasions.

# General

## MEDICAL SERVICES

### *The Technology Dames*

The wives of M.I.T. students, both undergraduate and graduate, form the Technology Dames. A social and service organization that begins activities in mid-October, the group numbers nearly 400 and sponsors monthly programs to suit a variety of interests. Special events of the year include International Night; a spring fashion show; a crafts sale; and a banquet at the end of the year. Smaller interest groups include a bridge group, bowling, cooking, an exercise class, and arts and crafts. Joining the Dames is an excellent way to meet new friends and become better acquainted with the M.I.T. community. For more information, contact Anna Palsson, H-4 Westgate, 868-8685.

### *Medical Services*

The Institute maintains a well-equipped Medical Department staffed by specialists, centrally located in the Homberg Memorial Infirmary, a wing of M.I.T.'s main buildings. On the first three floors are doctors' offices and special facilities for minor surgery, ophthalmology, otolaryngology, dental hygiene, X-ray, and laboratory diagnosis. An infirmary with 23 beds and an operating room are located on the upper floors. Facilities of the Boston and Cambridge hospitals are used in cases involving major operations or complicated procedures, after which students may return to the Infirmary for convalescence.

A Student Health Program has been established by the Institute to underwrite the major portion of the cost of complete medical care for the student. This program, which differs from previous years, now consists of two parts:

The first part covers ambulatory and infirmary care provided by the M.I.T. Medical Department and is required for full-time students at an annual cost of \$80.00. The second part covers hospitalization (other than in the M.I.T. Infirmary) due to accidents or illness at an annual cost of \$27.00; this portion of the program may be waived if the student has equivalent insurance, such as by a family insurance plan. There is an optional plan for the wife of a student and for his children. The additional cost of coverage for the wife, which includes care in the M.I.T. Medical Department and outside hospital care with a \$300.00 maternity benefit, is \$143.00. Hospital coverage for one or more children may be purchased for \$28.00.

	<i>M.I.T. Medical Department</i>	<i>Outside Hospital</i>	<i>Both</i>
Student	\$80.00	\$27.00	\$107.00
Student wife	\$80.00	\$63.00	\$143.00
Children, one or more	Not provided	\$28.00	—

Initial consultations with a member of the psychiatric service are available to all students and their wives without charge. Short-term psychotherapy, if recommended, will be provided without charge to those in the Student Health Program. Prolonged psychiatric treatment cannot be provided by the Institute psychiatric staff, nor is it underwritten by the Student Health Program. Students requiring such treatment will be referred to private psychiatrists or psychiatric clinics in the area.

Prior to matriculation, every student, undergraduate or graduate, is required to submit a report of a physical examination performed by his own physician and recorded on an Institute-furnished Medical Form, which is to be mailed by the physician to the Associate Medical Director. Immunizations against smallpox and tetanus are required; immunization against poliomyelitis is recommended but not required. After registering, the student must report to the Medical Department promptly for a tuberculin test, and a chest X-ray. Failure to comply with this requirement within six weeks after matriculation will make the student liable to a charge of \$10.

### *Associated Organizations*

Organizations associated with the Institute include:

#### *Alumni Association*

The M.I.T. Alumni Association has a complete program for keeping 55,000 former students informed of M.I.T. affairs. For example, the Alumni Association publishes *Technology Review*, a nationally circulated journal of contemporary affairs in science, engineering, and other fields represented among M.I.T. alumni. There are nearly one hundred regional M.I.T. clubs throughout the world, and the Alumni Fund ranks annually in the country's top half-dozen. Other alumni activities include Alumni Day, class reunions, alumni seminars, and conferences in major cities throughout the United States.

#### *Association of M.I.T. Alumnae*

The Association of M.I.T. Alumnae is an organization of former M.I.T. women students with

a continuing interest in women currently studying at the Institute. The group maintains and administers its own funds for special financial aid to women students.

#### **Lowell Institute School**

The Trustee of the Lowell Institute established this free evening school in 1903, under the auspices of M.I.T. The program is designed to bring systematic engineering study within the reach of young people in industry who would otherwise be denied these opportunities. For further information, write to the Director of the Lowell Institute School, Room 5-113, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.

#### **Lowell Institute Cooperative Broadcasting Council**

The Institute is associated with other Boston educational and cultural organizations in the Lowell Institute Cooperative Broadcasting Council. Boston's non-commercial educational stations, WGBH-FM (89.7 mc.), WGBH-TV (Channel 2), and WGBX (Channel 44), are operated with the advice and cooperation of the Council.

M.I.T. participation in programming is coordinated by the Office of Public Relations.

#### **The M.I.T. Press**

Since The M.I.T. Press became a wholly independent university press in 1962, it has developed complete facilities for selecting, editing, designing, promoting, and selling its books. More than 600 titles have been published by the Press (almost all are still in print), and currently about 100 hardcover and paperback works are published each year.

One function of the Press is to extend the distribution of M.I.T.'s research and scholarship throughout the world: a substantial proportion of M.I.T. Press books last year were sold in foreign countries. In general, the range of publication closely parallels the Institute's own range of activity — the Press has issued a balanced list of titles in economics and management, in architecture and urban planning, in science and technology, in international and social studies, and the list is marked by a steadily growing strength in the humanities. Linguistics, urban studies, history of science, and computation are areas characterized by a notable depth of coverage.

Titles also range from the specialized to those of broad general interest, from the topical to those of lasting concern, and from hardcover

originals to popular paperback reprints. A recent annual report and a complete descriptive catalogue are available upon request — write The M.I.T. Press, Cambridge, Massachusetts 02142.

#### **The Technology Matrons**

Wives of the faculty and senior staff, as well as women members of the faculty and staff, comprise the Technology Matrons. The Matrons usually hold four general gatherings and a number of smaller group meetings for members interested in special activities each year. They sponsor many service projects for the Institute and the Cambridge community. Special projects include seminars, hospitality for foreign and American students, aid to them in seeking housing, and a welcome for new faculty and staff families. The Student Furniture Exchange and English classes for foreign wives are sponsored by Matrons.

#### **Other Services**

Among the other important Institute services are:

##### **Faculty Club**

Membership in the Faculty Club is open to members of the Faculty and staff, to many members of the research staff, and to alumni. The Club has comfortable dining and lounge facilities in the Alfred P. Sloan Building at 50 Memorial Drive, Cambridge.

##### **Information Office**

This office (Room 7-111) is located in the main lobby at the Massachusetts Avenue entrance. Directions to various M.I.T. destinations, catalogues, directories, Institute maps, and Institute telephone service are available here.

##### **Personal Deposits Office**

While students are encouraged to maintain their own checking accounts in commercial banks, the Bursar's Office operates a Personal Deposits Office, Room W20-002, where students may deposit their personal funds in amounts up to \$1,000 and draw upon them without charge or interest.

##### **Parking**

Parking facilities at M.I.T. are limited. In general, the Institute cannot provide parking for the use of resident students. A limited number of spaces are available for assignment, with the approval of the Dean for Student Affairs,

# General

## GENERAL REGULATIONS

to students with physical handicaps demanding use of an automobile and to a few other undergraduates.

Because demand for student parking far exceeds supply, the matter is under study at the present time. A system of paid parking may be instituted. Students who plan to bring motor vehicles to Cambridge should take careful note of the information regarding pertinent Massachusetts laws which is mailed with their registration material.

### **Placement**

The Institute's Placement Office offers employment opportunities to students by arranging on-campus interviews with more than 400 prospective employers, including both company and government representatives. Additional organizations continually notify the Placement Office of their available jobs by telephone and letter. Students planning to obtain advanced degrees will find the reference library, which houses a collection of worldwide graduate school catalogues and financial aid announcements, very useful.

The Office of Student Employment (formerly Student Personnel) is now a part of the Placement Office. Students seeking part-time or temporary work (usually on-campus) will find positions in the dining and residence halls, the libraries, and the various M.I.T. laboratories. Information about summer work is also available here.

The Alumni Placement Office helps former students obtain positions in all 50 states and in many foreign countries. It also aids industry in selecting men for jobs requiring engineering, management, or scientific experience.

## **General Regulations**

### **Academic Year**

The academic work of the Institute is given principally in two 15-week terms, as indicated in the academic calendar elsewhere in this book. In addition, a limited number of subjects are given during a 10-week Summer Session in June, July, and August; this Session includes also a number of Special Summer Programs, intensive reviews of special technical fields for those not regularly enrolled at M.I.T. Most classes during the 15-week terms are scheduled between 9 a.m. and 5 p.m. on weekdays. During the Summer Session most classes are held between 8 a.m. and 5 p.m. on weekdays.

### **Registration**

Each student is required to fill in registration forms and present them to the Registrar on a date before the opening of each term specified in registration instructions. First-term registration material is mailed early in August to regular students whose home address is in the U.S. or Canada and should be returned by Labor Day. Second-term registration material is available at the Information Office immediately following the Christmas vacation and should be returned within two weeks.

### **Faculty Counselors and Registration Officers**

Every student is assigned to a member of the Faculty who serves as his academic advisor. Each student's program must be approved by this faculty member, and changes may be made only with his approval. In order to cancel a subject after 13 weeks of a regular term, an undergraduate student must petition the Committee on Academic Performance and a graduate student must petition the Committee on Graduate School Policy. All first-year students and those second-year students who have not yet made a Course selection have as their advisors Faculty Counselors, members of the Freshman Advisory Council. Other undergraduates enrolled in a department have a Faculty Counselor from that department, and graduate students have Graduate Registration Officers.

The deans, department heads, and all members of the Faculty are also available as consultants to students who seek advice relating to their professional careers.

### **Attendance**

The Institute expects regular and prompt attendance in classes and other meetings of the subjects for which a student is registered.

### **Freshman Grading**

Beginning in 1968-69 and continuing for a trial period of four academic years, the grades recorded by the Registrar for freshman students are on a pass-fail basis. At the middle and end of each term, every freshman student shall prepare an evaluation of his work and achievement in each subject and submit it to his instructor on a form provided. The instructor shall in turn write his evaluation. The form shall be delivered to the student and to the student's freshman advisor.

### **Grade Reports**

Grade reports are issued by the Registrar at the end of each term and summer session to all

registered students. Parents of first-year students receive term grade reports.

#### **Transcripts**

Students may order transcripts of their academic record at the Registrar's Office (Room E19-335) upon presentation of a receipt from the Cashier's Office (Room E19-215) at a cost of \$1 per copy.

#### **Final Examinations**

Final examinations are held at the end of each term; the schedule is issued about a month before the examination period. Each student is held responsible for obtaining an examination schedule at the Information Office (Room 7-111), for reporting any conflicts in his examinations before the time limit given on the examination schedule, and for attending the final examinations required in the subjects for which he is registered.

No member of the instructing staff is empowered to grant excuse from a scheduled final examination. Absence from any final examination is equivalent to complete failure except as, on presentation of adequate evidence of sickness or other valid reason for the absence, the Dean for Student Affairs or the Dean of the Graduate School may permit a student whose term work has been satisfactory to take the next scheduled examination on the subject. The instructor may, if the evidence warrants, issue a final grade without requiring a postponed final examination.

#### **Examinations for Advanced Standing**

Registered undergraduate students of outstanding ability may take examinations for advanced standing during the examination periods in each term, provided that they have never been registered for or attended classes in the subject concerned. Notice of intention must be filed with the Registrar at least three weeks before the examination period. Endorsement by the member of the Faculty in charge is required in all subjects which involve laboratory instruction or design.

The grade for an advanced standing examination is entered on the student's permanent record; a passing grade entitles him to full credit for the subject as well as to the appropriate placement if the subject is in a sequence.

#### **Withdrawal**

Undergraduate students who withdraw from the Institute must do so through the office of the Dean for Student Affairs.

#### **Conduct and Discipline**

M.I.T. assumes that all students come to the Institute for a serious purpose and expects them to be responsible individuals who demand of themselves high standards of honesty and personal conduct. Therefore, it is M.I.T.'s policy to have as few rules and regulations as are consistent with efficient administration and general welfare.

Fundamental to the principle of independent learning and professional growth is the requirement of honesty and integrity in the performance of academic assignments, both in the classroom and outside, and in the conduct of personal life. Accordingly, M.I.T. holds its students to the highest standards of intellectual integrity and thus the attempt of any student to present as his own any work which he has not performed or to pass any examinations by improper means is regarded by the Faculty as a most serious offense and renders the offender liable to immediate expulsion. The aiding and abetting of a student in any dishonesty is also held as a grave breach of conduct.

M.I.T. has traditionally placed considerable responsibility on undergraduate governing groups to deal with problems in the student community. Each residential unit has its own judicial system which is responsible to an over-all undergraduate judicial system, which in turn is responsible to the Dean for Student Affairs and the Faculty Committee on Discipline, a standing committee of the Faculty. Minor infractions are handled by that student judicial group which is closest to the problem. Major infractions are handled by the Undergraduate Judicial Committee, the judicial arm of the all-campus student government. Serious infractions which occur on campus and almost all off-campus infractions are considered by the Faculty Committee on Discipline. By custom this Faculty Committee invites one or more students from the undergraduate judicial committees to attend those hearings involving undergraduates.

At the graduate level, no formal student judicial system exists. The majority of cases calling for disciplinary considerations resulting from infractions within the Institute community are handled by the Student's Graduate Registration Officer in consultation with the Dean of the Graduate School and the Dean for Student Affairs. More serious cases including those involving off-campus violations are generally considered by the Faculty Committee on Discipline.

# General

## FEES

It should be noted that the Institute reserves the right to dismiss at any time a student whom it deems undesirable for any reason. Unethical conduct, wherever it may occur, is held to be sufficient grounds for dismissal.

If a student's infraction involves him both in Institute judicial proceedings and in court proceedings, and if an Institute decision might prejudice his court case, the Institute will hold its decision in abeyance until after the court proceedings have been concluded.

The office of the Dean for Student Affairs is responsible for all matters pertaining to general student welfare.

### *Official Notices*

It is each student's responsibility to keep informed of all official notices on the Official Bulletin Boards.

### *Motor Vehicles*

All motor vehicles operated by students must be registered each term with the Campus Patrol within 30 days after Registration Day. Students should also note the requirement that out-of-state automobiles operated by M.I.T. students must be registered with the Cambridge Police Department, and students should consult the Massachusetts Registry of Motor Vehicles to verify that their registration and operators' licenses are valid in the Commonwealth.

### *Fees*

The tuition for all regular full-time students<sup>1</sup>, including academic and graduate student staff, in the first and second terms is \$1,075 per term. The tuition for graduate fellows, trainees, and academic staff in the Summer Session is \$720. (Special tuition rates apply to other students in the Summer Session; these are published each year in the Summer Session Catalogue, available about March 25.)

Special Students (including M.I.T. sponsored-research staff), and regular students other than fellows and academic and graduate student staff, who are permitted by their Registration Officers or Faculty Counselors to take only a few subjects in the first or second term, will be

<sup>1</sup> A regular student is one who is enrolled as an applicant for an academic degree; others are Special Students. Special Students are not permitted to register for thesis.

charged at the rate of \$34 per unit taken either for credit or not for credit. Except for thesis, the minimum tuition is \$200 for regular students and for Special Students who are employed by the Institute or who are dependents of employees or students and \$400 for other Special Students. The maximum tuition is \$1,075 per term.

The tuition fee for thesis research for the Bachelor's degree is \$34 per unit credit in either regular term, with a minimum of \$100 and a maximum of \$1,075. If other subjects are taken in addition to thesis, the minimum tuition fee for thesis applies to the thesis portion of the registration and the minimum of \$200 applies to the total tuition for the term.

Any graduate student making progress on his thesis is expected to register for thesis and is considered a full-time student. If a graduate student requires only part of a term to complete his thesis, he must pay, initially, full tuition for the term; but if he was registered in the immediately preceding term, regular or summer, his tuition for thesis will be adjusted after delivery of the completed document on the basis of a charge of \$105 per week from the starting date of the term, with a minimum of \$105 for the Bachelor in Architecture, Master's or Engineer degree and \$210 for the doctor's degree. If the immediately preceding term was the summer term and if the graduate student was not registered for thesis in that summer term, but was registered in the previous regular term, the minimum tuition for thesis is \$525. A student who continues to hold a fellowship, traineeship, or academic or graduate staff appointment for the remainder of the term after delivery of the thesis continues to be regarded as a full-time student and his tuition will not be adjusted.

Upon recommendation of a department, the Dean of the Graduate School in the case of a graduate student or the Dean for Student Affairs in the case of an undergraduate student may set a special tuition rate in unusual circumstances.

The tuition fee for a student taking cooperative work in Electrical Engineering (Course VI-A) for the 12-month period, July 1 to June 30, is \$2,150, payable \$1,075 on the date when the first-term tuition is normally due and \$1,075 on the date when the second-term tuition is normally due. Upon recommendation of the Department, a special tuition rate may be set for an unusual case.

Students in the Cooperative Courses in Me-

chanical Engineering (Course II-B) and Aeronautics and Astronautics (Course XVI-B) pay a tuition fee of \$2,150 for the period extending from the end of the spring term of their sophomore year to the beginning of the fall term of their senior year. This fee is payable in two parts — \$1,075 on the date when the first-term tuition is normally due and \$1,075 on the date when the second-term tuition is normally due. This tuition fee covers registration by the student for regular and summer terms spent at the Institute and for time spent at the plant. Upon recommendation of the Department, a special tuition rate may be set for an unusual case.

For the School of Chemical Engineering Practice (Course X-A) for the period September through January or February through June, the tuition fee is \$1,075.

#### **Tuition Refunds**

Students withdrawing during the first or second term are charged one-tenth of the stated tuition for the term for each week from the starting date of the term. A student is financially obligated to the Institute for the fees appropriate to the program approved by his Faculty Counselor or Graduate Registration Officer at the first of the term. Any subsequent reduction in fees is based on the date that cancellation of a subject or withdrawal from the Institute is effected.

#### **Institute House Rentals and Meals**

All term rentals, both for Ashdown House and all undergraduate Houses, and all fees for commons meals are to be paid to the Bursar at the beginning of each term.

#### **Application Fee**

A citizen of the United States or of Canada, or a foreign student studying at a U.S. or Canadian institution, who files a final application for admission as a regular undergraduate or graduate student, or as a beginning special student, is required to pay a \$10 application fee. This fee is not required of a student who applies for re-admission as a candidate for the same degree, or, in the case of a graduate student, for a higher degree after a lapse of less than two years. Foreign students filing final application forms from their home countries are not required to pay the \$10 application fee.

#### **Other Fees**

If, in complying with the doctoral degree language requirement, a graduate student requests

a written examination in French, German, Russian, or Spanish at an unscheduled time, he is required to submit with his application a receipt from the Bursar indicating that he has paid a special fee of \$30 for this purpose. Any student who fails to appear for a predoctoral language examination is subject to a fine of \$10. The fees for the Student Health Service Program are listed on page 32 in this Catalogue.

#### **Late Registration or Payment Fine**

A fine of \$5 is imposed for late registration or late payment of fees. Registration is not complete until all fees are paid or arranged for.

#### **Deposits for Laboratory Supplies and Military Uniforms**

A deposit of \$50, from which will be deducted the costs of laboratory chemicals and supplies, damage to military uniforms, and shoes and other non-returnable equipment, is required of:

1. All first-year students taking MILITARY SCIENCE or AIR SCIENCE requiring uniforms.
2. All undergraduate and graduate students taking subjects requiring supplies from the Office of Laboratory Supplies.

All deposits must be made at the beginning of the academic year. Refunds are made at the end of the year; if the total cost of chemicals and supplies used exceeds the amount of the deposit, the extra charges must be paid at the end of the year. No refunds are made during the academic year except to students who leave the Institute.

### **Payments**

All payments are to be made to the Bursar, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, by the time specified in the registration instructions issued prior to the opening of each term. (For convenience, checks may be made payable to "Bursar, M.I.T.") Many students choose to make their payments under the budget plan described below.

#### **Deferred Payment Plan for Fees**

A student or his parents may arrange with the Bursar, by mail or in person, to pay fees in eight (or less) equal installments during the academic year. This arrangement may include all or part of the total charges incurred by the student. No interest or carrying charge is levied for this privilege. Such an arrangement should be made on the Bursar's Registration Form included with

# General

## FINANCIAL AIDS

each student's registration material, in the section captioned "Financial Plan."

These financial arrangements will be confirmed to the student by a "Fees Receivable Statement" shortly after the start of each term. These statements will be continued monthly as long as there is a balance in his account.

An example of a maximum arrangement for the 1969-70 fees for men students is shown below. Note that this covers certain fees only and does not represent the total expense for an academic year.

### EXAMPLE OF DEFERRED PAYMENT PLAN

<i>Fees</i>		<i>Payments</i>	
Tuition	\$2,150.00	September 17	\$ 421.25
Average dormitory rent	470.00	November 3	421.25
Commons meals	554.00	December 1	421.25
Medical insurance	80.00 <sup>1</sup>	January 2	421.25
Laboratory and/or military equipment deposit	50.00	February 4	404.75
		March 2	404.75
		April 1	404.75
		May 1	404.75
	\$3,304.00		\$3,304.00

<sup>1</sup> Covers ambulatory and infirmary care by the M.I.T. Medical Department for a 12-month period for a single person.

In the event of the termination of the student during the term, all fees due must be paid by special arrangement with the Bursar.

## Financial Aids

Financial assistance in three basic forms is available at M.I.T. to both graduate and undergraduate students. The three broad categories are: gift aid (scholarships, fellowships, etc.), loan aid (with varying conditions of repayment and interest rates), and employment. The precise types of aid granted within these categories vary with each student's academic status and financial circumstances.

Graduate student aid is outlined in detail in Section 3 of this Catalogue. The undergraduate program of assistance is described in Section 2.

Any student whose tuition is not paid by a grant or Institute loan may arrange to have that payment made in installments; details regarding arrangements are available from the Bursar. All students, regardless of finances, are eligible for the Deferred Payment Plan (described earlier in this section) and, with few

exceptions, students who wish to work will be able to arrange employment.

The Institute's Student Personnel Office is designed to assist students searching for jobs. Employment is usually available on campus in dining facilities, residence halls, libraries and laboratories. Listings of off-campus positions are also maintained. Students can earn from \$500 to \$700 per year from part-time work, depending on experience and, of course, availability of time. Beginning with the 1970-71 academic year, M.I.T. expects to participate in the Federal College Work-Study Program, thereby making available a greater variety of off-campus jobs in the community.

Students considering M.I.T. are strongly urged to explore all areas of assistance, including government scholarship and loan programs. A number of the states sponsor scholarship programs for residents, and information concerning eligibility is usually obtainable at the state capitals. The Guaranteed Loan Program is a broadly based, Federally guaranteed loan program administered in the several states. Local banks and lending institutions are usually able to answer initial inquiries concerning the availability of loans under the Program.

### Notice: Tuition Rates, 1970-71

The tuition for all regular full-time students beginning in the first and second terms, 1970-71, will be \$1,250 per term. The tuition for regular summer session 1970 will be \$830. Special tuition rates applying to other students in the summer session will be published in the Summer Session Catalogue. Other tuition charges will be adjusted proportionately.





## UNDERGRADUATE EDUCATION: *A Tradition of Excellence* 2.



The Massachusetts Institute of Technology maintains a tradition of excellence in preparing its undergraduates for creative graduate work or professional activity. Because standards of admission are high, the educational program is set at a level which offers to students the opportunity to acquire deep understanding of basic scientific principles and to develop habits of thought characteristic of leaders in science and engineering.

Engineering, science, architecture and planning, management, and humanities and the social sciences are the fields of principal concentration in undergraduate education at M.I.T. The underlying themes are the purposeful application of science through engineering, the study of science for its own sake, and the awareness of the impact of engineering and science upon our physical environment and upon our conduct of industry, government, and society. An integrated program of studies in the humanities and social sciences extends through the undergraduate years, developing powers of judgment and taste and strengthening the student's ability both to meet the basic requirements of his profession and to assume effectively wide responsibilities in public and private life.

Each Course curriculum leading to a Bachelor's degree consists of two major divisions: the General Institute Requirements and a Departmental Program.

The General Institute Requirements consist in part of certain specific subjects in science, and in part of science distribution subjects, a project-type laboratory, and humanities and social science offerings, among which each student may exercise a considerable range of individual choice.

Each Departmental Program consists, in part, of a grouping of subjects in the areas of professional interest to the Course or Courses represented by that particular department and, in part, of additional opportunities for the student to take subjects of his choice. By Institute rule, considerable time for electives is available to every student throughout the four years.

A student can use these elective opportunities to follow special interests, or to deepen and broaden his educational background. Alterna-

# Undergraduate

## THE UNDERGRADUATE PROGRAMS

tively, he can use his elective time to prepare for advanced study in some professional field, such as medicine or law; for graduate study in some area in which M.I.T. gives no undergraduate degree, such as meteorology or oceanography; or for advanced study in a field which is interdisciplinary, such as astrophysics, communication science, or space science and technology.

The pattern for the Bachelor's degree program provides a basis for education in rapidly developing and growing fields of knowledge; it is excellent for those who will follow professions in architecture, engineering, science, economics, political science, or management; and it offers a sound foundation for careers partly or wholly unrelated to these professions.

### *The Undergraduate Programs*

The undergraduate subjects are planned and coordinated to give each student an understanding of scientific and technological knowledge through a variety of alternative paths. Each subject attempts to give undergraduates an opportunity to explore the intrinsic intellectual excitement of its contents; to stimulate an aggressive rather than a passive involvement in the subject matter; and to provide motivation for creative work and continuing self-education.

An undergraduate at M.I.T. may choose his major field of study from among 29 Courses; a complete list of undergraduate Courses and degrees is given in Section 1 of this Catalogue. The program for the Bachelor of Science degree normally requires four years of full-time study.

To complete work for a Bachelor's degree in any Course, each student must fulfill the General Institute Requirements and must complete the Departmental Program specified by that Course. However, each student in every Course has considerable freedom in planning his academic program. Within limits imposed by the prerequisites, each student can schedule his own sequence of subjects in consultation with his Faculty Counselor. Flexibility in the choice of electives and subjects fulfilling the Science Distribution and Laboratory Requirements and, for superior students, the opportunity to take examinations for advanced standing, all permit a student to design a program around his own particular background, interests, abilities, and future goals.

Furthermore, in some cases, a student may substitute other subjects for certain of those

specified by his Course. To assure that such substitutions be well thought out and not haphazardly chosen, a student must obtain permission from his Faculty Counselor, during his junior year, to embark on a program involving a "major departure" from an approved curriculum. (The term "major departure" is understood to signify substitutions not-in-kind for more than one required subject, or substitutions of any sort for more than two required subjects.)

Each undergraduate Course offers the degree of Bachelor of Science with the field of the degree specified, as for instance Bachelor of Science in Electrical Engineering. Some departments also offer in addition an undesignated degree of Bachelor of Science. The purpose of this arrangement is to provide further flexibility by making available curricula which may cross disciplinary and departmental lines. While the undergraduate curriculum for an undesignated Bachelor of Science degree, as listed by a Department, may have its own unique features, each individual program must be laid out in consultation with a departmental representative to assure that it is meaningful in structure and challenging in content.

In the first year most students concentrate on a program centered around mathematics, physics, chemistry, and humanities.

During the second year studies are ordinarily continued with subjects meeting the Science Distribution, Laboratory, and humanities requirements and with the beginning subjects in the Departmental Programs. In the third and fourth years there is increasing diversity among the Courses as the students concentrate on their Departmental Programs.

The curricula for all the Courses are given in Sections 4 through 8 of this Catalogue, where descriptions of the departments in each school are arranged alphabetically by school. The General Institute Requirements are set forth in the next few pages, and the Departmental Programs are listed by each department.

### *Selection of Courses*

Many entering students have a well-defined preference for a specific field, while others have interests in several areas and have not yet decided upon a field of concentration. Experience shows that a substantial percentage of those who do enter with a decided preference find other areas to be more to their liking, and therefore every student should be prepared to examine with an open mind the various Courses avail-

able at the Institute. Students are encouraged to attend departmental orientation programs and to seek out and talk with faculty and others who have experience in fields of potential interest to them. They also are urged to select electives which will help them in deciding about their future careers. For many students this thoughtful consideration of available possibilities will reinforce existing convictions, while for others it will open up new avenues of interest; in either instance the result will be beneficial.

The Faculty recognizes that the most effective educational ally it can have is the creative interest of a student in the material he is studying. It believes, therefore, that the primary aim of each student in choosing a Course of study should be to find that area which holds maximum challenge and rewarding satisfaction for him. Each of the undergraduate Courses combines the study of basic principles with the study of their application in particular situations. From the interest aroused by this combination of principles and applications studied in depth in a particular Course comes the motivation for the continuing learning which leads to professional competence.

A student may enroll in a Course as early as the end of his first year, and he must do so by the end of his second year. This arrangement affords the opportunity for early concentration by a student who has settled on his Course and, at the same time, provides time for others to explore their interests, assess their abilities, and choose a Course which satisfies both.

Each student entering M.I.T. is assigned a Counselor, a member of the Faculty who assists the student in designing an effective program of study appropriate to his interests and aspirations. The selection of electives is one of the important problems on which each student should work in detail with his Counselor. For example, if a student has not decided on a specific Course, he is advised to register for electives and Science Distribution Subjects which are relevant to the Courses he is considering. It is important that these subjects be selected with care because each department has different recommendations for Science Distribution Subjects, and an inappropriate choice may delay graduation in some instances because of scheduling difficulties, or it may decrease elective freedom in the third and fourth years. Counselors can help students utilize most effectively the elective freedoms which are assured in all M.I.T. curricula.

#### **Wellesley Exchange Subjects**

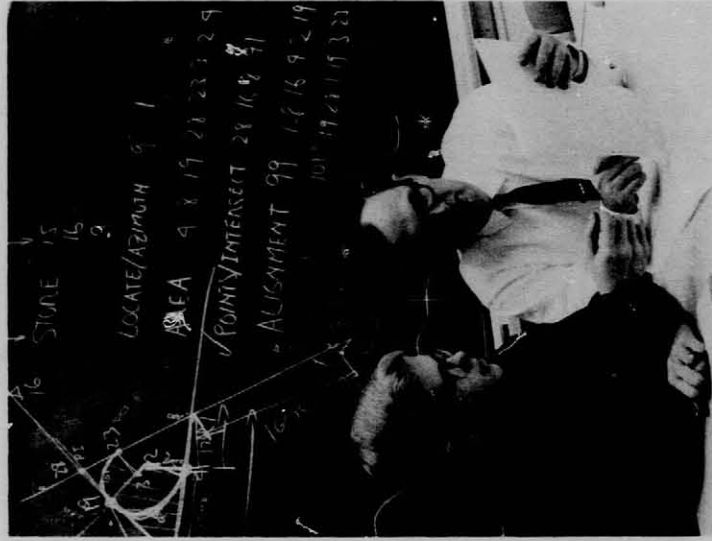
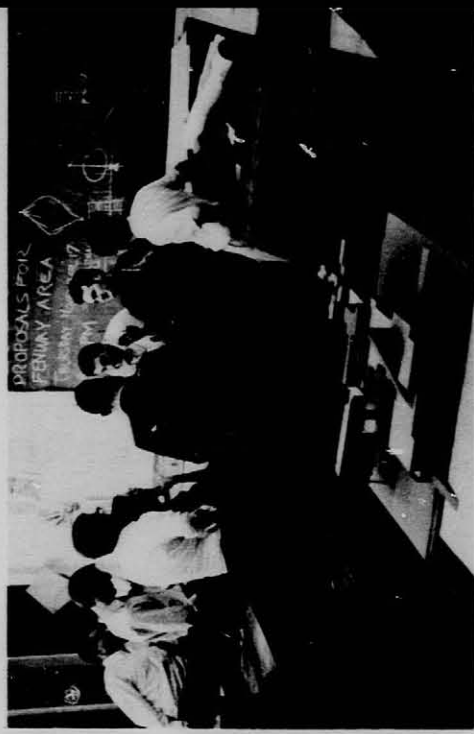
In the fall of 1968, Wellesley College and M.I.T. inaugurated a five-year experimental cross-registration program for undergraduates. The purpose of the program is to extend and diversify the educational programs now available to students in the curricula and environments of both institutions. Under this program, M.I.T. students may substitute subjects taken at Wellesley for M.I.T. subjects. Details on the exchange, including the rules governing the substitution of required subjects, are provided in a publication entitled *Wellesley-M.I.T. Undergraduate Exchange Program: Guide for M.I.T. Students*. New issues of the *Guide* are mailed to all undergraduates for each term: in April for the fall term, and in December for the spring term. Copies of the most recent *Guide* are available in the Information Office and in the office of the Dean for Student Affairs. Bus transportation between Wellesley and M.I.T. for academic purposes is provided to cross-registered students without cost.

Deadlines for cross-registration are in May for the following September, and in January for the spring term. The deadline date for each term is announced in the latest *Guide*.

#### **Premedical Education**

In recent years an increasing number of students has entered medical school upon graduation from M.I.T. Aeronautics and astronautics, biology, chemistry, electrical engineering, chemical engineering, physics, mathematics, political science as well as other fields in science, engineering and the humanities are regularly represented. Since no formal program of premedical studies exists at M.I.T., students have great flexibility in their choice of major fields. Specific medical school entrance requirements can be met in almost any of the Institute's Courses by proper selection of electives. The broad premedical programs that result fully meet the specifications of the Association of American Medical Colleges.

A Premedical Advisory Committee — whose members are directly involved in medical practice, related medical research and in student counseling — provides information to students interested in medical careers. Each student is encouraged to take advantage of the flexibility and diversity of the available academic programs. The Program is administered for the Committee by Professor Emily L. Wick, Associate Dean for Student Affairs, who maintains





# Undergraduate

## THE UNDERGRADUATE PROGRAMS

liaison among the student, his Faculty Counselor, and the Premedical Advisors.

### **Engineering and Living Systems**

An area of study which is of increasing interest to undergraduate and graduate students alike lies at the interface between the engineering and life and health sciences. Investigations on such varied topics as the physical properties of blood, mechanisms of sensory perception, and the control of prosthetic limbs, to name only a few, involve faculty and students from most of the engineering departments. Much of this research is carried out in interdepartmental laboratories, in collaboration with workers from medical centers in the Boston area. The undergraduate wishing to explore this developing area will have ample opportunity within his regular departmental major through elective subjects, special laboratory projects, and the senior thesis. These studies should be of special interest to students who are enrolled in a premedical curriculum. Graduate study in engineering and living systems is open to students with appropriate undergraduate background in either the engineering or biological sciences. The Steering Committee on Engineering and Living Systems serves as an advisory body which can assist students in setting up interdepartmental programs. The Chairman of this Committee is Murray Eden, Professor of Electrical Engineering.

### **Prelaw Education**

A small number of students enter law schools from M.I.T. each year. Although law schools do not prescribe particular undergraduate preparation as a condition of admission, a showing of thorough learning in some area of study, such as economics, science, government, or mathematics, is viewed favorably. While a typical M.I.T. education fits well with the preferences of the leading schools, students may wish to consult Stanley M. Jacks, the Institute's Prelaw Advisor, regarding preparation for law school. He maintains a list of accredited law schools, the dates of the law school admission test, and other information pertaining to the study of law.

### **Science and Mathematics Teaching**

Students who are interested in teaching high school science, humanities, or mathematics may obtain information and advice in the Department of Humanities from Professor Wayne O'Neil.

### **Program for the Bachelor's and Master's Degrees**

Any regular undergraduate student may undertake a program of study leading to the simultaneous award of the Bachelor's and Master's degrees, provided his departments recommend him to the Dean of the Graduate School as a candidate for the Master's degree. He must be enrolled at least one term as a graduate student and complete the requirements for both the Bachelor's and Master's degrees, including a Master's thesis. A student wishing to pursue this program should submit a petition approved by the undergraduate Faculty Counselor and the graduate Registration Officer. The requirements for the various honors and other designated five-year Courses leading to the S.B. and S.M. degrees are specified under the appropriate department statements.

### **Program for a Second Bachelor's Degree**

A student may work for a second Bachelor's degree to be received subsequent to or concurrent with the Bachelor's degree in his primary Course. The requirements for the second degree are the completion of a program of at least 90 units in addition to subjects used for the first degree, resulting in a total of at least 450 units for two Bachelor's degrees. Before starting on this program the student should submit a petition which lists the specific subjects for the second degree and which has been approved by the Faculty Counselors in the departments concerned. The student stays registered in his primary Course until the degree is received in this Course. Another petition should be submitted if there are any changes in the program for the second degree.

### **Subject Registration**

It is not usually necessary to restrict the number of students admitted to a subject. If an unexpectedly large number apply for an elective subject, however, it may be necessary to limit enrollment for the term to a number commensurate with the available staff and with the subject's educational objectives.

### **System of Credits**

The credit hours (units) for each subject indicate the number of hours spent each week in class and laboratory, plus the estimated time which the average student spends each week in outside preparation, for one regular term. Each subject is listed with three credit numbers, showing in

sequence the units allotted to: class; laboratory, design, or field work; and preparation. Each unit represents 15 hours of work per term. The total unit credit for a subject is obtained by adding together all the units shown. The typical undergraduate student load, based on a four-year program, is 45 to 51 units per term. However, if approved by his Faculty Counselor, a student may follow a program leading to an S.B. degree in either more or less than eight terms.

### Degree Requirements

To be recommended for the degree of Bachelor of Science, a student must have attended the Institute not less than one academic year, which ordinarily must be the year of his graduation. He must have completed satisfactorily a program of study approved in accordance with the rules and regulations of the Faculty, including the General Institute Requirements and the Departmental Program of the Course in which his degree is to be awarded. A student must petition the Committee on Curricula for any substitutions in the General Institute Requirements. Departures from the Departmental Programs are permitted with the consent of the Faculty Counselor. The Departmental Program and the total number of units required are shown for each Course in Sections 4, 5, 6, 7, and 8 of this Catalogue.

Effective for the Class of 1973, the General Institute Requirements include:

1. Completion of one of the following chemistry subjects: CHEMISTRY OF THE SOLID STATE (3.091), CHEMISTRY (5.01), INTRODUCTION TO STRUCTURE, BONDING AND MECHANISM (5.41T) or CHEMICAL EQUILIBRIUM (5.60); the physics requirement (8.01 or 8.011 and 8.02 or 8.021); and the calculus requirement (18.01 or 18.011 and 18.02 or 18.021).
2. Completion of the requirements in humanities and social sciences, described on pages 52-57 of this Catalogue.
3. Completion of the Science Distribution Requirement, described on pages 50-51 of this Catalogue.
4. Completion of the Laboratory Requirement, described on page 51 of this Catalogue.

5. Completion of the physical education requirements described on pages 51-52 of this Catalogue.

In summary, to be recommended for the degree of Bachelor of Science, a student must have satisfactorily completed the following units:

	<i>Total Units</i>
<b>GENERAL INSTITUTE REQUIREMENTS</b>	
<i>Science Requirement:</i>	
CHEMISTRY (3.091 or 5.01 or 5.41T or 5.60)	12
PHYSICS (8.01 or 8.011 and 8.02 or 8.021)	24
CALCULUS (18.01 or 18.011 and 18.02 or 18.021)	24
<i>Humanities:</i>	
First- and second-year humanities	36
Third- and fourth-year humanities	36 <sup>1</sup>
	<hr/> 132
<i>Science Distribution and Laboratory Subjects:</i>	
Science Distribution Subjects (in at least three fields)	36 <sup>2</sup>
Laboratory Subjects	12 <sup>2</sup>
<b>DEPARTMENTAL PROGRAM</b>	
As specified for each Course, a minimum of	180 <sup>3,4</sup>
Total units required for the S.B. degree, at least	<hr/> 360 <sup>5</sup>

<sup>1</sup> The requirement for classes '70, '71, and '72 is 32 units.

<sup>2</sup> Each department may specify some of the Science Distribution and Laboratory Subjects.

<sup>3</sup> Departments may require up to 205 units (leading to a total of 385 units) for graduation.

<sup>4</sup> Departmental Programs include at least 36 units of electives, usually more.

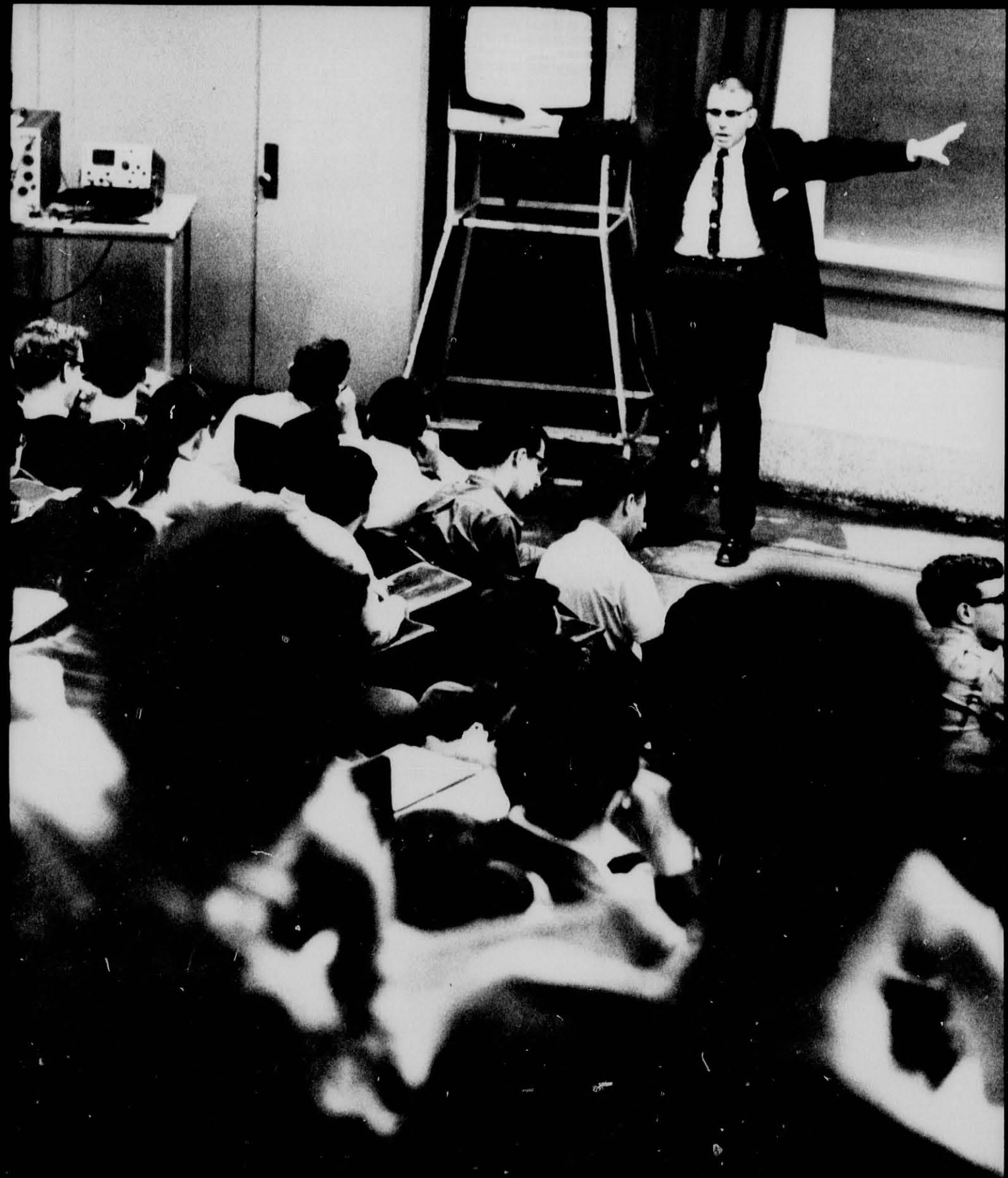
<sup>5</sup> This total does not include advanced Army R.O.T.C., if elected.

### The First-Year Program

For students entering M.I.T. with only the preparation implied by the entrance requirements, the first-year program commonly contains electives and required subjects in mathematics, physics, chemistry, and humanities. These subjects provide an appropriate preparation for all the Courses of undergraduate study offered at M.I.T.

A typical schedule for the two terms of the first year is as follows:

<b>First Term</b>		<i>Units</i>
8.01	PHYSICS I	5 0 7
18.01	CALCULUS	4 0 8
	HUMANITIES ( <i>see page 52</i> )	3 0 6
	SEMINAR	6
	<i>Elective</i>	9
		<hr/> 48





**Second Term**

5.01	CHEMISTRY	5	0	7
8.02	PHYSICS II	5	0	7
18.02	CALCULUS	4	0	8
	HUMANITIES (see page 52)	3	0	6

45

Many other programs are also appropriate. For example, the two-term physics sequence 8.011-8.021 may be substituted for 8.01-8.02. A number of students whose later programs do not require the entire 8.01 through 8.04 series will prefer the combination of topics presented in the two-term version. In addition to 5.01, there are three other chemistry subjects which meet the General Institute Requirements: INTRODUCTION TO STRUCTURE, BONDING AND MECHANISM (5.41T), CHEMICAL EQUILIBRIUM (5.60), and CHEMISTRY OF THE SOLID STATE (3.091). Acceptable alternatives to 18.01 and 18.02 are CALCULUS (18.011 and 18.021).

Entering students with degree credit in one or more of the first-year subjects may substitute more advanced subjects in the same areas or may use the time thus made available for electives or science distribution subjects. If the credit is in the appropriate prerequisites, the student may begin elementary work in a profes-

sional field by taking subjects which would usually occur in his second or third year. The procedures by which degree credit at entrance is earned are described in the section of this Catalogue dealing with admission to the Institute (page 67).

For freshmen with strong records in the first term, some subjects in the humanities and social sciences normally open only to upperclassmen are available during the second term.

Some students of outstanding ability prefer to avail themselves of the opportunities to accelerate their programs through the Advanced Standing Examinations described elsewhere in this Catalogue. However, neither regular language subjects paralleling those completed in secondary school nor Undergraduate Seminars can be completed through Advanced Standing Examinations.

As mentioned previously, 45 to 51 units per term is considered by the Faculty to be the typical student load. A heavier or lighter program can be carried by a student with the approval of his Faculty Counselor. No change in tuition fees is made either for carrying an extra subject or for omitting a subject in any term.

# Undergraduate

## THE SCIENCE DISTRIBUTION REQUIREMENT

### Electives

Any subject offered by the Institute is open to the freshman, provided he can satisfy the prerequisites. Including Undergraduate Seminars, there are more than one hundred subjects without prerequisites and an additional 15 to 20 with prerequisites or corequisites that most freshmen can satisfy at least by the second term. Except for the seminars, these subjects are described with the complete descriptions of subjects.

The Undergraduate Seminars differ from other electives in that they are designed to allow students to work in small groups in close association with faculty members. Less formally organized than customary classroom or laboratory subjects, they offer an opportunity for study with a high degree of individual responsibility and freedom in planning and executing a selected program. The seminars cover a wide range of topics and involve many different types of study. A list of those available is supplied to first-year students during the summer. Enrollment may be limited where demand exceeds facilities.

Electives can be used for several different purposes. For example, many students who are undecided about their eventual course of study will use part or all of their elective time to get more information about the various departments or fields they are considering. Other students who are more certain of their professional goals will use elective time to explore areas of secondary interest. Still others will choose to begin work on departmental or Institute requirements, deferring subjects of a more supplemental nature until a later year. The study of a language may be started, or continued, and most of the R.O.T.C. programs are normally begun as electives in the first year. Before deciding which electives to take, most freshmen will find it helpful to ask themselves which of these uses of electives best suit their individual needs.

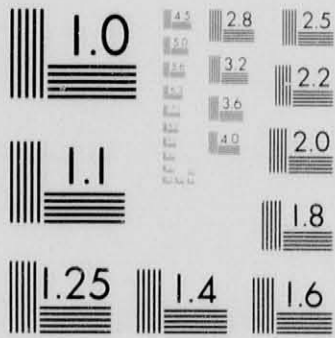
### The Science Distribution Requirement

The Science Distribution Requirement of 36 units is met by taking subjects especially designed for this purpose. Available subjects are listed below. To fulfill the requirement, students must study subjects in at least three different departments and in at least three different fields; the combination of subjects chosen must be approved by the student's Faculty

Counselor. Science Distribution Subjects are normally taken in the second year, but students who have the proper prerequisites may take them in the first year. The prerequisites for these subjects are given with the descriptions.

1.00	INFORMATION SYSTEMS (3-3-6)
1.01	ENGINEERING MECHANICS (4-0-8)
1.02	ENGINEERING MATERIALS (3-3-6)
1.08	GEOTECHNOLOGY (3-3-6)
2.00	INTRODUCTION TO ENGINEERING SYSTEMS (3-3-6)
2.01	MECHANICS OF SOLIDS (4-0-8)
2.02	INTRODUCTION TO SYSTEM DYNAMICS (3-1-8)
2.403	THERMODYNAMICS (4-0-8)
2.42	ELEMENTS OF CLASSICAL AND STATISTICAL THERMODYNAMICS (4-0-8)
2.901	POLYMER MATERIALS SCIENCE (3-0-9)
3.00	THERMODYNAMICS OF MATERIALS (4-0-8)
3.10	ELECTRONS AND ATOMS IN SOLIDS (4-0-8)
3.11	MECHANICS OF MATERIALS (4-0-8)
3.141	SCIENCE OF MATERIALS (4-3-5)
4.30	STRUCTURES I (3-3-6)
5.41T	INTRODUCTION TO STRUCTURE, BONDING AND MECHANISM (4-0-8)
5.60	CHEMICAL EQUILIBRIUM (4-0-8)
5.63	PHYSICAL CHEMISTRY (4-0-8)
6.001	ELEMENTS, SYSTEMS, AND COMPUTATION I (4-0-8)
6.01	INTRODUCTORY CIRCUIT THEORY (4-0-8)
6.013	INTRODUCTORY CIRCUIT THEORY (4-0-8)
6.14T	INTRODUCTION TO ELECTRONICS (4-2-6)
7.01	GENERAL BIOLOGY (4-0-8)
8.03	PHYSICS III (5-0-7)
10.12	STAGED CASCADES IN CHEMICAL PROCESSING (3-3-6)
10.13	CHEMICAL ENGINEERING THERMODYNAMICS (4-0-8)
12.002	THE EARTH AND THE PLANETS (2-0-4)
12.01T	GEOLOGY I (3-4-5)
12.051	CRYSTALLOGRAPHY (2-2-4)
12.052	THEORETICAL MINERALOGY (2-0-4)
12.111	ASTRONOMY I (2-0-4)
12.112	ASTRONOMY II (2-0-4)
12.21	PHYSICAL OCEANOGRAPHY (3-0-9)
16.001T	THERMODYNAMICS AND STATISTICAL MECHANICS (4-0-8)
16.01	DYNAMICS (4-2-6)
16.09	FIELDS IN CONTINUOUS MEDIA (4-2-6)
16.20	SOLID MECHANICS I (4-2-6)
16.84	AEROSPACE ENGINEERING (3-2-7)
18.025	THE WORLD OF MATHEMATICS (3-0-9)
18.031	LINEAR MATHEMATICAL SYSTEMS (3-0-9)
18.034	DIFFERENTIAL EQUATIONS (3-0-9)
18.10	APPLICATIONS OF PROBABILITY AND RANDOM VARIABLES (3-0-9)
18.161	INTRODUCTION TO THE MATHEMATICAL THEORY OF COMPUTATION (3-0-9)
18.18	PROBABILITY (3-0-9)
19.83	PHYSICAL OCEANOGRAPHY I (3-0-9)
20.30	NUTRITIONAL BIOCHEMISTRY AND METABOLISM (4-0-8)
22.01	INTRODUCTION TO NUCLEAR REACTOR ENGINEERING (3-0-9)

Through Science Distribution Subjects the student can broaden and deepen his educational foundation in basic science begun in his first-year program. These subjects are designed to give each student the opportunity to proceed further in areas already studied, or to explore other areas of potential interest.



MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

M. I. T. ANNUAL CATALOGUES AND BULLETINS

1969/70

92  
OF  
95

The available Science Distribution Subjects vary among themselves in approach and emphasis. Some give a systematic introduction to the fundamental concepts and principles of a field; others illustrate, through examples, some of the attitudes, concerns, and methods that are characteristic of professional work in a field.

Most Departmental Programs occupy 48 units in the second year. In many cases, subjects required by a department are also on the list of Science Distribution or Laboratory Subjects. Thus students following a particular Departmental Program may satisfy simultaneously part or all of the Science Distribution or Laboratory Requirements. This provides additional flexibility in the planning of a second-year program.

### *The Laboratory Requirement*

The Laboratory Requirement of 12 units may be met by enrolling in one or two laboratory subjects expressly designed for this purpose. Available subjects are listed below. The Laboratory Requirement is normally fulfilled in the first two years, but some students may choose to postpone it. The Laboratory Subjects must be approved by the student's Faculty Counselor.

1.10	CIVIL ENGINEERING LABORATORY (0-6-6)
2.654	PHYSICAL MEASUREMENT AND ANALYSIS (2-6-4)
2.67	DESIGN AND EXPERIMENT (2-6-4)
2.672	EXPERIMENTAL ENGINEERING I (1-3-2)
2.673	EXPERIMENTAL ENGINEERING II (0-4-2)
2.86	MANUFACTURING PROJECT LABORATORY (2-3-1)
2.861	ENGINEERING DESIGN AND MANUFACTURE (4-4-4)
3.04	MATERIALS RESEARCH LABORATORY (1-3-2)
3.05	MATERIALS RESEARCH LABORATORY (2-6-4)
5.20	LABORATORY PROBLEMS IN CHEMISTRY (1-3-2)
5.21	LABORATORY PROBLEMS IN CHEMISTRY (1-6-5)
5.31	INTRODUCTION TO CHEMICAL EXPERIMENTATION (2-8-2)
6.272	DIGITAL SYSTEMS PROJECT LABORATORY (2-8-2)
6.71	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY (1-4-1)
6.711T	DIGITAL SYSTEMS PROJECT LABORATORY (3-7-2)
6.712	BIOELECTRONICS PROJECT LABORATORY (2-8-2)
6.714	ELECTRONIC LIGHT MEASUREMENTS PROJECT LABORATORY (2-8-2)
6.715	POWER SYSTEMS PROJECT LABORATORY (2-8-2)
6.716	PARTICLE OPTICS PROJECT LABORATORY (2-8-2)
6.717	AUDIO FREQUENCY COMMUNICATIONS PROJECT LABORATORY (2-8-2)
6.719	SEMICONDUCTOR DEVICES PROJECT LABORATORY (2-8-2)
6.722	MODERN OPTICS PROJECT LABORATORY (2-8-2)
6.723	IMAGE TRANSMISSION SYSTEMS PROJECT LABORATORY (0-12-0)
7.02T	EXPERIMENTS IN BIOLOGY (1-8-3)
8.11	PHYSICS PROJECT LABORATORY I (1-6-5)
8.12	PHYSICS PROJECT LABORATORY II (1-6-5)

8.13	EXPERIMENTAL ATOMIC PHYSICS I (0-6-6)
9.50	RESEARCH IN PSYCHOLOGY (Arr. — minimum 6 units)
10.91	EXPERIMENTAL RESEARCH PROBLEM (Arr. — minimum 6 units)
15.36T	BEHAVIORAL SCIENCE RESEARCH PRACTICUM (2-8-8)
15.571	FEEDBACK DYNAMICS LABORATORY (2-6-4)
16.62	EXPERIMENTAL PROJECTS (2-6-4)
17.76	POLITICAL SCIENCE LABORATORY (2-6-4)
20.02	NUTRITION AND FOOD SCIENCE PROJECTS LABORATORY (1-8-3)
20.73	UNDERGRADUATE RESEARCH PROBLEMS (Arr. — minimum 6 units)
20.74	UNDERGRADUATE RESEARCH PROBLEMS (Arr. — minimum 6 units)

<sup>1</sup> Students taking 2.861 (12 units) receive 6 units of laboratory credit.

These Laboratory Subjects call for a major commitment of the student's attention to one or a few experimental problems and emphasize as much as possible work of project type rather than routine experimental exercises. They are designed to stimulate the student's resourcefulness and his own ideas.

The Laboratory Requirement is not intended to teach specific basic techniques for later experimental work, to provide broad coverage of a particular field, or to be a complement to a specific lecture subject. The Laboratory Subjects are planned to give each student, at an early stage of his educational experience at M.I.T., an opportunity to work on one or a few experimental problems, exercising the same type of initiative and resourcefulness as a professional man would in similar circumstances.

### *The Physical Education Requirement*

The Institute expects each student to gain experience in recreational athletics during his first two years at M.I.T.; by the end of this period each male student must have compiled at least 8 points of athletic credit. These points may be acquired by participating in a physical education class (2 points per quarter) or by membership on one of the 20 freshman or varsity teams (2 points for fall or spring sports, 4 points for winter sports).

The program consists of both individual and team activities with the major emphasis placed on the development of interests which can be carried on in later life. A student who elects individual sports such as golf, tennis, sailing, or squash will receive a strong background in the fundamentals of the sport. Instruction in phys-

# Undergraduate

## UNDERGRADUATE HUMANITIES PROGRAM

ical education classes often leads to inter-collegiate participation.

Physical education classes for the year are divided into four quarters, with these activities: *First quarter* — September to mid-November: archery, development class, golf, gymnastics, touch football, lacrosse, sailing, beginning swimming, pistol, beginning tennis, and intermediate tennis.

*Second quarter* — mid-November through January: badminton, basketball, bowling, development class, fencing, judo, scuba diving, skating, skiing, squash, rifle, beginning swimming, intermediate swimming, and Red Cross senior life saving.

*Third quarter* — February through March: development class, diving, fencing, judo, skating, skiing, squash, beginning swimming, volleyball, pistol, and Red Cross senior life saving and instruction.

*Fourth quarter* — April through May: archery, development class, beginning golf, intermediate golf, sailing, soccer, softball, beginning swimming, beginning tennis, intermediate tennis, rifle, and Red Cross instructors' program (continued).

Upon entering M.I.T. each male student must submit a record of a medical examination and take a swimming and physical fitness test. Students who fail the swimming test are required to take beginning swimming, and students who fail the fitness test are recommended for the development class. If the medical examination indicates any disability which might limit physical activities, the athletic requirements may be modified.

Although there are no specific requirements for women students, facilities are provided for many activities of their choice, and women may participate in many physical education classes.

### ***The Undergraduate Program in Humanities and Social Sciences***

The M.I.T. program in humanities and social sciences has several objectives. It seeks first to develop attitudes and skills basic to a life of effective thought, action, and appreciation as a responsible citizen and broadly educated human being. Second, it seeks to provide some understanding of man's experience at key points in his history and of the human problems which must be the concern of every civilized man. Third, it seeks to provide some sense of the intellectual discipline involved in a particular

area in the humanities or social sciences, some study in depth in a field outside the student's professional specialization. Finally, it seeks to develop skill in accurately and effectively communicating facts and ideas orally and in writing.

Every candidate for a Bachelor's degree must take eight term subjects in the humanities and social sciences; normally one subject is taken during each of the eight terms of residence.

During the first year each student takes one of five two-term sequences: THE WESTERN TRADITION: THE CLASSICAL HERITAGE (21.011) and THE WESTERN TRADITION: THE EUROPEAN HERITAGE (21.012); or IDENTITY AND AUTOBIOGRAPHY: THE NINETEENTH CENTURY (21.013) and IDENTITY AND AUTOBIOGRAPHY: THE TWENTIETH CENTURY (21.014); or CONTEMPORARY MORAL ISSUES (21.015T) and CONTEMPORARY MORAL ISSUES (21.016T); or CONFLICT AND COMMUNITY IN AMERICA (21.017) and CONFLICT AND COMMUNITY IN AMERICA (21.018); or REASON AND REVELATION: RELIGIOUS VISIONS IN THE WEST (21.019) and REASON AND REVELATION: RELIGIOUS VISIONS IN THE WEST (21.020). The subject matter of the freshman curriculum is drawn in each case from the several disciplines of the Humanities and directed toward certain major achievements of Western intellect, imagination or social development. The interdisciplinary emphasis of the freshman year is followed by a sophomore curriculum in which the student is asked to examine the perspective and the distinctive languages of two separate disciplines in the School of Humanities and Social Science. The sophomore has a choice between two sets of options. In the first set he is asked to elect either LITERATURE: FORMS OF A MAJOR THEME (21.03); or, LITERATURE: SELF, NATURE AND SOCIETY (21.031); or, PHILOSOPHY: CLASSIC AND CONTEMPORARY (21.04). In the second option he is asked to make a choice between the TWENTIETH CENTURY: REVOLUTION AND TOTALITARIANISM (21.05); or THE TWENTIETH CENTURY: CONSCIOUSNESS IN INDUSTRIAL SOCIETY (21.06); or SOCIETY AND MAN (17.01). Frequent written exercises, with criticism from instructors and scheduled conferences, give each student an opportunity to improve his capacity for clear, critical writing. Students with insufficient training or other language handicaps are urged to take advantage of small group remedial instruction; for those who are seriously deficient such instruction is required.

*(text continues on page 57)*

**HUMANITIES FIELDS AND SUBJECTS**

**FIRST YEAR<sup>1</sup>**

*One of the following combinations of subjects:*

THE WESTERN TRADITION: THE CLASSICAL HERITAGE (21.011) *and*

THE WESTERN TRADITION: THE EUROPEAN HERITAGE (21.012)

*or*

IDENTITY AND AUTOBIOGRAPHY: THE NINETEENTH CENTURY (21.013) *and*

IDENTITY AND AUTOBIOGRAPHY: THE TWENTIETH CENTURY (21.014)

*or*

CONTEMPORARY MORAL ISSUES (21.015T) *and*

CONTEMPORARY MORAL ISSUES (21.016T)

*or*

CONFLICT AND COMMUNITY IN AMERICA (21.017) *and*

CONFLICT AND COMMUNITY IN AMERICA (21.018)

*or*

REASON AND REVELATION: RELIGIOUS VISIONS IN THE WEST (21.019) *and*

REASON AND REVELATION: RELIGIOUS VISIONS IN THE WEST (21.020)

*or*

THE GREEK TRADITION (23.011)<sup>2</sup> *and*

THE JUDAEO-CHRISTIAN TRADITION (23.021)<sup>2</sup>

*or*

THE WESTERN TRADITION: THE CLASSICAL HERITAGE (21.011) *and*

THE EUROPEAN TRADITION: GOETHE ERA (23.022)<sup>3</sup>

**SECOND YEAR<sup>1</sup>**

*One of the following subjects:*

LITERATURE: FORMS OF A MAJOR THEME (21.03)

LITERATURE: SELF, NATURE AND SOCIETY (21.031)

PHILOSOPHY: CLASSIC AND CONTEMPORARY (21.04)

THE NATURE OF LITERATURE (23.031)<sup>2</sup>

THE NATURE OF LITERATURE (23.032)<sup>3</sup>

*and one of the following subjects:*

SOCIETY AND MAN (17.01)

THE TWENTIETH CENTURY: REVOLUTION AND

TOTALITARIANISM (21.05)

THE TWENTIETH CENTURY: CONSCIOUSNESS IN INDUSTRIAL SOCIETY (21.06)

THE FRENCH ENLIGHTENMENT (23.051)<sup>2</sup>

THE TWENTIETH CENTURY: REVOLUTION, WAR, AND

"TOTALISM" (23.052)<sup>3</sup>

**THIRD AND FOURTH YEARS<sup>1</sup>**

Any one of the following combinations of subjects may be taken without the approval of a humanities advisor. Other combinations are not prohibited but must be specifically approved by a humanities advisor. Subjects indicated by a dagger (†) may be taken as a single subject to satisfy the distributional requirement.

<sup>1</sup> Each subject in the program for the first and second years carries 3-6 units of credit. Each subject in the program for the third and fourth years carries 9 units of credit, unless otherwise specified.

<sup>2</sup> Open only to students having an adequate background in French.

<sup>3</sup> Open only to students having an adequate background in German.

**FIELD ONE: HISTORY**

(For additional and related subjects see the special Interdisciplinary Sequence on p. 57.)

*Any three of the following:*

HISTORY OF ENGINEERING (21.411T)†

HISTORY OF ENGINEERING (21.412T)†

HISTORY OF MATERIALS (21.414T)†

TECHNOLOGY AND ECONOMIC GROWTH (21.415T)†

DEVELOPMENT OF AMERICAN ECONOMIC INSTITUTIONS (21.421T)†

HISTORY OF TRANSPORTATION IN THE UNITED STATES (21.422T)†

THE BUSINESSMAN IN AMERICAN HISTORY (21.424T)†

HISTORY OF TECHNOLOGY IN THE UNITED STATES (21.426T)†

INTRODUCTION TO SOCIAL ANTHROPOLOGY (21.452T)†

NEAR EASTERN ARCHAEOLOGY: THE FOUNDATIONS OF CIVILIZATION (21.454T)†

PEASANT SOCIETY (21.455T)†

ECONOMIC ANTHROPOLOGY (21.456T)†

CULTURES AND SOCIETIES OF MEXICO (21.459T)†

THE EMERGENCE OF MODERN AFRICA (21.463T)

ROME: REALITY AND IDEA (21.473T)†

CULTURE AND SOCIETY IN MEDIEVAL EUROPE (21.475T)†

THE ITALIAN RENAISSANCE (21.476T)†

THE NORTHERN RENAISSANCE AND THE REFORMATION (21.478T)†

SOCIAL CRITICISM IN AMERICA FROM TOCQUEVILLE TO RIESMAN (21.482T)†

DISSENT AND REFORM IN TWENTIETH-CENTURY AMERICA (21.483T)†

THE AMERICAN METROPOLIS (21.484T)

THE BLACK GHETTO (21.485)

SCIENCE AND NATURAL PHILOSOPHY IN CHINESE TRADITION (21.512T)

INTELLECTUAL HISTORY OF MODERN EUROPE (21.515T)†

RUSSIA: ORTHODOXY, AUTOCRACY, AND REBELLION (21.517T)†

ANARCHISM (21.518)

MARX, DARWIN, AND FREUD (21.522T)†

HISTORY AND PSYCHOANALYSIS (21.524T)†

AMERICAN INTELLECTUAL HISTORY (21.531T)†

AMERICAN IDEAS AND INSTITUTIONS (21.532T)†

AMERICAN CONSTITUTIONAL HISTORY (21.533)

THE AMERICAN REVOLUTION (21.541T)

CHINA, JAPAN, AND THE WEST (21.543T)†

FRANCE: THE MODERNIZATION OF A DEVELOPED SOCIETY (21.544T)†

WAR AND THE MILITARY INSTITUTIONS OF THE MODERN STATE (21.545T)†

NATIONALISM AND POLITICS IN CENTRAL EUROPE FROM THE FRENCH REVOLUTION TO THE THIRD REICH (21.547T)†

VIENNA AND VERSAILLES (21.548T)†

NATIONALISM IN AFRICA (21.551J)

THE SOVIET UNION: AN INDUSTRIAL SOCIETY IN HISTORICAL PERSPECTIVE (21.552T)

SPANISH CIVIL WAR, 1936-1939 (21.554T)†

SOVIET-AMERICAN DIPLOMACY (21.556T)†

RECONSTRUCTION OF EUROPE, 1945-1965 (21.558T)†

NINETEENTH CENTURY EUROPEAN LIBERALISM: ITS DECLINE AND TRANSFORMATION (21.574T)†

VARIETIES OF FASCISM: ORIGINS AND COMPARATIVE DEVELOPMENT IN GERMANY AND FRANCE, 1900-1945 (21.576T)†

SCIENCE AND PHILOSOPHY FROM ANTIQUITY TO COPERNICUS (21.701T)†

ORIGINS OF MODERN SCIENTIFIC THOUGHT (21.702T)

(list continued on page 54)

# Undergraduate

## UNDERGRADUATE HUMANITIES PROGRAM

(list continued from page 53)

### FIELD TWO: PHILOSOPHY

(For additional and related subjects see the Special Interdisciplinary sequence on page 57.)

Any three of the following:

HISTORY OF PHILOSOPHY I (21.611T)  
HISTORY OF PHILOSOPHY II (21.612T)  
CLASSICAL PHILOSOPHY (21.613T) †  
PHILOSOPHY OF HISTORY (21.617T) †  
SOCIAL THEORY FROM MARX TO THE PRESENT (21.618T) †  
SYMBOLIC LOGIC (21.641T) †  
ETHICS (21.644T)  
PHENOMENOLOGY (21.645T)  
EXISTENTIALISM (21.646T)  
THEORY OF KNOWLEDGE (21.647T)  
PROBLEMS IN ETHICS (21.652T) †  
NATURE AND JUSTIFICATION OF LIBERTY (21.653T) †  
PHILOSOPHICAL ANTHROPOLOGY (21.668T) †  
PHILOSOPHY OF THE ARTS (21.671T) †  
PHILOSOPHY IN LITERATURE (21.672T) †  
PHILOSOPHIES AND RELIGIONS OF ASIA (21.691T) †  
RELIGIOUS PHILOSOPHY IN THE WEST (21.692T) †  
PHILOSOPHY OF RELIGION (21.693T) †  
SCIENCE AND PHILOSOPHY FROM ANTIQUITY TO COPERNICUS (21.701T) †  
ORIGINS OF MODERN SCIENTIFIC THOUGHT (21.702T)  
PHILOSOPHY OF SCIENCE (21.712T)

### FIELD THREE: LITERATURE

(For additional and related subjects see the Special Interdisciplinary sequence on page 57.)

LITERARY ANALYSIS (21.11T) ††  
plus any two of the following:  
INTRODUCTION TO THE WRITING OF FICTION (21.101T)  
THE WRITING OF FICTION (21.102T) †  
THE WRITING OF POETRY (21.103T) †  
PLAYWRITING (21.104)  
THE WRITING OF PROSE (21.105)  
CRITICISM AND CULTURE (21.122T)  
THE EPIC (21.13T)  
SHAKESPEARE (21.15T)  
SHAKESPEAREAN TRAGEDY (21.151)  
CHAUCER (21.16T)  
LITERATURE OF THE ENGLISH RENAISSANCE (21.17T)  
NARRATIVE FICTION (21.27T)  
UTOPIAN LITERATURE (21.271)  
NARRATIVE AND THE NOVEL (21.272)  
LITERATURE IN THE EMERGENCE OF AMERICAN WORLD POWER (21.274)  
THE SHORT STORY (21.276T)  
DRAMA AND COMMUNITY (21.281T)  
MODERN DRAMA (21.282T)  
COMEDY (21.284T)  
AMERICAN FOLKLORE (21.285T)  
DOSTOEVSKY, TOLSTOI, CHEKHOV: RUSSIA AND THE MODERN AGE (21.29T)  
NON-WESTERN LITERATURE (21.301T)  
CHINESE LITERATURE (21.302T)  
THE CONFESSION IN LITERATURE (21.312T)  
MAJOR AUTHORS: FRIEDRICH NIETZSCHE (21.313T)  
MAJOR AUTHORS: T. S. ELIOT (21.314T)  
STUDIES IN LITERATURE AND NATIONAL VALUES (21.317T)  
SOCIAL VISION IN LITERARY ART: SHAW, LAWRENCE, FAULKNER (21.35T)  
SOURCES OF MODERNISM (21.38T)  
LITERATURE TODAY (21.381T)  
LYRIC AND DISCOURSE (21.385)

LITERATURE AND INTERPERSONAL RELATIONSHIPS (21.386T)  
METAPHOR (21.387)  
THE MODERN GERMAN NOVEL (23.24T) §  
MODERN GERMAN DRAMA (23.26T) §  
DANTE I (23.87T) †  
DANTE II (23.88T) †  
SOVIET RUSSIAN LITERATURE (23.951T) §  
GOGOL AND LITERARY METHODOLOGY IN RUSSIA (23.961T) §  
MAYAKOVSKY AND PASTERNAK (23.981T) §  
TOLSTOI'S "WAR AND PEACE" (23.991T) §  
CONTEMPORARY SOVIET LITERATURE (23.993T) §  
THE RUSSIAN SHORT STORY (23.995)

### FIELD FOUR: FOREIGN LITERATURES

#### Group A — German

ADVANCED GERMAN (23.14) ¶

or

LITERARY ANALYSIS (21.11T) ††

plus any two of the following:

GOETHE'S POETRY (23.15T) †  
GERMAN ROMANTICISM (23.16T) †  
GOETHE'S "FAUST" (23.19T) †  
SEMINAR IN GERMAN POETRY (23.20T)  
MODERN GERMAN DRAMA (23.21T) †  
MODERN GERMAN FICTION (23.22T) †  
THE MODERN GERMAN NOVEL (23.24T) §  
MODERN GERMAN DRAMA (23.26T) §

#### Group B — French

CONVERSATIONAL FRENCH (23.54) ¶

or

LITERARY ANALYSIS (21.11T) ††

plus any two of the following:

CONTEMPORARY FRENCH DRAMA (23.61T)  
FRENCH ROMANTICISM (23.62T)  
FRENCH PROSE FICTION (23.63T) †  
SEMINAR IN FRENCH LITERATURE (23.64T)  
CLASSICAL FRENCH DRAMA (23.65T)  
MODERN FRENCH POETRY (23.66T)

#### Group C — Russian

INTRODUCTION TO RUSSIAN LITERATURE (23.941T) †

or

LITERARY ANALYSIS (21.11T) ††

plus any two of the following:

PUSHKIN AND RUSSIAN ROMANTICISM (23.95T)  
SEMINAR IN MODERN RUSSIAN POETRY (23.96T) †  
SELECTED PROBLEMS IN SOVIET LITERATURE (23.98T) †  
SEMINAR IN RUSSIAN PROSE (23.99T) †

#### Group D — Spanish

INTRODUCTION TO SPANISH LITERATURE (23.41T) †

or

LITERARY ANALYSIS (21.11T) ††

plus any two of the following:

SPANISH DRAMA (23.35T)  
TWENTIETH-CENTURY SPANISH LITERATURE (23.36T)  
MASTERPIECES OF SPANISH LITERATURE (23.42T)

#### Group E — Comparative Literature

DANTE I (23.87T) †

DANTE II (23.88T) †

plus any literature subject

† Students who elect 21.03 or 21.031 or 23.031 or 23.032 in partial fulfillment of their second-year humanities requirement are to take three subjects, in place of two, from the list in Field Three: Literature. If 21.03 or 21.031 or 23.031 or 23.032 are taken, 21.11T may not be taken for credit.

¶ Accepted as one subject in the humanities and social sciences.

§ Readings in English; conducted in English.

(list continues on page 55)

**FIELD FIVE: MUSIC**

MATERIALS OF MUSIC (21.81T)\*  
*and*  
 INTRODUCTION TO MUSIC (21.82T)†  
*plus one of the following:*  
 MUSIC THEORY I (21.821T)  
 MUSIC THEORY II (21.822T)  
 MUSIC THEORY III (21.823T)  
 MUSIC THEORY IV (21.824T)  
 ORCHESTRATION (21.825T)  
 PROBLEMS AND TECHNIQUES OF MUSIC RESEARCH (21.826)  
 MUSICAL FORM AND ANALYSIS (21.827T)  
 WESTERN MUSIC IN THE MIDDLE AGES AND THE RENAISSANCE (21.83T)  
 WESTERN MUSIC IN THE BAROQUE ERA (21.84T)  
 WESTERN MUSIC IN THE CLASSIC ERA (21.85T)  
 WESTERN MUSIC IN THE ROMANTIC ERA (21.86T)  
 TWENTIETH-CENTURY MUSIC (21.871T)  
 TWENTIETH-CENTURY MUSIC: SCHOENBERG, BERG AND WEBERN (21.872T)  
 THE OPERA (21.88T)  
 SEMINAR IN MUSIC (21.891T)  
 SEMINAR IN MUSIC (21.892T)

**FIELD SIX: ECONOMICS**

ECONOMIC PRINCIPLES I (14.01T)†  
*and*  
 ECONOMIC PRINCIPLES II (14.02T)  
*and one of the following:*  
 PRICES AND PRODUCTION (14.03T)  
 ECONOMIC FLUCTUATIONS AND GROWTH (14.05T)  
 INDUSTRIAL ORGANIZATION AND PUBLIC POLICY (14.20T)  
 DISTRIBUTION OF INCOME AND EMPLOYMENT OPPORTUNITY (14.41T)  
 URBAN ECONOMICS (14.51T)  
 ECONOMICS OF THE SOVIET UNION (14.52T)  
 COMPARATIVE ECONOMIC SYSTEMS (14.53T)  
 LABOR ECONOMICS AND PUBLIC POLICY (14.64T)  
 ECONOMIC HISTORY (14.71T)  
 ECONOMIC GROWTH AND DEVELOPMENT (14.74T)

**FIELD SEVEN: POLITICAL SCIENCE**

*Any three of the following subjects:*  
 POWER, INFLUENCE, AND POLICY DECISIONS (17.14T)  
 POLITICAL PSYCHOLOGY (17.15T)  
 THE AMERICAN POLITICAL PROCESS (17.21T)†  
 COMPARATIVE POLITICAL SYSTEMS (17.24T)†  
 STATE AND LOCAL POLITICS (17.25T)  
 THE POLITICS OF NATIONAL ECONOMIC CONTROL (17.26T)  
 BUREAUCRACY (17.27T)  
 POLITICAL PARTIES (17.28T)  
 THE GOVERNANCE OF CAMBRIDGE (17.29T)  
 EVOLUTION OF STRATEGIC NUCLEAR SYSTEMS (17.31T)  
 EVOLUTION OF FORCES FOR LIMITED WAR (17.32T)  
 GOVERNMENT, POLITICS AND TECHNOLOGY (17.42T)  
 INTERNATIONAL RELATIONS (17.51T)†  
 PRINCIPLES AND PROBLEMS OF AMERICAN FOREIGN POLICY (17.52T)  
 SEMINAR IN INTERNATIONAL POLITICS (17.53T)  
 ARMS CONTROL, DISARMAMENT, AND FOREIGN POLICY (17.54T)  
 POLITICAL AND ECONOMIC DEVELOPMENT OF TROPICAL AFRICA (17.61T)  
 SEMINAR: MECHANISMS AND FORMS OF PROTEST (17.63T)  
 POLITICAL SCIENCE SEMINAR (17.64T)  
 NATIONALISM IN AFRICA (17.65J)  
 POLITICAL IDEAS AND INDUSTRIAL SOCIETY (17.66)  
 MATHEMATICAL POLITICS (17.73T)§  
 PREDICTION IN SOCIAL SCIENCE AND PUBLIC POLICY (17.75T)

STRUCTURE OF URBAN LIFE (17.81)  
 SEMINAR IN CONTEMPORARY URBAN SOCIOLOGY (17.82)  
 POLITICS OF URBAN EDUCATION (17.83)  
 THEORY AND PRACTICE OF COMMUNITY ACTION (17.84)

**FIELD EIGHT: LABOR RELATIONS**

**Group A**  
 ECONOMIC PRINCIPLES I (14.01T)†  
*and*  
 LABOR RELATIONS (14.63T)†  
*and*  
 LABOR ECONOMICS AND PUBLIC POLICY (14.64T)  
**Group B**  
 LABOR RELATIONS (14.63T)†  
*and*  
 LABOR ECONOMICS AND PUBLIC POLICY (14.64T)  
*and*  
 DISTRIBUTION OF INCOME AND EMPLOYMENT OPPORTUNITY (14.41T)

**FIELD NINE: PSYCHOLOGY**

INTRODUCTORY PSYCHOLOGY (9.00T)†  
*and any two of the following subjects:*  
 PHYSIOLOGICAL PSYCHOLOGY I (9.01T)  
 PHYSIOLOGICAL PSYCHOLOGY II (9.02T)  
 NEURAL MECHANISMS OF LEARNING AND MOTIVATION (9.03T)  
 COMPARATIVE PSYCHOLOGY (9.30T)  
 PSYCHOLOGY OF PERCEPTION (9.35T)  
 COLOR SCIENCE AND COLOR VISION (9.37)  
 LEARNING (9.40T)  
 PROBLEM SOLVING (9.45T)  
 PSYCHOLOGY OF LANGUAGE AND COMMUNICATION (9.59T)  
 PERSONALITY STRUCTURE AND DEVELOPMENT (9.60T)  
 SOCIAL PSYCHOLOGY (9.70T)  
 BEHAVIOR IN GROUPS (9.80T)  
 SEMINAR IN THE ORIGINS OF BEHAVIOR (9.88T)  
 DEVELOPMENTAL PSYCHOLOGY (9.89T)  
 ADVANCED PSYCHOLOGY SEMINAR (9.92T)

**FIELD TEN: VISUAL ARTS**

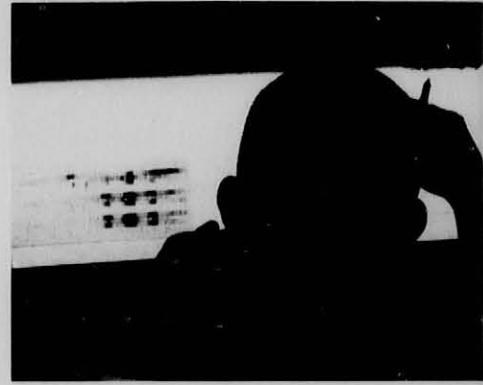
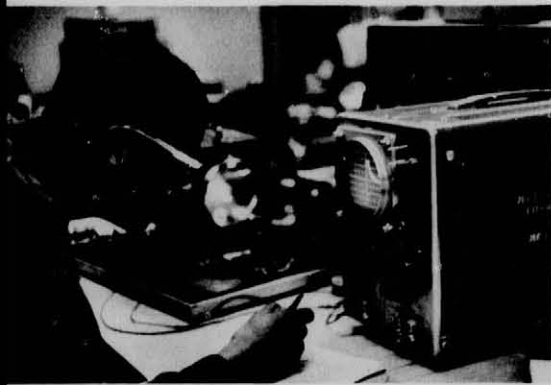
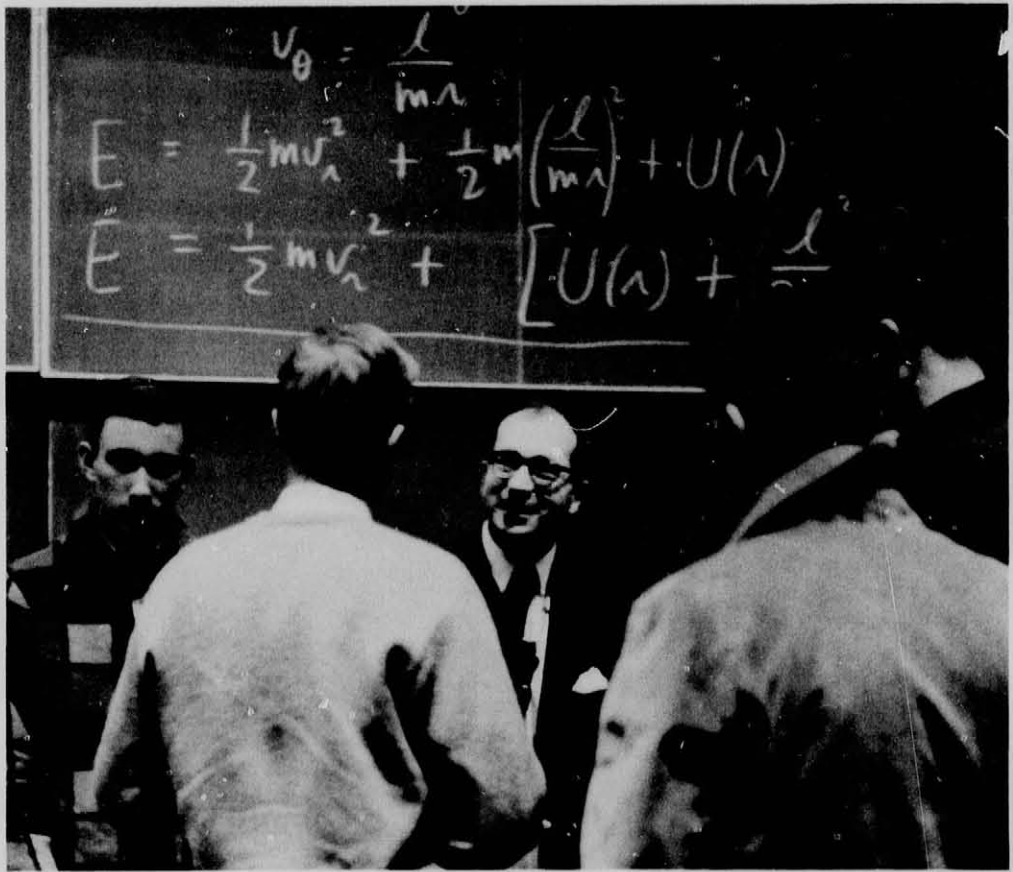
*Three subjects: selections within both groups required*

**Group A**  
 VISUAL DESIGN PROBLEMS I (4.021T)  
 VISUAL DESIGN PROBLEMS II (4.022T)  
 CREATIVE PHOTOGRAPHY I (4.051T)†  
 CREATIVE PHOTOGRAPHY II (4.052T)  
 PAINTING (4.071T)  
 INTRODUCTION TO FILM MAKING (4.091J)  
**Group B**  
 EVALUATING PHOTOGRAPHY (4.053T)  
 TOPICAL STUDIES IN THE HISTORY AND THEORY OF ART (4.601T)†  
 INTRODUCTION TO MODERN ART (4.602T)†  
 PAINTING AND SCULPTURE IN THE MIDDLE OF THE NINETEENTH CENTURY (4.603T)†

\* Students may omit 21.81T if they have adequate background for 21.82T. In this case they should select one additional subject from Field Five.

§ A "time arranged" subject. At least 9 units must be taken to be accepted as one subject in the humanities and social sciences.

*(list continues on page 57)*



MODERN ART FROM POST-IMPRESSIONISM TO CUBISM (4.604T) †  
 PAINTING IN THE TWENTIETH CENTURY (4.605T) †  
 SCULPTURE IN THE TWENTIETH CENTURY (4.606T) †  
 ARCHITECTURE IN THE ANCIENT WORLD (4.61T) †  
 ARCHITECTURE 1400-1750 (4.62T) †  
 ARCHITECTURE IN THE MIDDLE AGES (4.63T) †  
 ARCHITECTURE FROM 1750 TO THE PRESENT (4.64T) †

**SPECIAL INTERDISCIPLINARY SUBJECTS ‡**

SPECIAL TOPICS IN INTERDISCIPLINARY STUDIES (21.901) §  
 SPECIAL TOPICS IN INTERDISCIPLINARY STUDIES (21.902) §  
 ELEMENTS OF URBAN EVOLUTION (21.92J)  
 (Same subject as 4.671J)  
 GREAT CITIES: PARIS (21.93J)  
 (Same subject as 4.672J)  
 POETIC AND SCIENTIFIC DISCOURSE IN CLASSICAL LITERATURE  
 (21.95T)  
 INTRODUCTION TO THE FAR EAST (21.951T) †  
 SEMINAR ON THE AMERICAN UNIVERSITY (21.958)  
 EDUCATION AND SOCIETY (21.959)  
 CONTEMPORARY PHILOSOPHY AND THEOLOGY (21.96T)  
 SEMINAR ON TECHNOLOGY AND SOCIETY (21.961)  
 MORALITY AND THE LAW (21.962)  
 TECHNOLOGY, VALUES AND SOCIAL CHOICE (21.963)  
 RELIGION AND SOCIETY IN AMERICA (21.964T)  
 SEMINAR ON BOSTON (21.965T)  
 SEMINAR IN URBAN EDUCATION (21.967T)  
 SEMINAR IN URBAN EDUCATION (21.968T)  
 BIOLOGICAL BASES OF PERCEPTION AND KNOWLEDGE  
 (21.97T) †  
 ORIGINS OF MODERN AND POST MODERN (21.99T)  
 TRADITION AND INNOVATION IN TWENTIETH-CENTURY  
 PHYSICS (21.992T)  
 INTRODUCTION TO FILM MAKING (21.994J)  
 INTELLECTUALS AND SOCIAL CHANGE (21.995T) †  
 AMERICAN VALUES OF THE 1920's (21.996T)  
 THE CONCEPT OF FREEDOM IN MODERN LITERATURE  
 (21.997T)  
 LITERATURE AND COMMUNICATION (21.998T)

‡ Subjects in this category are additional subjects which may be taken to satisfy the Humanities distribution requirement; but they may also be combined, by petition to the Department of Humanities, with other elective subjects in the above ten fields to satisfy the concentration requirement of three subjects in a single field.

§ A "time arranged" subject. At least 9 units must be taken to be accepted as one subject in the humanities and social sciences.

For students with suitable preparation, special variations of the first- and second-year humanities subjects are conducted in French and German by the Department of Foreign Literatures and Linguistics.

Every undergraduate is required to take a concentration of three humanities or social science subjects in one of ten fields, and a fourth or distributional subject in another field; these subjects are usually taken in the third and fourth years. The fields in which they are grouped are: History, Philosophy, Literature, Foreign Literatures, Music, Economics, Political Science, Labor Relations, Psychology, and Visual Arts. In addition, some special interdisciplinary subjects are available, mainly serving as distributional subjects.

The humanities or social science field is selected on a basis of particular interest, except that students enrolled in Shipping and Shipbuilding Management (Course XIII-B) or Economics (Course XIV) may not select either the Economics or Labor Relations fields; and those in Political Science (Course XVII) may not select the Political Science field. Students in Architecture (Courses IV and IV-B) may not select certain subjects to satisfy the humanities and social science program, as specified under the curricula for these Courses.

The subject offerings are described on the preceding pages. At least some of the work in each concentration must be of higher than elementary level. Although elementary language subjects may not be counted as junior-senior humanities, qualified students are encouraged to build on previous training in modern languages by taking subjects in French, German, or Russian literature.

ECONOMIC PRINCIPLES I (14.01T) is a subject which must be taken by all undergraduates in the School of Architecture and Planning; and in the School of Engineering by those in Civil Engineering (Course I) and Naval Architecture and Marine Engineering (Course XIII). It may be taken either as the distributional subject or as part of an appropriate three-term concentration.

### ***Military Science, Aerospace Studies, and Naval Science***

The general purpose of the Reserve Officers' Training Corps is to qualify students as officers in the active and reserve forces as well as for

# Undergraduate

MILITARY, AIR, AND NAVAL SCIENCE

positions of leadership in civilian pursuits. The Army, Navy, and Air Force each conducts a program at M.I.T. for this purpose.

## THE ARMY R.O.T.C. PROGRAM

Full-time male students may enroll in the R.O.T.C. program. Completion of the four-year program and commissioning are contingent upon meeting published Army standards. Books, uniforms, and equipment required for the program are furnished.

Four years of classroom work and a six-week Advanced Summer Camp qualify students for commissions upon graduation. The curriculum is designed to provide a challenging and academically oriented course of study. Emphasis is placed upon individual development using the lecture, seminar, guest lectures, and programmed instruction.

The Military Science Program consists of two divisions:

1. *Pre-Professional Division.* The first year of the Pre-Professional Division is designed to develop in the student a broad, liberal appreciation of the historical development of military institutions and their interrelationship with society. The first-term subject in World Military History focuses on the causes and conditions of conflicts, the relation of policy objectives to military strategy, and the adaptation of military institutions to social, economic, and technological factors. The second-term subject, offered by the Department of Humanities as 21.545T, concentrates on the interrelationship of civil and military institutions in modern states. No leadership laboratory is required in the first year. General Institute elective credit is awarded for the first term (3-0-4) and Humanities elective credit is awarded for the second term (3-0-6). The second year is designed to provide a conceptual framework of international relations and an analysis of military force structures and strategies. The first term has two subject components, International Relations (3-0-6) and Leadership Development (0-1-0). International Relations is offered by the Department of Political Science as 17.51T and presents an investigation of the comparative instruments of foreign policy and an examination of the decision-making processes. Leadership Development is a laboratory emphasizing organizational and leadership training. The second term is also divided in two components, Concepts of General and Limited War Systems (3-0-5) and Leader-

ship Development. Concepts of General and Limited War Systems analyzes general and limited war systems with emphasis on the technological, strategic, and political factors affecting their employment. Leadership Development is a continuation of the laboratory of the previous term.

2. *Professional Division.* The objective during these two years is to develop the student's understanding and capabilities in the application of the principles and techniques of leadership and management, with emphasis on organizational behavior and the effective and economical employment of men and materiel.

Between the third and fourth years, the student attends a six-week Advanced Summer Camp conducted within a military environment. Reinforcement of classroom instruction is accomplished through the use of practical field training. Major emphasis is given to leadership development by placing the student into leadership positions.

Students receive \$50 per month during their junior and senior years. They are also paid for the summer camp according to the current active duty pay scale. Mileage allowances are paid for travel to and from the summer camp.

Two- and four-year scholarships covering full tuition, fees, and a monthly stipend of \$50 are available on a competitive basis. Details may be obtained by writing to the Professor of Military Science.

Students in the Army R.O.T.C. program must, while completing degree requirements in one of the M.I.T. Courses, take the following required subjects:

### FIRST YEAR

#### *First Term*

MS11T WORLD MILITARY HISTORY (3-0-4)  
(M.I.T. elective credit)

#### *Second Term*

21.545T WAR AND THE MILITARY INSTITUTIONS OF THE MODERN STATE (3-0-6)  
(M.I.T. elective credit)

### SECOND YEAR

#### *First Term*

MS21T LEADERSHIP DEVELOPMENT (0-1-0)  
(No M.I.T. credit)  
17.51T INTERNATIONAL RELATIONS (3-0-6)  
(M.I.T. elective credit)

#### *Second Term*

MS22T CONCEPTS OF GENERAL AND LIMITED WAR SYSTEMS (3-0-5)  
(M.I.T. elective credit)  
MS221 LEADERSHIP DEVELOPMENT (0-1-0)  
(No M.I.T. credit)

**THIRD YEAR****First Term**

MS31T MILITARY TACTICS AND COMMUNICATIONS (2-1-0)  
(No M.I.T. credit)

**Second Term**

MS32T PRINCIPLES OF MILITARY TEACHING AND LEADERSHIP (2-1-0)  
(No M.I.T. credit)

**FOURTH YEAR****First Term**

MS41T PRINCIPLES AND APPLICATION OF MILITARY LAW AND ADMINISTRATION (2-1-0)  
(No M.I.T. credit)

**Second Term**

MS42T PRINCIPLES OF MILITARY MANAGEMENT AND LOGISTICS (2-1-0)  
(No M.I.T. credit)

**Application Procedure**

Application is effected by enrollment in MS11T in the same manner as in other Institute subjects. The student should contact the Department of Military Science if additional information is desired.

**The Two-Year Program**

A two-year program is available to qualified students under certain circumstances. Students may apply during the year preceding the year in which they desire to be enrolled in the two-year program. Selections are based on nationwide competition with initial processing in January of each school year. Details may be obtained from the Department of Military Science.

**THE AIR FORCE R.O.T.C. PROGRAM**

The Air Force R.O.T.C. program is designed to prepare students for commissions in the United States Air Force upon successful completion of an M.I.T. undergraduate Course. The Department of Aerospace Studies offers two programs — one of four years and one of two years — for M.I.T. students to qualify for commissions.

**The Four-Year Program**

The four-year program consists of classroom and corps training work during the four undergraduate years and one summer training period of four weeks, usually between the junior and senior years, at a United States Air Force base.

During the first two years the program acquaints students with the major military forces of the world and develops an understanding of how the United States Air Force serves national interests in the modern context of international relations. Leadership training is also begun. During the last two years, emphasis is placed on personal development. Students increase their ability to communicate their

thoughts to others both orally and in writing by discussing military and aerospace technological advances and current research and development activities. Understanding of people and interpersonal relationships are also stressed. Students increase their leadership ability by assuming positions of responsibility in the Cadet Corps at M.I.T. and in the required summer training.

While in an undergraduate status, Air Force R.O.T.C. students are furnished all text and reference books, uniforms, and equipment required for aerospace study. Under the provisions of the Reserve Officers Training Corps Vitalization Act of 1964, Air Force R.O.T.C. cadets in the four-year program are offered an opportunity to compete, on a nationwide basis, for financial assistance grants. These grants provide full coverage for tuition and laboratory fees plus \$50 monthly for subsistence and an allowance for books. Those students who do not obtain a scholarship will receive \$50 monthly for subsistence during their junior and senior years.

At the beginning of the junior year each student is required to sign a formal agreement that he will complete the Professional Officer Course and accept a commission as a Second Lieutenant in the United States Air Force when he has been granted his degree from M.I.T. Also, at the beginning of the junior year the student is sworn into the Enlisted Reserve of the United States Air Force. The term of active duty commitment after commissioning varies depending upon the professional area chosen. For those entering research and development, engineering, or any other non-flying field, the term of service is four years. If the student is physically qualified and desires to become a pilot or navigator, the required term of service is six years.

Students in the Air Force R.O.T.C. program must, while completing degree requirements in one of the M.I.T. Courses, take the following required subjects in aerospace studies:

**FIRST YEAR****First Term**

AS11T WORLD MILITARY SYSTEMS (3-0-3)

(M.I.T. elective credit)

AS111 CORPS TRAINING (0-1-0)

(No M.I.T. credit)

**Second Term**

AS12T AIRPOWER AND WORLD MILITARY SYSTEMS

(3-0-3)

(M.I.T. elective credit)

AS121 CORPS TRAINING (0-1-0)

(No M.I.T. credit)

# Undergraduate

MILITARY, AIR, AND NAVAL SCIENCE

## SECOND YEAR

### First Term

AS21 AIR FORCE ENVIRONMENT I (0-1-0)  
(No M.I.T. credit)

### Second Term

AS22 AIR FORCE ENVIRONMENT II (0-1-0)  
(No M.I.T. credit)

## THIRD YEAR

### First Term

AS31T SEMINAR IN GROWTH AND DEVELOPMENT OF AEROSPACE POWER (3-0-1)  
(No M.I.T. credit)

AS311 LEADERSHIP PRACTICE (0-1-0)  
(No M.I.T. credit)

### Second Term

AS32T SEMINAR IN SPACE OPERATIONS (3-0-1)

(No M.I.T. credit)  
AS321 LEADERSHIP PRACTICE (0-1-0)  
(No M.I.T. credit)

## FOURTH YEAR

### First Term

AS41T PRINCIPLES OF LEADERSHIP (3-0-6)  
(M.I.T. elective credit)

AS411 MANAGEMENT EXPERIENCES (0-1-0)  
(No M.I.T. credit)

### Second Term

AS42T PRINCIPLES OF MANAGEMENT (3-0-6)  
(M.I.T. elective credit)

AS421 MANAGEMENT EXPERIENCES (0-1-0)  
(No M.I.T. credit)

## The Two-Year Program

The two-year program is for those students who do not complete the first two years (general military education program) of the four-year Air Force R.O.T.C. program. Such students may apply during their sophomore year for acceptance into the two-year program. In lieu of completing the freshman and sophomore years of the four-year program, these men will receive field training in a six-weeks' Officer Training Course conducted on an Air Force base during the summer between the sophomore and junior years. Upon successful completion of the six-week intensive military and academic program, they will return to the campus to be enrolled in the Professional Officer Course. They will receive \$50 a month in subsistence allowance and complete the same academic program required of the upperclass four-year students.

## General Information on Both Programs

Adjustment in the aerospace program will be made to accommodate students enrolling in an honors or cooperative Course. Students who are eligible for and desire graduate training immediately after completing their undergraduate work may:

1. Request a delay in reporting for active duty until completing graduate training.
2. Submit an application to the Air Force Institute of Technology for graduate training at Air Force expense immediately after commissioning.
3. Request an assignment at an educational institution to pursue graduate training under a fellowship grant.

## Eligibility Requirements

To be eligible for the Air Force R.O.T.C. program a student must be:

1. A male citizen of the United States.
2. Physically qualified for commission in the United States Air Force in accordance with existing Air Force regulations.
3. Not under 14 years of age; and upon graduation not more than 30 years of age.
4. Planning to pursue work at M.I.T. leading to at least a Bachelor's degree in any Course offered by the Institute.
5. Willing to sign a formal agreement and enlist in the Air Force Reserve at the beginning of the junior year, which obligates him to remain in the R.O.T.C. program for the two final years, to accept a commission, and to serve the required period in the Air Force upon graduation.

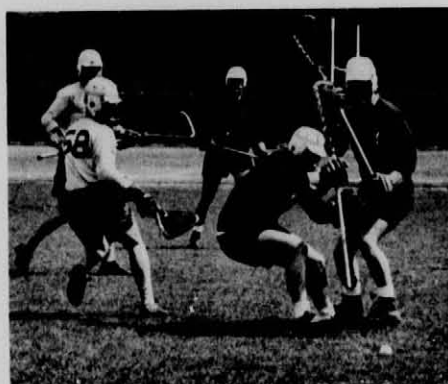
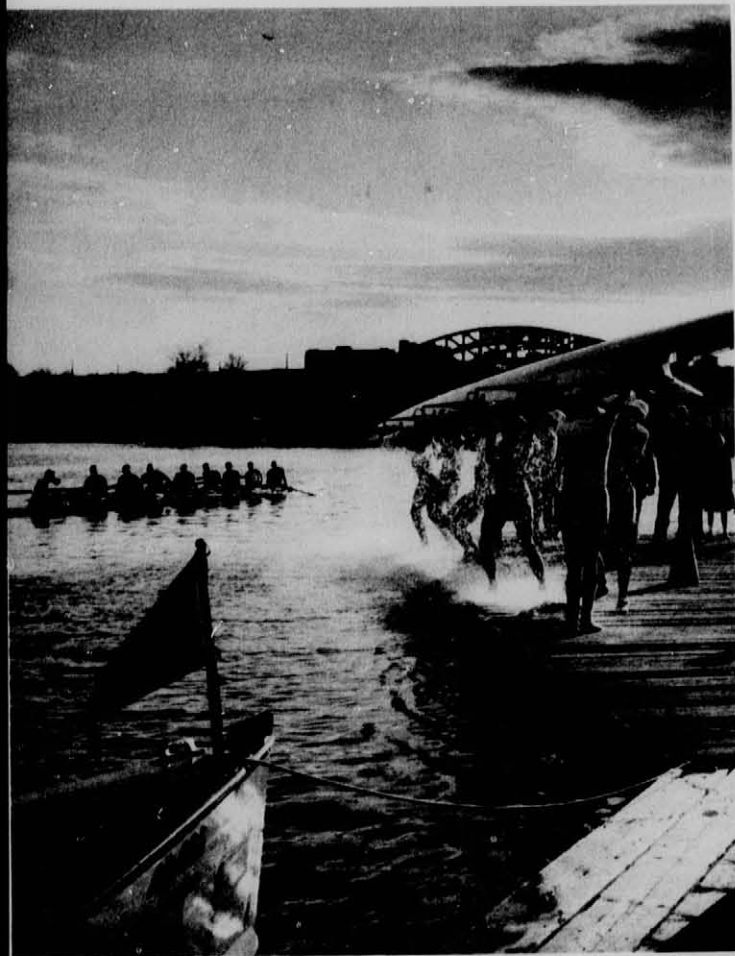
## Application Procedure

Eligible students should apply for admission to the Air Force R.O.T.C. after they have been notified of admission to the Institute. Application should then be made directly to the Professor of Aerospace Studies, either by mail or by personal visit as soon as possible. Further information, including physical standards, will be forwarded upon receipt of an initial application.

## THE NAVAL R.O.T.C. PROGRAM

The purpose of the Naval R.O.T.C. program is to provide instruction and training in essential Naval Science subjects, which, when coupled with the prescribed M.I.T. engineering or science curricula, will qualify selected male students for commissions as Naval Reserve Officers in the restricted line category (engineering duty only).

The M.I.T. Navy unit is the only one of the 54 nation-wide Naval R.O.T.C. programs designed to produce solely "engineering duty only" officers. Graduates of this program may serve their obligatory active duty as engineering officers aboard ship, in naval shipyards, or in other technical assignments. Students may apply for the Navy Nuclear Power Program or for Submarine or Flight Training, or they may request that they be commissioned in the Civil Engineer Corps of the Navy, if qualified. Postgraduate work leading to a Master's degree prior to active duty assignment is allowed



# Undergraduate

MILITARY, AIR, AND NAVAL SCIENCE

when the quality of the student's work and the technical specialty involved warrant. Selected Master of Science candidates can be deferred from active duty to complete work for the doctorate. The work for the advanced degrees need not be taken at M.I.T.

The Naval R.O.T.C. instruction and training consists of three hours of classroom and one hour of laboratory work per week during the freshman and senior years and one hour of lecture per week during the sophomore and junior years. One summer period of six to eight weeks is devoted to practical engineering training at sea aboard a naval ship. This period is scheduled during the summer between the third and fourth academic years.

While in an undergraduate status, the Naval R.O.T.C. student is furnished all necessary text and reference books required for the Naval Science course and all uniforms and uniform equipment, and in addition he receives retainer pay of \$50 per month during his third and fourth academic years. Transportation to and from the port of embarkation for the summer cruise is furnished by the Navy, and the student is paid at the current rate of \$171.10 per month while on the cruise. Upon completion of the program and receipt of a Bachelor of Science degree from M.I.T., the student is commissioned as an Ensign (EDO), U.S. Naval Reserve; he is ordered to active duty in an engineering duty billet either afloat or ashore for a period of three years, unless he plans to attend graduate school, as noted above. At the end of this three-year period he may be released to inactive duty, but he must retain his commission as a Reserve Officer for a total of six years from the date of its original acceptance.

In addition to the standard four-year Naval R.O.T.C. program, the Navy now has a two-year program for which sophomores may apply. Sophomores enrolled in this program attend a six-week summer training session at specified colleges between their sophomore and junior years. This summer training consists of both classroom and laboratory sessions designed to put the student on a level with his fellow Naval R.O.T.C. students at the start of the junior year. The material covered is comparable to the first two years of Naval Science subjects.

Upon completion of summer training and enrollment in the Naval R.O.T.C. program, the two-year student takes the same subjects as the four-year student during his junior and senior

years. He receives all text and reference books required for the Naval Science course and all uniforms and uniform equipment, and receives retainer pay of \$50 per month during his third and fourth academic years. In addition, he must take six weeks practical engineering training at sea aboard a naval ship, normally during the summer between the third and fourth academic years. The active duty and reserve requirements are the same as for the four-year program.

## **Eligibility Requirements**

To be eligible for the four-year Naval R.O.T.C. program, an entering student must be:

1. A male citizen of the United States.
2. At least 17 years of age and not more than 21 years of age by June 30 of the year in which enrolled in the program. The lower age limit may be reduced to 16 years if the student is considered of sufficient maturity to take Naval Science courses.
3. Physically qualified in accordance with the standards for entrance to the United States Naval Academy, except that visual acuity as low as 20-200 correctable to 20-20 by the use of lenses is acceptable. Waivers may be requested for exceptional students.
4. Planning to pursue work at M.I.T. leading to a Bachelor's degree in any Course except the following: Cooperative Courses II-B, VI-A, and XVI-B; Architecture IV; Life Sciences VII; Economics XIV; Political Science XVII; and Humanities and Engineering (or Science) XXI. Students in Architecture, Life Sciences, Economics, Political Science and Humanities will be considered for eligibility provided they complete as part of their elective and science distribution subjects at least eight subjects from the required core curriculum for an S.B. degree in any single department within the Schools of Science and Engineering.
5. Willing to sign a contract with the Navy which obligates the student, after completing the requirements for a commission, to fulfill the following additional requirements: to accept a commission, to serve on active duty for a period of three years subsequent to graduation, and to retain the commission for a period of six years from the date of original acceptance.

To be eligible for the two-year Naval R.O.T.C. program, a student must be:

1. A male citizen of the United States.
2. A sophomore in good standing with not less than a C average.
3. At least 18 years of age upon enrollment and of such age that he will not have reached the 25th anniversary of birth on June 30 of the year in which he will receive a Baccalaureate Degree and complete all requirements for a commission.
4. Physically qualified in accordance with the physical standards prescribed for the four-year Naval R.O.T.C. Program except that visual acuity may be as low as 20/200 correctable to 20/20 with the use of lenses. Waivers may be requested for exceptional students.

5. Planning to pursue work at M.I.T. leading to a Bachelor's degree in any Course except the following: Cooperative Courses II-B, VI-A, and XVI-B; Architecture IV; Life Sciences VII; Economics XIV; Political Science XVII; and Humanities and Engineering (or Science) XXI. Students in Architecture, Life Sciences, Economics, Political Science and Humanities will be considered for eligibility provided they complete as part of their elective and science distribution subjects at least eight subjects from the required core curriculum for an S.B. degree in any single department within the Schools of Science and Engineering.

6. Willing to sign a contract with the Navy which obligates the student, after completing the requirements for a commission, to fulfill the following additional requirements: to accept a commission, to serve on active duty for a period of three years subsequent to graduation, and to retain the commission for a period of six years from the date of original acceptance.

#### **The Four-Year Program**

Students in the Naval R.O.T.C. program must, while completing degree requirements in one of the acceptable Courses, take the following required subjects:

#### **FIRST YEAR**

##### **First Term**

NS11T NAVAL ORGANIZATION AND MANAGEMENT (3-0-6)  
(M.I.T. elective credit)

NS111 NAVAL ORIENTATION AND LEADERSHIP (0-1-0)  
(No M.I.T. credit)

##### **Second Term**

21.545T WAR AND THE MILITARY INSTITUTIONS OF THE MODERN STATE (3-0-6)  
(M.I.T. elective credit)

NS12 ORIENTATION AND SEA POWER (0-1-0)  
(No M.I.T. credit)

#### **SECOND YEAR<sup>1</sup>**

##### **First Term**

NS21 NAVAL GUIDED MISSILES (1-0-0)  
(No M.I.T. credit)

##### **Second Term**

NS22 NAVAL GUIDED MISSILES (1-0-0)  
(No M.I.T. credit)

#### **THIRD YEAR<sup>1</sup>**

##### **First Term**

NS31 NAVAL ENGINEERING (1-0-0)  
(No M.I.T. credit)

##### **Second Term**

NS32 NAVAL ENGINEERING (1-0-0)  
(No M.I.T. credit)

#### **FOURTH YEAR<sup>1</sup>**

##### **First Term**

NS41T NAVAL INDUSTRIAL MANAGEMENT AND LEADERSHIP (3-0-6)  
(M.I.T. elective credit)

NS411 NAVAL ORIENTATION AND LEADERSHIP (0-1-0)  
(No M.I.T. credit)

##### **Second Term**

NS42T NAVAL INDUSTRIAL MANAGEMENT AND LEADERSHIP (3-0-6)  
(M.I.T. elective credit)

NS421 NAVAL ORIENTATION AND LEADERSHIP (0-1-0)  
(No M.I.T. credit)

<sup>1</sup> EVOLUTION OF STRATEGIC NUCLEAR SYSTEMS (17.31T) must be taken as a prerequisite for NS 42T.

#### **Application Procedure**

Eligible students should apply for admission to the Naval R.O.T.C. program as soon as they have been notified of their admission to the Institute. Applications should be made directly to the Commanding Officer of the Naval R.O.T.C. Unit, either by mail or by personal visit by Registration Day or as soon as possible thereafter.

The Naval R.O.T.C. program at M.I.T. is not open to students selected under the nationwide Navy scholarship program known as the Regular N.R.O.T.C. or Holloway Plan. Further inquiries regarding the M.I.T. program should be addressed to the Commanding Officer, N.R.O.T.C. and Naval Administrative Unit, M.I.T.

Sophomores interested in the two-year Naval R.O.T.C. Program must submit applications to the Commanding Officer, N.R.O.T.C. and Naval Administrative Unit, M.I.T., prior to March 5 of their sophomore year.

#### **Selective Service Office**

M.I.T. undergraduates who are subject to Selective Service will find all the necessary information at the Institute's Selective Service Office, Room 7-105. The Graduate School Office, Room 3-140, provides similar assistance to graduate students, described in Section 3 of this Catalogue.

#### **Opportunities for Overseas Study**

Many opportunities exist for M.I.T. undergraduates to experience the stimulation and expanded horizons associated with a "junior year abroad." Through participation in any of the well-organized and well-established programs administered by existing organizations and other colleges, an M.I.T. student has a wide choice of country and program. Although almost any field can be studied abroad, most students find it advisable to plan their total undergraduate programs to emphasize professional work at M.I.T. Thus, the year abroad can become a major experience in another culture by emphasizing the language, literature, history and culture of the host country, for which substantial academic credit is normally granted toward the M.I.T. degree. For science or engineering majors a science course or two can provide the flavor of such work in the foreign scene.

For a mature student with exceptional competence in the language and some previous

# Undergraduate

## COSTS

experience in the culture, an individually arranged independent program may not be too demanding of time and effort, but careful planning is essential.

A junior-year-abroad student maintains official M.I.T. registration as "undergraduate on foreign study" and has thereby maintained his student aid and Selective Service status. Total costs, including travel, have proved to be no more than expenses for a year at the Institute.

Effective working command of the language of instruction is vital. A student without prior study can, by conscientious work in the subjects available here, achieve such command of a Western European language if he begins by the second term of his freshman year. Early planning is obviously important.

Because of important differences in academic practices and levels among foreign universities, there are no general rules for obtaining academic credit for work and study overseas toward M.I.T. degree requirements. However, M.I.T. student experience has been good, especially after careful advance planning with faculty advisors. It is the responsibility of each student to work out with his own department and Faculty Counselor the arrangements for academic credit for work he proposes to undertake overseas.

Professor Harold L. Hazen, Dean Emeritus of the Graduate School, is Foreign Study Advisor, and he is prepared to discuss opportunities with students and to assist them in planning their programs. Students interested in overseas study should consult him as early as possible for help in organizing their objectives and plans of study, selecting their overseas institutions, and preparing in language studies. M.I.T. is cooperating with a number of international student agencies which contribute greatly in the areas of travel, housing, and hospitality.

### **Cooperative Arrangement with Harvard University**

A limited number of M.I.T. undergraduates, usually fourth-year students with excellent academic records, may be permitted to take one or more subjects given at Harvard University for degree credit and at no extra charge. Arrangements to take subjects at Harvard, which must be in areas not covered by regularly offered M.I.T. subjects, are made through the Headquarters of the Department of Humanities.

### **Costs**

M.I.T. is an independent, endowed institution; the 1969-70 tuition of \$2,150 per year paid by each student covers less than half the cost of facilities and teaching. The balance is met by income from endowment and by gifts.

The Institute believes it essential that each student make a detailed estimate of his expenses, including basic costs, variable personal expenses, and needs for transportation. This estimate should be considered carefully in the light of his resources and of the financial aids which may be available to him.

The following list gives an estimate of the average student's basic costs for the academic year 1969-70 at M.I.T.:

Tuition	\$2,150
Board and room	1,270
Books and materials	150
Medical insurance	80
	<hr/>
	\$3,650

In addition to these costs, about \$450 per academic year should be allowed for such expenses as clothes, laundry, and personal necessities. The cost of travel varies with the distance involved, and is not included in the above.

### **Financial Aid for Undergraduates**

The Institute Student Aid Committee provides scholarships, loans, and employment on the basis of the financial need of the individual student, as determined by analysis of the Parents' Confidential Statement of personal finances. This form is submitted through the College Scholarship Service of the College Entrance Examination Board.

Other means of meeting expenses, which are available to all students regardless of need, are described in Section 1 of this Catalogue.

### **SCHOLARSHIPS**

The Student Aid Committee reviews applications and makes awards from the most suitable scholarship resources; *applicants need not request aid from a specific fund.* That portion of an applicant's need which results from travel costs, as fixed by the Committee, will be covered by scholarship funds. Need in addition to travel costs, not met by scholarship, may be offset by long-term loans or term-time employment.

**LOANS**

Loan funds allow the student to pay part of the cost of his education on long-term credit under favorable financial terms. However, loan fund capital is limited, and loans are granted only on the basis of financial need as established by the Parents' Confidential Statement.

Undergraduate loans are provided from a number of sources, including the Institute's own Technology Loan Fund, the National Defense Student Loan Program, and the Federal Government's Guaranteed Loan Programs. Complete details are given in Appendix A.

**EMPLOYMENT**

Students may be offered a choice between a loan and a job of equal dollar value as an incremental portion of their aid. A brief description of available employment opportunities will be found in Section 1 of this Catalogue.

**APPLICATIONS FOR FINANCIAL AID*****Entering Freshmen***

Students who wish to be considered for financial aid should complete and return the Financial Aid Application which is included with the Final Application for Admission. In addition, a Parents' Confidential Statement (P.C.S.) must be submitted to the College Scholarship Service, designating M.I.T. as a recipient. The P.C.S. form may be obtained from a secondary school or from the College Scholarship Service, P.O. Box 176, Princeton, New Jersey 08540, or P.O. Box 1025, Berkeley, California 94701. Both the application form and the P.C.S. must be submitted prior to January 15.

An application for admission is not prejudiced by an application for aid. There is no reason for a person with the ambition to attend M.I.T. to be deterred from applying concurrently for admission and aid.

***Upperclassmen***

Most M.I.T. awards are on an annual basis, and recipients are invited to reapply in December or January each year for continued assistance. Upperclassmen who have not received prior assistance may make application at this time.

Upperclass financial aid application forms are available from the Student Aid Center about December 15. A new Parents' Confidential Statement must be completed, and both forms must be returned to the Student Aid Center no later than February 1.

***Undergraduate Admission to M. I. T.***

The great majority of undergraduate students enter M.I.T. as members of the freshman class, directly following completion of secondary school studies. Each year a limited number of students whose previous studies at other colleges and universities entitle them to advanced standing are accepted for entrance.

First-year students may enter only at the beginning of the first term, which is the Monday prior to the last Monday in September.

**ADMISSION FROM SECONDARY SCHOOLS**

The size of the first-year class is limited. The Committee on Admissions will give preference to applicants whose evidence of academic fitness and of professional promise indicates that they are particularly qualified to pursue Institute Courses with success. It is the desire of the Faculty to admit only those candidates who possess qualities of character and intellect which indicate their adaptability to an academic environment and who show promise of development into useful and forceful citizens.

***Academic Preparation***

Most good public, parochial, and independent secondary schools in the United States and equivalent schools in other countries will provide suitable preparation for the student who takes full advantage of the opportunities which such schools afford.

Students should bear in mind that the wider their intellectual development and the more extensive their attainments, the greater will be the advantages they may expect to gain from study at the Institute. The preparatory course in high school should be a broad one, not confined to technical subjects.

Attention is called particularly to the necessity for thorough preparation in English and mathematics. An applicant's training in English should enable him to read with intelligence and sensitivity and to express his ideas clearly in oral and written form. In mathematics, emphasis should be on thorough mastery of fundamental principles, operations, and definitions rather than on covering a wide range of topics.

Each applicant is required to have completed the following specific preparatory subjects; the figures in parentheses represent the usual "unit" rating, a unit being a full year's study in a

# Undergraduate

## UNDERGRADUATE ADMISSION

secondary school subject taken four or five times a week:

- English (4)
- Algebra (2)
- Plane Geometry (1)
- Physics (1)
- Chemistry (1)
- Trigonometry ( $\frac{1}{2}$ )

In some states, algebra is completed in  $1\frac{1}{2}$  years; this will satisfy the algebra requirement for candidates from those states. The plane geometry requirement may be met either by a course of the traditional type or by a one-year course which is mainly devoted to plane geometry but which includes some work in analytic geometry, solid geometry, or other fields, as suggested by the Commission on Mathematics of the College Entrance Examination Board. For courses which go beyond the minimum, work in elementary functions, advanced algebra, and such topics as probability and logic is recommended.

In addition to the subjects specifically required, the applicant normally will have completed at least 6 additional units in secondary school studies; no limitations are imposed in the choice of these elective subjects. In the selection of the entering class the Committee will be guided by the quality of the applicant's work and by his apparent promise on grounds of intellect and character, rather than by his choice of electives.

It is recommended that the elective subjects include one or more years' study of history.

While there is no language requirement for admission, the study of modern foreign languages in secondary school is obviously desirable and is recommended. The choice of languages should be guided by the educational opportunities open to each student and by the nature of his probable future work.

A student who has ties with a particular foreign country, or who expects to develop such ties, might well study the language of that country. Those who look forward to advanced work in research or design in a scientific or engineering field will almost certainly need a knowledge of German, Russian, or French, since there is an extensive and important technical literature in each of these languages.

In unusual cases, students of exceptional promise may be considered for admission without having fulfilled all of the stated requirements.

### *Application Procedure*

Upon initial inquiry, applicants will receive information about M.I.T. as well as about the application procedure. At the same time they will receive a Request for Application Material form which may be filed as early as desired in advance of the anticipated date of entrance. Filing of this form will assure that the applicant will receive Final Application forms at the proper time (in the fall preceding the desired date of entrance), any announcements which may be issued, as well as information about a personal conference (as noted below).

Candidates should complete the Final Application and submit it with a non-returnable fee of \$10 (required only of students who are citizens of or resident in the United States and Canada). Application and fee are due by January 15 of the year of intended entrance.

### *Interviews (Conferences)*

Each applicant for admission to the freshman class is expected, if possible, to have a personal conference either in the Admissions Office or with a designated member of the M.I.T. Educational Council near his home. Council members are alumni who have been selected for their ability to represent M.I.T. and for their interest in and liking for young people. They welcome the opportunity to meet students interested in M.I.T. and to help them in their educational plans.

Each applicant will be referred for a personal conference to a member of the Council at the time of receipt of his Request for Application Material in the Admissions Office. This personal conference is an essential part of the final application and should take place prior to January 15 of the year of entrance.

Counselors are glad to speak with applicants at any time for general information and counseling purposes. If an applicant sees a counselor before the spring of his junior year, he should have another conference with him after May 1 of that year.

Prospective applicants and their families are welcome at the Admissions Office Monday through Friday between 9 and 5; it is not necessary to make an appointment. Visitors may wish to plan their time to include a student-guided tour of the campus, available at 10 and 2 o'clock each day that the Admissions Office is open.

### **Entrance Examinations**

All candidates are required to take the following tests given by the College Entrance Examination Board: the Scholastic Aptitude Tests and three one-hour achievement tests; (1) Level I Mathematics *or* Level II Mathematics, (2) Physics *or* Chemistry, (3) English Composition *or* American History and Social Studies *or* European History and World Cultures.

The Board offers these examinations in the principal cities of the United States and abroad. The test dates, locations, and fees for the current year are outlined in an Information Bulletin which may be obtained by writing directly to the College Entrance Examination Board, Box 592, Princeton, New Jersey 08540. (Residents of western North America, Mexico, Australia, Pacific Islands, Japan, and Formosa should apply to the College Entrance Examination Board, Box 1025, Berkeley, California 94701.)

Candidates should plan to complete the required series of tests not later than the January test date of their senior year, but may choose any date they wish or divide the tests among two or more dates in the same or in different years. A student taking physics or chemistry in his junior or 11th-grade year should probably take the achievement test in that subject, along with the Scholastic Aptitude Test, in May or July of that year. The Board should be requested to send the scores directly to the Institute.

Candidates who complete the tests in January and have submitted all other required material will be notified about admission to M.I.T. early in April.

### **Early Decisions on Applications**

M.I.T. requires a complete set of application materials before considering a candidate for admission; there is no "early decision" plan in the usual sense. The Institute believes the freshman class is selected with most fairness to the candidates by comparing them with each other on the basis of their records through the first half of their senior year. However, if a student takes all the required College Board tests before the senior year and files all of the application material by November 1 of the senior year, he may request the Committee on Admissions to review his application by December 1. If his test scores, school grades through the junior year, and other qualifications are so excellent that he will clearly be acceptable later, the Com-

mittee will offer him admission immediately; if it feels that it should compare his application with those of other candidates, it will hold his application until the usual time. A student who seeks early consideration in this way is free to file applications at other colleges and, if offered admission at M.I.T., is not required to reply to the Institute before the colleges' common reply date, May 1 in 1970. A student interested in his academic standing relative to M.I.T.'s standards should consult the published M.I.T. Report to Secondary Schools, available in the guidance office at his school or through the M.I.T. Admissions Office.

### **Advanced Placement**

M.I.T. has always encouraged students to move ahead academically according to their capabilities; it offers three procedures by which students entering from secondary school may go directly into a subject at an advanced level: by the College Entrance Examination Board Advanced Placement Program; by college transcript; by Advanced Standing Examination at M.I.T.

Qualified juniors and seniors who take college-level subjects offered in their schools in cooperation with the College Entrance Examination Board Advanced Placement Program should take the appropriate three-hour examinations administered by the Board each year in May and instruct the Board to send the scores, test papers, and reports from the school to M.I.T. Degree credit for M.I.T. subjects, and, where appropriate, advanced placement, is given on the basis of a high achievement in the tests. The student is notified before registration of the credit (and, if appropriate, placement) offered so that he may discuss with his Faculty Advisor an optimum schedule.

In some secondary schools, selected students take college-level subjects directly under the auspices of the faculty of a local college. Such students may submit an official transcript from the college showing subjects taken and grades earned in order to receive M.I.T. credit under the regular college transfer procedures.

Students whose advanced study does not follow either of these patterns and who are interested in being considered for M.I.T. degree credit at entrance should write to the Director of Advanced Placement at M.I.T. before August 1 about their studies and should request information about the Advanced Standing Examinations at M.I.T.

# Undergraduate

## UNDERGRADUATE ADMISSION

A special leaflet concerning Advanced Placement and Degree Credit at M.I.T. is available upon request.

### FOREIGN STUDENTS

The M.I.T. undergraduate student body includes a significant number of students from foreign nations. These students normally join the freshman class after completing secondary school at the highest level. Students from British Commonwealth countries should reach the Higher School Certificate Level or the G.C.E. "A" Level in three subjects, two of which should be in physics and mathematics.

#### *Foreign Residents of the U.S. or Canada*

Foreign citizens applying for undergraduate entrance from secondary schools in the United States or Canada must have completed their applications, including College Entrance Examination Board tests, by January 15. They will be expected to have filled the requirements listed in the preceding section.

#### *Application Procedure for Other Foreign Students*

Students should write to the Admissions Office for application materials in September or October of their final year in secondary school. The materials include an application form, teachers' evaluations and a school report form. Applications must be completed, including College Board examinations, by March 1.

#### *Interviews*

Applicants may be asked to arrange an interview with a local M.I.T. alumnus or representative of the Institute for International Education.

#### *Examinations*

Applicants are required to take three one-hour achievement tests given by the College Entrance Examination Board in major cities of most nations. The tests should be taken in May, July, December or January. M.I.T. requires the Physics, Chemistry and Level I or Level II Mathematics achievement tests. The English Composition test is required for students whose first language is English and may be substituted by any applicant for either (but not both) the Physics or Chemistry test. See the preceding section on Entrance Examinations for details about requesting a test information bulletin and registration form.

Applicants whose first language is not English, or whose schooling has not been predomi-

nantly in English, must take the Test of English as a Foreign Language (TOEFL). A TOEFL information bulletin and registration form can be obtained by writing the Educational Testing Service, Box 899, Princeton, New Jersey.

#### *Financial Aid*

M.I.T. has small amounts of scholarship and loan funds which are made available to exceptionally well-qualified foreign students who can demonstrate financial need. Students who wish to be considered for financial aid should so indicate in their letter requesting final application material for admission. Because our financial aid funds are quite limited, students should seek aid from sources other than M.I.T. Students applying for financial aid must submit the completed application forms for admission and financial aid by February 15.

Foreign students should make all arrangements for their financial obligations to M.I.T. and for their entire stay in the United States before leaving their countries. For details regarding expenses at M.I.T., please refer to the preceding section on Costs.

Application material and further information about the admission of foreign students is available from the Advisor to Foreign Students, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, U.S.A.

### COLLEGE TRANSFERS

Students who have completed two or more semesters with high standing at a recognized college, university, engineering school, or junior college and who are entitled to honorable dismissal may be admitted to M.I.T. by transfer.

Applications from students in their first year in college will normally be considered only after the college record for the entire year becomes available.

#### *Selection of Students*

Transfer students' eligibility for admission will be determined by the Committee on Admissions after a review of their records. They will be expected in every case to have completed the academic preparation required of students entering the Institute from secondary schools.

Such applicants should take the test program prescribed above for entering freshmen. The tests may be waived by the Committee on Admissions for applicants who have completed a substantial amount of college-level work in mathematics and science.

**Advanced Credit**

Students admitted by transfer may expect to receive credit for subjects of study completed elsewhere which are substantially equivalent to corresponding Institute subjects. A grade above the lowest passing grade is necessary.

Students whose records appear not to warrant credit in a subject may be permitted to demonstrate, by passing an Advanced Standing Examination, that they are entitled to such credit.

A student in another college contemplating later transfer should plan his program of study to cover the basic subjects of the Course he expects to enter, paying particular attention to mathematics and physics.

Applicants admitted with advanced standing in architecture will be placed in the DESIGN sequence in accordance with their performance in their first problem.

All remaining questions about credits must be settled within two weeks after the opening of the academic year. In these cases, the student should consult the Director of Admissions.

**Application Procedure**

College students considering transfer to the Institute should file a Preliminary Application for Admission with Advanced Standing on a form obtainable from the Admissions Office. The Director of Admissions will advise the applicant of those parts of the regular entrance requirements which he must fulfill and will arrange for the final application material to be sent.

The applicant should then submit the following to the Director of Admissions:

1. A completed Application for Admission with Advanced Standing, indicating all subjects which he will have completed at the time of transfer, and a non-returnable fee of \$10.
2. A certified transcript of his college record to date, including a statement of good standing. A certified statement covering subjects subsequently taken should be sent as soon as it is available.
3. Catalogue pages describing all subjects which will have been completed; the applicant's name should be written on each page and each subject indicated by a check mark in the margin. Complete catalogues should not be sent.
4. Three evaluation reports, including two from faculty instructors and one from the Dean of Students or the applicant's chief faculty advisor. These forms should be sent directly to the Director of Admissions by the endorsers.

As soon as the applicant's status is determined, he will be informed of whether or not he is admitted and how much advanced credit he will be granted. In some cases action may be deferred until final grades are available.

Transfer applicants seeking financial aid should submit applications for aid and Parents' Confidential Statements not later than April 15.

**The Two-Degree Plan**

A number of liberal arts colleges grant their Bachelor's degree to students who have attended for three years and who have then gone on to qualify for a Bachelor's degree in engineering, management, or architecture at M.I.T. or a similar institution. A student who plans his three college years carefully to include the requisite mathematics and science, as well as humanities and social science, can usually obtain the Bachelor of Science degree at M.I.T. in two additional years.

Students interested in this plan should communicate with the college they wish to attend first and secure admission there. Later acceptance at M.I.T. will depend, as with all transfer applicants, on the quality of the college record.

**Foreign Transfers**

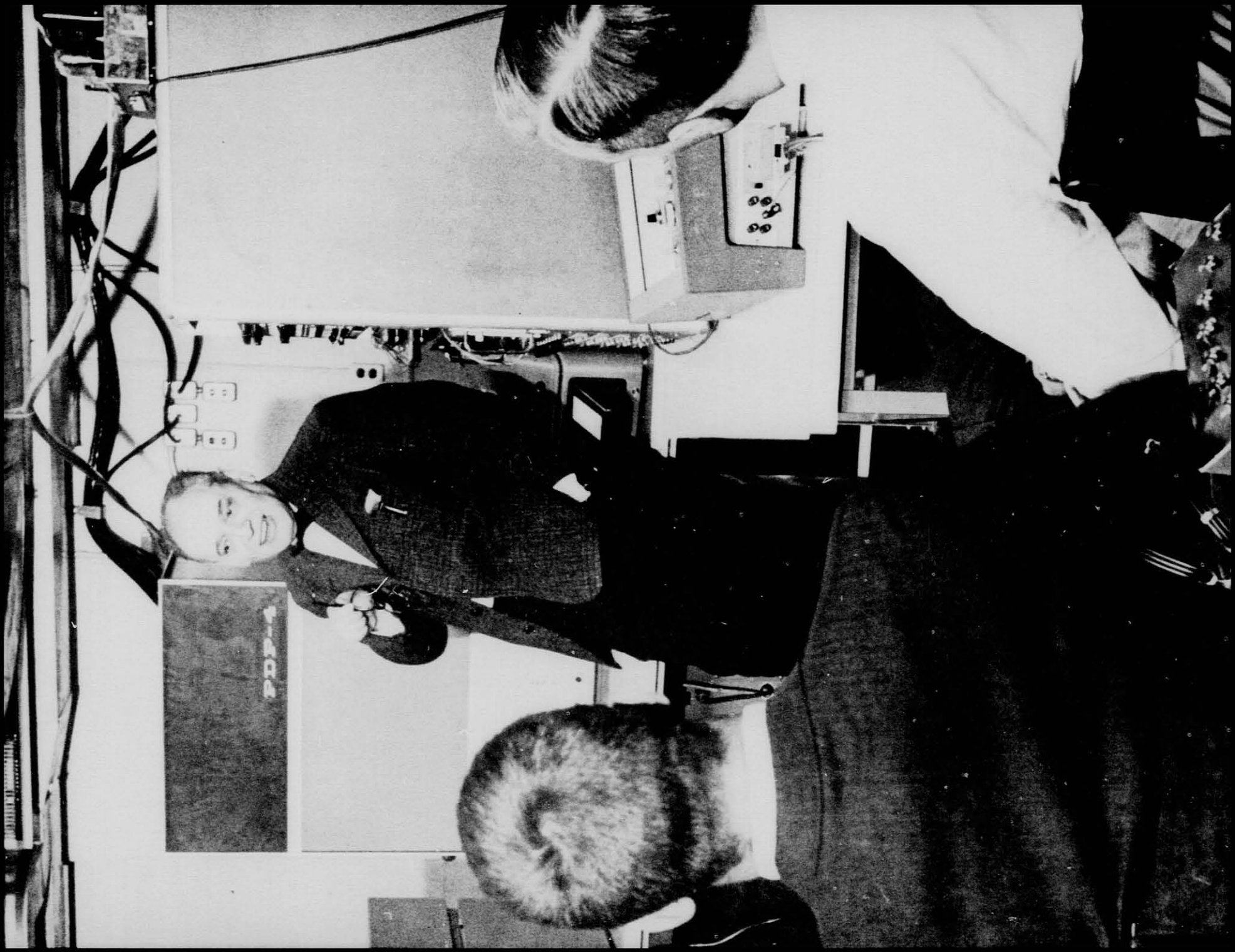
Foreign students applying for admission with advanced standing should refer to the preceding section on College Transfers, noting that they may be required to take part or all of the test program. The tests will be waived by the Committee on Admissions for candidates who are enrolled in programs which have substantial amounts of advanced college work in physics, chemistry, and mathematics.

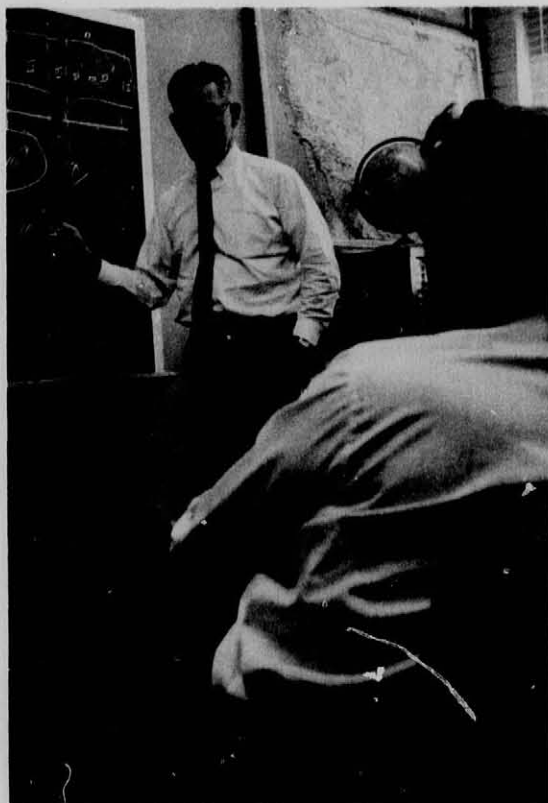
The usual \$10 application fee is not required of foreign students, except those studying or living in the United States or Canada.

**SPECIAL STUDENTS**

A limited number of undergraduates who wish to carry on special studies and who are not degree candidates may enroll as Special Students. The Admissions Office will act on the application after seeking approval of the individual instructors if there is doubt about the applicant's ability to take the particular subjects for which application has been made or if there is a question of space in these subjects. Applicants must present academic credentials of high quality or evidence of professional experience which justifies undertaking the program planned.

The admission of Special Graduate Students is described in Section 3 of this Catalogue.





Study and research for advanced degrees have held a prominent place at M.I.T. for more than 60 years.

The Graduate School seeks to promote the best environment for advanced study and for intimate association among creative workers, both faculty and students, as a community of scholars, and to extend the boundaries of knowledge in their fields of study.

Through the Graduate School the departments collaborate to establish over-all requirements for admission, for character and quality of programs, and for degrees. Each student's program is guided by a department and its faculty in accord with these over-all standards.

Of first importance to any graduate school is the quality and productivity of its faculty. Faculty strength is needed over a wide range of fields to serve varied student interests. National, indeed international, recognition as a productive scholar and authority in his field is normally expected of each faculty member. Satisfaction in his work and in his association with students characterizes the effective teacher. M.I.T. is proud of its Faculty as judged by these criteria.

An outstanding characteristic, indeed a major asset, of graduate education at M.I.T. is the atmosphere of intellectual independence and individual creativity combined with a strong sense of group unity and cooperation.

Our primary aim is to develop in each student the realization that his intellectual growth and his subsequent success are directly related to the depth of his command of basic principles. Although graduate study is often popularly associated only with a high degree of specialization, M.I.T. believes that such specialization, while valuable, is secondary to extending intellectual and humanistic horizons, producing new orientations, and developing growth in intellectual courage and in depth of understanding and social responsibility. Achieving mastery of basic principles develops the mind as no mere acquisition of specialized knowledge can; it provides the power to attack unsolved problems with success and to explore new areas of knowledge with confidence.

Successful graduate study is also closely associated with the ability to organize and express

# Graduate

## RESOURCES FOR GRADUATE STUDY

important ideas in clear and simple terms. Thus graduate students find assignments as teaching assistants rewarding and stimulating as an integral part of their graduate education. These and similar positions as research assistants offer the student professional assignments with an approach to financial self-sufficiency. At M.I.T., graduate students are in a very real sense junior partners of the Faculty in study, in teaching, and in pioneering research. They have the responsibilities of mature students and independent professional workers.

For almost 50 years the Institute has consistently awarded the largest number of Master's and doctor's degrees in engineering in the nation, and in recent years M.I.T. has ranked at or very near the top in doctoral output in the physical sciences and mathematics. In addition, more recent programs in the life sciences, social sciences and humanities, architecture and city planning, and management have now assumed an integral role in the Graduate School of the Institute. Enrollment of Regular Graduate Students now stands at about 3,300. About 1,200 students enter the Graduate School each year, more than 900 of them coming to M.I.T. with baccalaureate degrees from about 200 other American colleges and universities. Some 70 foreign countries and more than 100 foreign universities are typically represented among the 800 foreign students enrolled in the Graduate School.



### *Resources for Graduate Study*

Extensive resources for graduate study have developed naturally at M.I.T. from a long tradition of emphasis on contributions to new knowledge in fields of the Institute's interest. M.I.T.'s high productivity of advanced degrees is the result of these pioneering interests of its Faculty that have generated both demand and support for advanced research. The wealth and diversity of teaching and research resources, described in this Catalogue, particularly by the individual departments in their respective sections, are a direct result. Graduate students — and, in appreciable numbers, undergraduate students — have central roles in all of the Institute's wide-ranging research activities; this participation is vital to the educational experience of both students and faculty and to the success of the research itself.



Interdisciplinary developments are especially vigorous and seminal. For example, in the Research Laboratory of Electronics graduate students and faculty from 12 departments, ranging from physics and life sciences to modern languages and economics, find an effective and congenial environment for their creative work. The rapidly evolving and productive interaction between science and engineering in the field of materials has generated both a standing interdepartmental committee for the guidance of doctoral work and a large interdisciplinary Center for Materials Science and Engineering. The new Urban Systems Laboratory relates to many graduate departments. These and other interdepartmental teaching and research groups are described in Section 1.



Although most graduate students find their interests served by programs available within a single department, some elect to work in interdisciplinary fields which reach into two or more departments. In general, each graduate student's program can be designed to fulfill his own particular interests, subject to the general requirement that the field thus defined has scope and depth appropriate for an advanced degree regardless of whether or not its boundaries happen to fall within the scope of a single department. Most important, the faculty tend to regard departmental organization more as an administrative convenience than as a limit to the bounds of their scholarly interests.

The M.I.T. Libraries, described in detail in Section 1 of this Catalogue, provide a major resource for graduate study. They serve New England as a depository for unclassified reports of the Department of Defense, the Atomic Energy Commission, the National Aeronautics and Space Administration, and the Rand Corporation. The collections are notably strong in U.S.S.R. science and technology.



Another significant resource for graduate study is the cooperative cross-registration privilege with Harvard University, used comparably by graduate students of both institutions.

While the graduate student tends normally toward intensive preoccupation with his professional field, M.I.T. encourages breadth of experience as well. Leaders in many areas of knowledge give lectures and seminars on the campus, and in general these are open to all members of the Institute community.

The cultural and social life and recreational facilities of the M.I.T. campus, described in

# Graduate

## GRADUATE STUDENT ACTIVITIES

Section 1 of this Catalogue under the headings The Campus, Campus Activities, and Student Housing, are shared alike by undergraduate and graduate students. Concerts and dramatic performances are frequent on the campus, given by both Institute groups and professional performers; and Greater Boston is an outstanding cultural and intellectual center. Many graduate students take advantage of these exceptional opportunities for extending interests to new fields.

Graduate students are encouraged to use all of M.I.T.'s extensive athletic facilities; a number of informal teams composed of both undergraduate and graduate students schedule intercollegiate competitions, and graduate student entries are frequently successful in the intramural athletic program. The Nautical Association also welcomes graduate students.

Ashdown House for single men and women and Eastgate and Westgate apartments for married students, all described in Section 1 of this Catalogue, provide comfortable living accommodations, while Ashdown House and Walker Memorial also serve as centers for graduate student social life. A member of the Faculty serves as Master of Ashdown House, presiding informally over its activities.

### ***Graduate Student Activities and Organizations***

All graduate students at the Institute are included in the Graduate Student Organization. Its executive body is an elected Council, whose membership includes representatives of all Courses, of Ashdown House, of women graduate students, of foreign students and of off-campus graduate residents. The Organization is concerned primarily with the general welfare of the graduate student body; encouraging social, athletic, cultural and other extracurricular activities; promoting closer relations between graduate students and faculty outside formal academic exercises; and giving voice to ideas and suggestions of graduate students. The Graduate Student Council sends two students to represent the Organization on the Committee on Graduate School Policy, the faculty committee responsible for the administration of the Graduate School.

Ashdown House residents have an Ashdown House Student Organization, which functions

autonomously and in a similar way through its Executive Committee.

### ***Organization of the Graduate School***

The administration of the Graduate School rests with the President and the Provost of the Institute; the Dean, Associate Dean, and Executive Officer of the Graduate School; and the Committee on Graduate School Policy, comprised of a faculty member from each department offering graduate degrees. The Institute Faculty is the same for undergraduate and graduate instruction.

Each department exercises a large measure of responsibility for its graduate program under a policy established for the Institute as a whole. Under the general responsibility of the Department Head, each department has a departmental Committee on Graduate Students, which, with one or more Graduate Registration Officers, administers departmental graduate activities. The Graduate Registration Officer advises and assists individual students in all aspects of their graduate work. The membership of the Committee on Graduate School Policy is listed with that of other faculty committees at the back of this Catalogue.

Because this catalogue statement is necessarily abridged, the *definitive* statement of organization, policies, and procedures of the Graduate School is given in the *Graduate School Manual*, a copy of which is sent with the registration material to each new graduate student. (Copies are also available from the Graduate School Office and from departmental Graduate Registration Officers.) Each graduate student is expected to be familiar with this manual in order that he may know his privileges and his obligations and be familiar with operations of the School.

### **DEGREES**

Graduate students may pursue work leading to any of the following degrees:

Doctor of Philosophy, **PH.D.**

Doctor of Science, **SC.D.**

Engineer Degrees (see page 82)

Master of Science, **S.M.**

Master in Architecture, **M.ARCH.**

Master in City Planning, **M.C.P.**

Bachelor in Architecture, **B.ARCH.**

**FIELDS OF STUDY**

The major fields for graduate study are listed below. Each graduate program is described by the department concerned, in its statement on graduate education given later in this Catalogue, and these statements should be consulted for more definite information.

**School of Architecture and Planning**

Department of Architecture  
ARCHITECTURE, Course IV

Department of Urban Studies and Planning  
CITY AND REGIONAL PLANNING, Course XI

**School of Engineering**

Department of Aeronautics and Astronautics  
AERONAUTICS AND ASTRONAUTICS, Course XVI  
Aerodynamics and gas dynamics  
Aeroelasticity  
Aeronautical and astronautical engineering  
Flight transportation  
Fluid mechanics  
Instrumentation  
Instrumentation and automatic control  
Materials engineering  
Physics of fluids  
Plasma physics and space sciences  
Propulsion  
Space mechanics  
Structures  
Vehicle design

Department of Chemical Engineering  
CHEMICAL ENGINEERING, Course X  
Applied chemistry  
Biochemical engineering  
Biomedical engineering  
Catalysis and reactor engineering  
Engineering operations  
Fuel engineering  
Materials  
Materials engineering  
Polymers and plastics  
CHEMICAL ENGINEERING PRACTICE, Course X-A

Department of Civil Engineering  
CIVIL ENGINEERING, Course I  
Applied earth science  
Civil engineering  
Civil engineering systems  
Construction and operations  
Hydrodynamics  
Materials  
Materials engineering  
Ocean engineering  
Operations research  
Planning and design  
Soil mechanics  
Structural mechanics  
Structures  
Transportation  
Urban engineering  
Urban systems analysis  
Water resources

Department of Electrical Engineering  
ELECTRICAL ENGINEERING, Course VI

Communications  
Communications bio-engineering  
Computer science  
Control engineering  
Electrical engineering  
Electrical science and engineering  
Electromagnetic theory  
Electronics  
Energy processing  
Materials engineering  
Operations research  
Quantum electronics  
Solid-state electronics  
Systems science

Department of Mechanical Engineering  
MECHANICAL ENGINEERING, Course II  
Materials engineering  
Mechanical engineering

Department of Metallurgy and Materials Science  
METALLURGY AND MATERIALS SCIENCE, Course III  
Ceramics  
Materials science  
Metallurgy

Department of Naval Architecture and Marine Engineering  
NAVAL ARCHITECTURE AND MARINE ENGINEERING, Course XIII  
Acoustics  
Hydrodynamics  
Naval engineering  
Ocean engineering  
Operations research  
Ship propulsion  
Ship systems analysis  
Structural mechanics  
NAVAL CONSTRUCTION AND ENGINEERING (USN and USCG), Course XIII-A  
SHIPPING AND SHIPBUILDING MANAGEMENT, Course XIII-B

Department of Nuclear Engineering  
NUCLEAR ENGINEERING, Course XXII  
Applied plasma physics  
Fission technology

**School of Humanities and Social Science**

Department of Economics  
ECONOMICS, Course XIV

Department of Humanities  
HUMANITIES, Course XXI  
Philosophy

Department of Foreign Literatures and Linguistics  
LINGUISTICS, Course XXIII  
Linguistics

Department of Political Science  
POLITICAL SCIENCE, Course XVII

Department of Psychology  
PSYCHOLOGY, Course IX  
General experimental psychology  
Physiological psychology  
Social-developmental psychology

**Alfred P. Sloan School of Management**  
MANAGEMENT, Course XV

# Graduate

## FIELDS OF GRADUATE STUDY

### *School of Science*

Department of Biology  
BIOLOGY, Course VII  
Biochemistry  
Biophysics  
Cell biology  
Microbiology  
Physiology

Department of Chemistry  
CHEMISTRY, Course V  
Analytical chemistry  
Biophysical chemistry  
Chemical physics  
Geological chemistry  
Inorganic chemistry  
Nuclear chemistry  
Organic chemistry  
Physical chemistry

Department of Earth and Planetary Sciences  
EARTH AND PLANETARY SCIENCES, Course XII  
Geochemistry  
Geology (classical geology, theoretical geology)  
Geophysics  
Oceanography  
Oceanography (Joint Program with Woods Hole  
Oceanographic Institution)  
Planetary Sciences

Department of Mathematics  
MATHEMATICS, Course XVIII

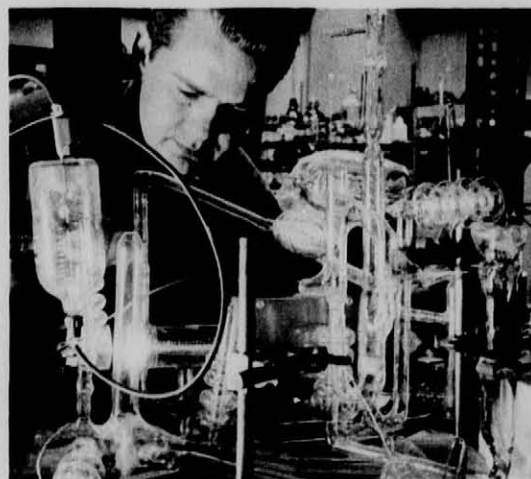
Department of Meteorology  
METEOROLOGY, Course XIX  
Oceanography  
Oceanography (Joint Program with Woods Hole  
Oceanographic Institution)

Department of Nutrition and Food Science  
NUTRITION AND FOOD SCIENCE, Course XX  
Biochemical engineering  
Clinical nutrition  
Food engineering  
Food science and technology  
Food toxicology  
Nutritional animal pathology  
Nutritional biochemistry and metabolism  
Oral biology

Department of Physics  
PHYSICS, Course VIII

Each graduate student is officially enrolled in one department or Course. His program is not limited, however, to subjects offered in a single department. Subjects and research programs may be chosen from several departments, with the aid and counsel of the staff, as long as the over-all program is integrated and well balanced with respect to a major field of study.

In addition to specialized professional competence, graduate students are expected to have a background in the humanities and social sciences. The Faculty believes that those who receive advanced degrees should have the breadth of interests and understanding which tend to promote qualities of leadership and an awareness



of professional, social, and moral responsibility, along with specialized competence. To further this objective, graduate students may take electives offered by the School of Humanities and Social Science or at Harvard University.

#### INTERDEPARTMENTAL DOCTORAL PROGRAMS

Their interdisciplinary character is a notable feature of many recent developments in the physical and social sciences and engineering. Team research is one result of this; another result is that individual interests now frequently span several conventionally defined fields. Thus a number of graduate students now desire doctoral programs in fields that may be adequate in both scope and depth to meet doctoral standards but whose boundaries overlap substantially two or more departments. In certain areas, such as materials engineering, instrumentation, and operations research, special continuing committees provide guidance. In other fields, interdepartmental doctoral programs are normally administered by *ad hoc* committees appointed for each case by the Dean of the Graduate School. Details of this procedure are found in the *Graduate School Manual*.

#### Admission to the Graduate School

The term Regular Graduate Student designates a student who is in residence at the Institute and registered for a program of advanced study and research leading to any of the post-baccalaureate degrees offered by M.I.T. A Regular Graduate Student may or may not concurrently hold an academic staff appointment such as research assistant, teaching assistant, instructor, or, rarely, assistant professor. A student registered in a program of study leading to the simultaneous award of the degrees of Bachelor of Science and Master of Science is considered for admission as a Regular Graduate Student in competition with other applicants during his fourth undergraduate year.

To be admitted as a Regular Graduate Student, an applicant must have received a Bachelor's degree or its equivalent from a college, university, or technical school of acceptable standing. His academic record and other credentials must indicate ability to accomplish satisfactorily an approved program of study and research. Admission to each department is by competition among the applicants for the places available.

Applicants are evaluated by the department in which they propose to register, on the basis of their prior performance and professional promise. These are evidenced by academic records, letters of evaluation from individuals familiar with the applicants' capabilities, and any other pertinent data furnished by the applicants. While previous high academic achievement does not guarantee admission, such achievement, or other unusually persuasive evidence of professional promise, is expected.

The engineering departments normally require students seeking a doctor's degree to qualify for a Master's degree first. At the time of registration the student decides, with the advice and consent of his department, for what degree he will register.

#### UNDERGRADUATE PREPARATION FOR ADVANCED DEGREES

In line with the Institute's conception of a broad undergraduate curriculum with emphasis in mathematics and science, most departments require the following preparation:

*Mathematics.* Preparation substantially equivalent to that provided by the Institute subjects 18.01, 18.02, and 18.034 (calculus and differential equations).

*Physics.* Preparation substantially equivalent to that provided by the Institute subjects 8.01, 8.02, and 8.03T (particles, Newtonian mechanics, relativity, oscillations and waves, electricity and magnetism).

*Chemistry.* Preparation substantially equivalent to that provided by Institute subject 5.01 (atomic theory, kinetic theory, chemical equilibrium, electrochemistry).

Some departments, however, require only a year of college mathematics and some only a year of natural science.

*Humanities and Social Science.* All M.I.T. departments require at least six semester subjects in the humanities or social sciences equivalent in scope to those included in the undergraduate humanities curricula of the Institute. Deficiencies may be satisfied by completing appropriate subjects from fourth-year or graduate electives in the humanities and social sciences.

*Languages.* Several departments require a candidate for the doctor's degree to demonstrate competence in one or more foreign languages. A prospective doctoral candidate is urged to include language study in his college preparation.

*Professional subjects.* Requirements of individual

# Graduate

## GRADUATE ADMISSION

departments are given in each department's statement on graduate education.

### **Deficiencies in Preparation**

Students with minor deficiencies in preparation may be admitted to the Graduate School; however, deficiencies in prerequisite, general or professional subjects must be made up before the student may proceed with graduate work dependent on them.

If an applicant lacks so many undergraduate requirements that his work for the advanced degree is likely to be unduly protracted, he may be advised to postpone his application until some of his deficiencies have been made up.

In an exceptional individual case, the Committee on Graduate School Policy will entertain a departmental proposal for altering admission requirements and can modify any of the above requirements.

### **APPLICATION FOR ADMISSION TO THE GRADUATE SCHOOL**

Students normally enter the Graduate School in September. However, in several of the departments suitable programs can be arranged for students entering in June or February. Customarily, the Department of Psychology does not admit students in February.

Students wishing to enter in June or September should apply on the prescribed forms by January 15; candidates for admission in February should apply by November 1. However, applications submitted later by students who are not also candidates for financial aid may be considered if vacancies still exist.

Candidates for admission in June or September *who are also applicants for financial aid* should be careful to observe the deadline of February 1.

An applicant attending a college or university which is on the semester system should not wait until the end of the fall semester at his institution to submit an application for admission in June or September but should apply before the end of the term, submitting a transcript of his fall semester grades as soon as it is available.

Applications for admission should be submitted to the Director of Admissions, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139. A \$10 application fee is required of all citizens of the United States or Canada and of all foreign students studying at United States or Canadian institutions. The fee should accompany the application form.

Payment should be by check or money order, payable to the Bursar, M.I.T. The fee is not required of a student who applies for readmission as a candidate for the same degree or for a higher graduate degree after a lapse of less than two years.

Notification about admission is sent as soon as action is taken (usually on or about April 1).

The admission of a student who is in his final year of work toward a Bachelor's degree is made conditional upon his subsequently providing evidence that he has been awarded the degree.

Correspondence concerning admission, including requests for application material, should be addressed to the Director of Admissions. Inquiries about preparation or subject content should be addressed to the chairman of the appropriate departmental Committee on Graduate Students.

### **ADMISSION AS A PROVISIONAL GRADUATE STUDENT**

Admission as a Provisional Graduate Student may be granted to an applicant who, although unable to meet all of the above requirements for acceptance as a Regular Graduate Student, is judged by a departmental Committee on Graduate Students to be able to pursue graduate studies successfully. Provisional graduate student status will be changed to that of Regular Graduate Student upon demonstration of such ability.

### **ADMISSION AS A SPECIAL GRADUATE STUDENT**

A Special Graduate Student is one whose intended program of study is essentially graduate in nature but who is not registered as a candidate for a degree; normally he will have received a Bachelor's degree. The applicant's qualifications for the specific program desired will normally be evaluated by the Chairman of the Graduate Committee of the department which best corresponds with his major area of interest. Admission is valid for only one term; a student must seek readmission each term to continue at the Institute. To be allowed to continue as a Special Graduate Student, he must receive grades satisfactory to the Committee on Graduate School Policy.

A Special Graduate Student who is subsequently admitted as a Regular Graduate Student may offer subjects, which he has completed, in partial fulfillment of requirements for an advanced degree. His department will determine to what extent such subjects are acceptable and whether he will receive residence credit for them.

Correspondence concerning admission as a Special Graduate Student should be addressed to the Director of Admissions, from whom application material may be obtained. Applications must be filed at least two weeks prior to the beginning of the term.

#### **ADMISSION OF FOREIGN STUDENTS TO THE GRADUATE SCHOOL**

Applications for admission to the Graduate School from foreign students are welcomed. About one in five graduate students is from abroad. A foreign applicant is considered on the same basis as a United States applicant and the same requirements apply to him. Detailed information is contained in the *Application for Admission from Foreign Citizens* and a leaflet, *Information for Foreign Students*, which may be obtained from the Office of the Advisor to Foreign Students, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.

Action on admission is not taken until complete application material has been received by the Director of Admissions. Applications accompanied by incomplete credentials cannot be considered.

Foreign graduate applicants whose native language is not English and whose schooling has not been predominantly in English must take the Test of English as a Foreign Language (TOEFL). This test is described in the paragraphs on Admission of Foreign Students (undergraduates) in Section 2 of this Catalogue.

Foreign students who wish to enter the Institute for undergraduate study should refer to Section 2 of this Catalogue.

#### **GRADUATE RECORD EXAMINATIONS**

Applicants for admission to graduate study in the Departments of Biology and Political Science are required to submit scores in the Aptitude Test and in the appropriate Advanced Test of the Graduate Record Examination. The Department of Biology will accept such test scores resulting from the advanced test in either chemistry, physics, or biology. The Department of Psychology requires the Aptitude Test for Verbal and Quantitative Ability as well as the appropriate Advanced Test of the Graduate Record Examination. It is recommended that the Miller Analogy Test be taken. The Department of Physics does not require, and makes no recommendation regarding, these examinations. All other departments recommend, but do not require, the submission of such scores, with the

exception of the Sloan School. The Sloan School of Management requires applicant scores on the Admission Test for Graduate Study in Business (an aptitude test) only. Applicants are urged to consult with appropriate departments to confirm test requirements and recommendations.

Information as to time and location at which these tests are given can be obtained by writing to Graduate Record Examinations, Educational Testing Service, Box 955, Princeton, New Jersey 08540. Inquiries from students in western states should be addressed to 1947 Center Street, Berkeley, California 94704.

#### **Registration**

Registration material is available in advance of each term. This material should be filled out and returned to the Registrar's Office before the beginning of the term, in accordance with instructions provided. A student entering the Graduate School from another college usually will not be able to indicate specific subjects for which he will register, but he should complete as much as possible of the registration material for prompt return to the Registrar, leaving the final choice of subjects to be determined in consultation with his Registration Officer before or on Registration Day.

#### **Academic Standards**

Continuing registration of graduate students from term to term is contingent upon satisfactory academic performance. At the end of each term the Committee on Graduate School Policy reviews the performance of all graduate students whose grades during that term average less than midway between C and B. In addition, departmental graduate committees may at any time recommend to the Committee on Graduate School Policy that a student be refused further registration or that he be allowed to register only for a less advanced degree.

#### **Cooperative Arrangement with Harvard University**

A graduate student at M.I.T. or Harvard University who is engaged full time in study or in a combination of study and academic staff duties equivalent to full time may, by permission, enroll for advanced study (exclusive of research) at the other institution without paying additional



tuition, provided that this exchange enrollment does not exceed one-half of his total registration for the term. Included in the above category are full-time Special Graduate Students who are carried on the rolls of the Graduate School at M.I.T. This cooperative arrangement is applicable to the regular academic terms and not to the Summer Session.

Requests for registration under this cooperative arrangement should be confined to subjects which are not offered at the student's own institution; if there is an apparent duplication of a requested subject in the two schools, acceptable reasons for the request must be presented. Students will not be allowed to attend classes which are so crowded that additional registration puts an undue load on the instructors.

The procedures to be followed and deadlines to be observed by both M.I.T. and Harvard students wishing to enroll in subjects under this cooperative arrangement are given in the *Graduate School Manual*.

### ***Cooperative Arrangement with Boston University***

An arrangement analogous to that described above for Harvard has been made between the M.I.T. Departments of Economics and Political Science and the African Studies Program at Boston University. Details of the procedures to be followed, which are similar to those for Harvard-M.I.T. cross-registration, are given in the *Graduate School Manual*.



### ***Cooperative Arrangement with Tufts University***

A third cooperative arrangement exists between the M.I.T. Department of Nutrition and Food Science and the School of Dental Medicine at Tufts University. The program is restricted to specific graduate subjects at each institution, a list of which may be obtained from the Office of the Dean of the Graduate School. More complete information is given in the *Graduate School Manual*.

### ***Medical Services and Requirements***

Information concerning Medical Services and the requirement of a medical examination for *all* entering students, including graduate students, will be found in Section 1 of this Catalogue. Participation in the Institute's Health Insurance Program is required as a means of avoiding the serious financial burden experienced each year by a number of students as a result of prolonged illness or accident.

### ***Military Service***

The Office of the Graduate School counsels and assists enrolled and prospective (admitted) graduate students in their representations to Selective Service Boards and/or the various military services relative to classification, deferment, and delay and is prepared to help in every way possible. Every such student, whether or not he anticipates a junior staff appointment as



a teaching assistant, research assistant, or instructor, is invited to seek the School's advice and assistance in this matter.

With regard to Selective Service, the Institute has taken the position that a graduate student, in good standing, who enters the armed forces will be readmitted to the Graduate School provided he reapplies within five years after leaving M.I.T.

The Committee on Graduate School Policy has further resolved that: A graduate student, in good standing, whose education is interrupted for reasons related to Selective Service will be readmitted irrespective of whether he enters the armed forces or does not serve because of moral or conscientious objection, provided he applies for readmission within five years after leaving M.I.T. Students are urged to keep abreast of such forthcoming developments through the Graduate School Office and their Selective Service Boards.

### ***Requirements for Degrees***

Candidates for advanced degrees must satisfactorily complete an approved program of study and research, including an appropriate portion done in residence, before being recommended for a degree. The amount of time required to attain any one degree varies; candidates who lack undergraduate prerequisites for graduate work may be permitted to make up these deficiencies in the course of their graduate work, but those who do so must expect to

spend a longer period of time in the Graduate School than is otherwise required for the degree. All the general requirements for the different degrees, as well as the residence requirements, are described in the following paragraphs.

A student who expects to come to M.I.T. for an advanced degree after earning an undergraduate degree elsewhere should give careful attention to undergraduate subjects prerequisite for the advanced work which he intends to undertake; these requirements are outlined by each department in following sections of this Catalogue. For advice on such subjects, a student should write to the chairman of the Committee on Graduate Students of the department in which he wishes to enroll.

Degrees are awarded by the Corporation of the Institute upon the recommendation of the Faculty. Favorable faculty action is based upon approval by the Committee on Graduate School Policy on recommendations from the appropriate departmental Committees on Graduate Students.

### **THE DEGREE OF BACHELOR IN ARCHITECTURE**

The graduate degree of Bachelor in Architecture is awarded upon the satisfactory completion of a program of study of at least 164 subject units approved by the Department of Architecture, of which 96 units must be in "A" subjects, and the completion of a thesis acceptable to the Department. ("A" subjects are those intended primarily for graduate students; they are indi-

# Graduate

## DEGREE REQUIREMENTS

cated in the Descriptions of Subjects given at the back of this Catalogue.)

A student who has obtained the degree of Bachelor of Science in Art and Design at the Institute or an equivalent degree at another institution may attain the degree of Bachelor in Architecture in two years. A student who enters without previous experience in a department of architecture may take four years.

### THE MASTER'S DEGREES

A student who has a Bachelor's degree from the Institute in the same department in which he enrolls for the Master's degree, or who has had equivalent preparation elsewhere, may attain the Master's degree in one year. Others with less direct or extensive preparation will require a longer time.

A student who completes the requirements for the Bachelor's degree at the Institute with substantial extra advanced credits in graduate subjects may, upon application, be granted a relaxation of the normal residence requirement (apart from thesis) and may be recommended for the Master's degree upon completion of the academic requirements.

#### *Degree Requirements*

The degrees Master of Science, Master in Architecture, and Master in City Planning are awarded upon the satisfactory completion of an approved program of study of at least 66 subject units, of which 42 units must be in "A" subjects, and the completion of an acceptable thesis.

The choice of field of specialization must be approved by the Committee on Graduate Students of the department in which the student is enrolled. Approval of the entire program must be obtained from this Committee and from the student's Registration Officer. A special interdepartmental committee may be appointed by the Dean of the Graduate School to supervise a program in a field which spans two or more departments.

To be recommended for a Master's degree, a student must have, in addition to a clear record in a program of graduate study and research as defined above, a scholastic standing of a distinctly high grade.

#### *Degrees With and Without Specification*

In an approved program for a Master of Science degree, if 34 units of "A" subjects and the thesis are in a single field of science or engineering (as determined by a departmental Committee on

Graduate Students), the degree is recommended with specification in the field in which the student has thus specialized; otherwise, the degree is recommended without specification. The same high standard of academic performance is required in either case.

#### *Programs for the Simultaneous Award of the Bachelor's and Master's Degrees*

Information concerning the opportunity for programs of study leading to the simultaneous award of the Bachelor's and Master's degrees is given under "The Undergraduate Programs" in Section 2 of this Catalogue.

### THE ENGINEER DEGREES

The objective of a program leading to an Engineer degree is a more advanced level and a broader range of competence in engineering and science than that required for the Master's degree, but with less emphasis on creative research than that characterizing a doctoral program. In general terms, the Master's degree requires a minimum of one academic year and the Engineer degree two academic years beyond a baccalaureate in the same field.

The following Engineer degrees are awarded: Chemical Engineer (CHEM.E.), Civil Engineer (C.E.), Electrical Engineer (E.E.), Engineer in Aeronautics and Astronautics (E.A.A.), Marine Mechanical Engineer (MAR.MECH.E.), Materials Engineer (MAT.E.), Mechanical Engineer (MECH.E.), Metallurgical Engineer (MET.E.), Mineral Engineer (MIN.E.), Naval Architect (NAV.ARCH.), Naval Engineer (NAV.E.), Nuclear Engineer (NUCL.E.), and Ocean Engineer (OCEAN E.).

The requirement for such a degree is the satisfactory completion of a program of advanced study and research approved by the appropriate department of the School of Engineering. The minimum program consists of at least 162 subject units and the completion of an acceptable thesis. A department may accept a Master's thesis of superior quality for the Engineer degree.

A graduate of the Institute who enrolls for an Engineer degree in the same department in which he received his Bachelor's degree, or others with equivalent preparation, may complete the requirements for that degree in four academic terms; a student with less direct or extensive preparation will require a longer time.

***The Thesis for the Master's and Engineer Degrees***

The caliber and scope of the Master's and Engineer theses are, in general, such as to require the equivalent of the full time of a student for at least a half of a term. Many theses may require a somewhat longer time. Every degree candidate working on a thesis is expected to register for the appropriate number of hours per week devoted to thesis in all periods during which his thesis research is actually in progress.

**THE DOCTORATES**

M.I.T. offers the degrees of Doctor of Science and Doctor of Philosophy interchangeably in branches of science and engineering, and the degree of Doctor of Philosophy alone in city and regional planning, economics, political science, biology, psychology, philosophy, linguistics, and management. These degrees certify to performance of original research of high grade and to creditable completion of an approved program of advanced study, principally at the Institute.

The two basic requirements for a doctorate are:

1. Completion of a program of advanced study, including a general examination.
2. Completion and oral defense of a thesis on original research.

Experience has strongly indicated that the purposes of doctoral work are effectively served only by full-time effort in formal study or by a combination of formal study and relevant work as an academic staff appointee.

***The Program of Advanced Study***

The program of advanced study and research may be selected in any field approved by the department in which the student is enrolled. The thesis is in this same field. The program often comprises subject areas reaching into several departments. If the field requires substantial participation by two or more departments, an interdepartmental faculty committee may be appointed by the Dean of the Graduate School to advise with a Graduate Registration Officer in the administration of the student's program.

Each doctoral candidate will have a general examination in his field at such time and in such manner as his departmental or interdepartmental committee approves. This examination consists of both oral and written parts.

***The Thesis***

The caliber and scope of the doctoral thesis are such as to require, in all but very exceptional cases, the equivalent of at least one full-time academic year of research. Many doctoral researches require a substantially longer time. Each doctoral candidate is expected to register for the appropriate number of units of thesis in all periods during which work pertaining thereto is actually in progress.

The investigation must be carried out under the supervision of an M.I.T. faculty member. Work already accomplished elsewhere which has not been under the supervision of an Institute faculty member cannot be accepted in partial fulfillment of the thesis requirement, nor can credit be granted for thesis research done *in absentia*, except under very special conditions and with specific prior approval by the Committee on Graduate School Policy. A full statement of policy on thesis research *in absentia* is given in the *Graduate School Manual*.

A final oral examination on the thesis and its field will be held after the thesis has been submitted and tentatively evaluated by the examiners.

***Minor Program***

The Institute believes that candidates for the doctor's degree should be aware of the context of their special field in the spectrum of human knowledge. Although there is no Institute requirement of a Minor for the doctor's degree, certain departments require that candidates take a number of subjects outside their major field.

***Language Proficiency***

Scholars from different countries should have the means of communicating with one another. The American scholar is fortunate in that much foreign professional literature is now written in English, or readily available in English, and many foreign scholars speak English. Nevertheless the American scholar should have studied other languages enough to be able to communicate with foreign scholars in a spirit of reciprocity. There will also be times when the knowledge of a foreign language will be important to him in his work.

Although there is no Institute language requirement, prospective doctoral students are urged to include language study in their college preparation. Several departments have a language requirement for the doctorate, normally

# Graduate

## FINANCIAL ASSISTANCE

the requirement that a candidate be able to read or speak one or two foreign languages with intermediate competence. Typically, a student may satisfy the requirement in three ways:

1. He may satisfy the requirement before entrance by passing one or more intermediate or advanced courses with a grade of C or better.
2. He may be examined by the Department of Foreign Literatures and Linguistics.
3. He may take a two-term subject in the language or languages concerned offered by the Department of Foreign Literatures and Linguistics. Depending on student demand, the Department of Foreign Literatures and Linguistics offers a choice of two-term language subjects, stressing the ability to read or to speak, in French, German, Russian or Spanish.

The Department of Foreign Literatures and Linguistics gives, for the purpose of 2 above, written and oral examinations in French, German, Russian, and Spanish twice a year at the end of each term. Written and oral examinations in other approved languages are arranged individually upon request. A student who requests a written or oral examination in French, German, Russian or Spanish at an unscheduled time, or in any other language at any time, is required to submit with his application a receipt from the Bursar indicating that he has paid a special fee of \$30 for this purpose. *Any student who fails to appear for a predoctoral language examination is subject to a fine of \$10.*

Further information concerning the above and other departmental requirements may be obtained from the individual departments.

### RESIDENCE REQUIREMENTS

M.I.T. degrees are "residence" degrees in the sense that a major portion of the work for which each is awarded must be done with opportunity for full-time association with the Faculty, other graduate students, and the Institute community. In this academic environment a student lives and works in a stimulating and scholarly atmosphere; he enjoys free and unhampered discussion with his colleagues, both faculty and students, within his professional field and over a broad range of other subjects. This environment includes easy access to libraries and reference sources, to the educational opportunities offered by other disciplines, and also to recreational, cultural, religious, and athletic opportunities. Experienced together, these offer the challenge and inspiration of being a working member of

a team mutually striving for professional growth and advancement and transmission of knowledge.

All thesis work must be done under the supervision of an authorized member of the Institute's academic staff.

For all the Master's degrees the minimum residence requirement is one full academic term.

For the Engineer degrees, the equivalent of two terms of full-time graduate work must be completed with residence credit.

For the doctor's degree, the course of advanced study must be pursued under the direction of the Committee on Graduate School Policy for at least two academic years of full-time graduate work, including the research for and writing of a thesis, normally with residence credit. In the case of students who satisfy the Committee that they have successfully accomplished at another institution advanced work of a grade similar to that required at the Institute, the required period of residence may be reduced. In no case may the required period of residence be reduced to less than the equivalent of three full-time academic terms, not more than one of which may be a summer term.

### Financial Assistance to Graduate Students

Financial support is available to graduate students from a variety of sources and in several different forms — fellowships, traineeships, scholarships, teaching and research assistantships, and loans. Resident tutorial positions in undergraduate Institute Houses and fraternity houses provide room and board. Application from students who have completed at least one graduate year at M.I.T. or who have been M.I.T. undergraduates may be made to the Dean for Student Affairs. The Deferred Payment Plan, tuition payment plan, and student employment are available to students with few exceptions. Every prospective student is strongly urged to explore all the sources of aid available to him as he considers the means of financing his graduate education. For the majority of applicants for admission, expenses need not be a deterrent.

### FELLOWSHIPS, TRAINEESHIPS, AND SCHOLARSHIPS

A fellowship or traineeship is a grant to a graduate student which covers his tuition and provides, in addition, a stipend to help defray his

living expenses. In the context of the Graduate School, a scholarship is a grant which fully or partially covers tuition only. Awards are made on the basis of academic promise and to some extent financial need, and are intended solely to assist a student in the pursuit of his studies. No services are expected in return. Under Section 117 of the U.S. Internal Revenue Code of 1954, such grants, held by degree candidates, are not subject to income tax.

The Institute is fortunate to have received funds from individual donors and corporations which provide for the support of about 250 fellowships and scholarships each year; the funds which make these possible are listed in Appendix A of this Catalogue. In addition, many government agencies and foundations offer fellowships and other grants which they award either directly to outstanding students for use at institutions of their choice or to institutions for award by them to students. Fellowships available under these national programs, including fellowships and traineeships granted by national agencies for award by M.I.T., are summarized in the adjoining column. About 800 graduate students at M.I.T. have fellowships or other grants from national agencies for the academic year 1969-70.

***Application for Fellowships, Traineeships, or Scholarships Administered by M.I.T.***

Applicants to the Graduate School who seek financial support from any of the fellowships, traineeships, or scholarships administered by M.I.T., including those granted by national agencies and foundations for award by the Institute, should check the appropriate items on the regular Application for Admission to the Graduate School. Each applicant is automatically considered for all awards for which he is eligible. Currently enrolled graduate students who seek financial support should consult with the appropriate departmental office.

Applications for fellowship aid for the regular academic year, beginning with the fall term, must be filed by the previous February 1. Applications for fellowship aid filed after these dates are considered only as funds are available. An application for aid from a prospective student will not be considered unless he has also filed the completed Application for Admission. Final action on applications is taken on the recommendation of departments to the Com-

*(text continues on page 86)*

---

**NATIONAL FELLOWSHIPS FOR GRADUATE STUDY**

***Atomic Energy Commission***

Over 200 fellowships awarded annually by the Oak Ridge Institute of Nuclear Studies for U.S. graduate students in nuclear science and engineering. Twelve months' tuition plus \$2,400 to \$2,800 and dependency allowances. Renewable. Apply to the AEC Fellowship Office, University Relations Division, Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tennessee 37831.

***Danforth Foundation***

About 120 fellowships annually to male students graduating from U.S. colleges who seek to become teachers. Tuition plus \$1,800 for a single student, \$2,200 if married, with dependency allowances for up to three children. Renewable for four years of study. Nomination in early fall by the student's undergraduate college to the Danforth Foundation, 607 North Grand Boulevard, St. Louis, Missouri 63103.

***National Defense Education Act, Title IV***

Fellowships granted by the U.S. Department of Health, Education, and Welfare for award by M.I.T. to graduate students in new, expanded, or ongoing programs of study. Tuition plus \$2,000 to \$2,400 for nine months and summer and dependency allowances. Tenable for three years. Application on standard M.I.T. fellowship form to the student's prospective department at M.I.T. M.I.T. was allotted 30 new NDEA Fellowships for the academic year 1969-70.

***National Institutes of Health***

A large program of fellowships for U.S. graduate students in the medical sciences and areas of the biological, physical, and behavioral sciences related to health, environmental health, and other health-oriented fields. Twelve months' tuition plus \$2,400 to \$2,800 and dependency allowances. Renewable. Application to the Career Development Review Branch, Division of Research Grants, National Institutes of Health, Bethesda, Maryland 20014.

Grants of the National Institutes of Health provide traineeships for award by M.I.T. to U.S. graduate students in the medical sciences and health-related fields. Tuition plus a stipend determined by the department handling the grant, comparable to the stipend from a NIH fellowship. Application on standard M.I.T. fellowship form to the student's prospective department at M.I.T.

***National Science Foundation***

About 2,500 fellowships awarded annually to U.S. graduate students for study in the mathematical, physical, medical, biological, and engineering sciences, anthropology, economics, geography, the history and philosophy of science, linguistics, political science, psychology, and sociology. Twelve months' tuition plus \$2,400 to \$2,800 stipend and dependency allowances. Awarded for one or two years; renewable. Application in the fall to the National Science Foundation, Washington, D.C. 20550. Watch for NSF announcements on dates.

Grants of the National Science Foundation provided for 143 traineeships in the same fields at M.I.T. in 1969-70 as part of a national traineeship program. Financial terms identical with those of the graduate fellowships. Renewable. Application on standard M.I.T. fellowship form to the student's prospective department at M.I.T.

***Woodrow Wilson National Fellowship Foundation***

One hundred fellowships to first-year graduate students, primarily to candidates in the humanities and social sciences but science and mathematics majors with a clear interest in teaching careers may be chosen. U.S. and Canadian citizens only. Nine months' tuition plus stipend of \$1,800 and dependency allowances. Not renewable. Nomination in early fall by a faculty member to the Chairman of the appropriate Regional Committee. For information, write the Woodrow Wilson National Fellowship Foundation, Box 642, Princeton, New Jersey. (This program may be modified in the near future.)

***Other***

These include the Federal Housing and Urban Development National Fellowship Program, NDFL Traineeships, NASA International Fellowships, Department of the Interior Traineeships, NIH Air Pollution Fellowships, and the Hertz Foundation Fellowship Program for support in certain fields of graduate study, based on M.I.T. nominations, and Ford Foundation Fellowships for Black Students. Contact appropriate agency or see Graduate School Office for details. Also consult the Graduate School Office publication *Financial Support for Graduate Students*.

---

# Graduate

## FINANCIAL ASSISTANCE

mittee on Graduate School Policy at the end of March after the announcement of awards to applicants by the national agencies and foundations under their national competitive programs. A student who individually secures such award is not considered further for a fellowship or traineeship by M.I.T.

### ***Award of Fellowships, Traineeships, and Scholarships***

Notices of award by the Institute are mailed for delivery by the end of March. In accordance with a resolution of the Council of Graduate Schools in the United States, to which over 180 graduate schools have signified their assent, a student has until April 15 to accept or decline an offer. If a student does not reply to an offer by this date, it may be cancelled.

Every student holding a fellowship, traineeship, or scholarship for graduate study at the Institute is expected to register as a regularly enrolled student for the period of the award, pursuing a full program of studies. If a student with an award which is paid to him through M.I.T. withdraws from the Institute before his tenure expires, the Institute will consider him to have relinquished the award, and he will be required to make such refund of any sum already paid to him as the Committee on Graduate School Policy deems appropriate. An award may also be terminated for failure to maintain a satisfactory standard of scholarship.

### **TEACHING ASSISTANTSHIPS**

About 600 graduate students are appointed each year as instructors or teaching assistants. They assist the faculty in grading undergraduate quizzes, instructing in the classroom and laboratory, and conducting tutorials. They receive salaries which, after taxes, are roughly comparable to fellowship stipends. They are generally awarded scholarships to cover their tuition.

After four years or more of intensive study at the undergraduate level, many students enjoy the new view of their subject afforded by a teaching assignment. The departments consider important the benefits of a teaching assistantship as a preparation for a career in university teaching, and the Institute offers a prize each year — the Goodwin Medal — for conspicuously effective teaching by a graduate student. A student accepting a teaching assistantship typically does not prolong his time to the doctor's degree. The average time taken by

students who have held assistantships is not significantly different from the time taken by students who have held fellowships during the same period.

The units for which an instructor or teaching assistant may register as a student are determined by his department in the light of his assistantship duties, his compensation being adjusted accordingly.

Appointments to teaching assistantships are made upon recommendation of the head of a department. A student who wishes to be considered for a teaching appointment should write to his prospective department; such applications from new students will be considered only after an Application for Admission to the Graduate School has been filed with the Admissions Office.

### **RESEARCH ASSISTANTSHIPS**

About 1,000 graduate students at M.I.T. each year hold appointments as research assistants. They assist members of the Faculty in the research projects which are a major characteristic of the academic life of the Institute and a prime reason for its vitality. It is a policy of the Institute to accept only such projects as will be in keeping with its educational objectives.

Research assistants receive stipends which are intended to be comparable in attractiveness, after payment of tuition, with fellowship stipends. Insofar as the duties of a research assistant relate to the thesis work which he is required to perform for his degree, his salary is normally considered the equivalent of a fellowship stipend for tax purposes, and taxes are not withheld. (A research assistant's stipend may be found liable to tax in an individual case.)

The units for which a research assistant may register are determined by his department in the light of his duties and his program of study, his stipend being adjusted accordingly.

Many students prize the opportunity a research assistantship gives them to participate as junior colleagues of the faculty in an ongoing research project. The experience enlivens their Course work and frequently determines their choice of thesis topic. In most cases a research assistant's thesis work parallels closely his contribution to the project.

Appointments to research assistantships are made in the same manner as appointments to teaching assistantships.

**GRADUATE ASSISTANTSHIPS**

Some departments also appoint graduate students to junior academic staff positions as graduate assistants. The appointment is a flexible one which allows a department to vary a student's duties as he progresses in his academic work; at one point he may be engaged in teaching, at another in research. A graduate assistant is normally compensated in the same manner as a teaching assistant if he is primarily engaged in teaching and in the same manner as a research assistant if he is primarily employed in research. Appointments are made in the same manner as appointments to research and teaching assistantships.

**STUDENT LOAN FUNDS**

The Institute administers a loan program under which financial assistance is available to students in all fields of study. A student may borrow to support a modest budget for which he has insufficient resources. Students are expected to have explored all other sources of aid (including employment opportunities and home-state Government Insured Loan Programs) before requesting loan funds from the Institute. To be considered, a student must submit a budget giving evidence of his need. Full details about loan funds will be found in Appendix A. Application should be made to the Director of Student Aid, from whom forms may be obtained.

**RELATIONSHIP OF THE D.S.R. STAFF TO THE GRADUATE SCHOOL**

In view of their full-time responsibilities on assigned research and corresponding non-academic salary scales, staff members of the Division of Sponsored Research do not enjoy full academic privileges but may, under conditions outlined below, be granted the status of Special or Limited Graduate Student.

A graduate student may not interrupt his academic program to accept a staff appointment in the Division of Sponsored Research (D.S.R.), the Instrumentation Laboratory, or Lincoln Laboratory either during the academic year or during the summer unless he has the approval of his Department Head and of the appropriate Academic Dean and unless his work as an employee is unrelated to his thesis research. No graduate student may present as thesis any material based in whole or in part upon work done while holding a D.S.R. appointment or

receiving the D.S.R. rate of compensation.

Many members of the staff of the Division of Sponsored Research (D.S.R.) study graduate subjects as Special Graduate Students. However, a D.S.R. appointee who desires to work for an advanced degree must meet the residence requirement by becoming a Regular Graduate Student at some time during his degree program.

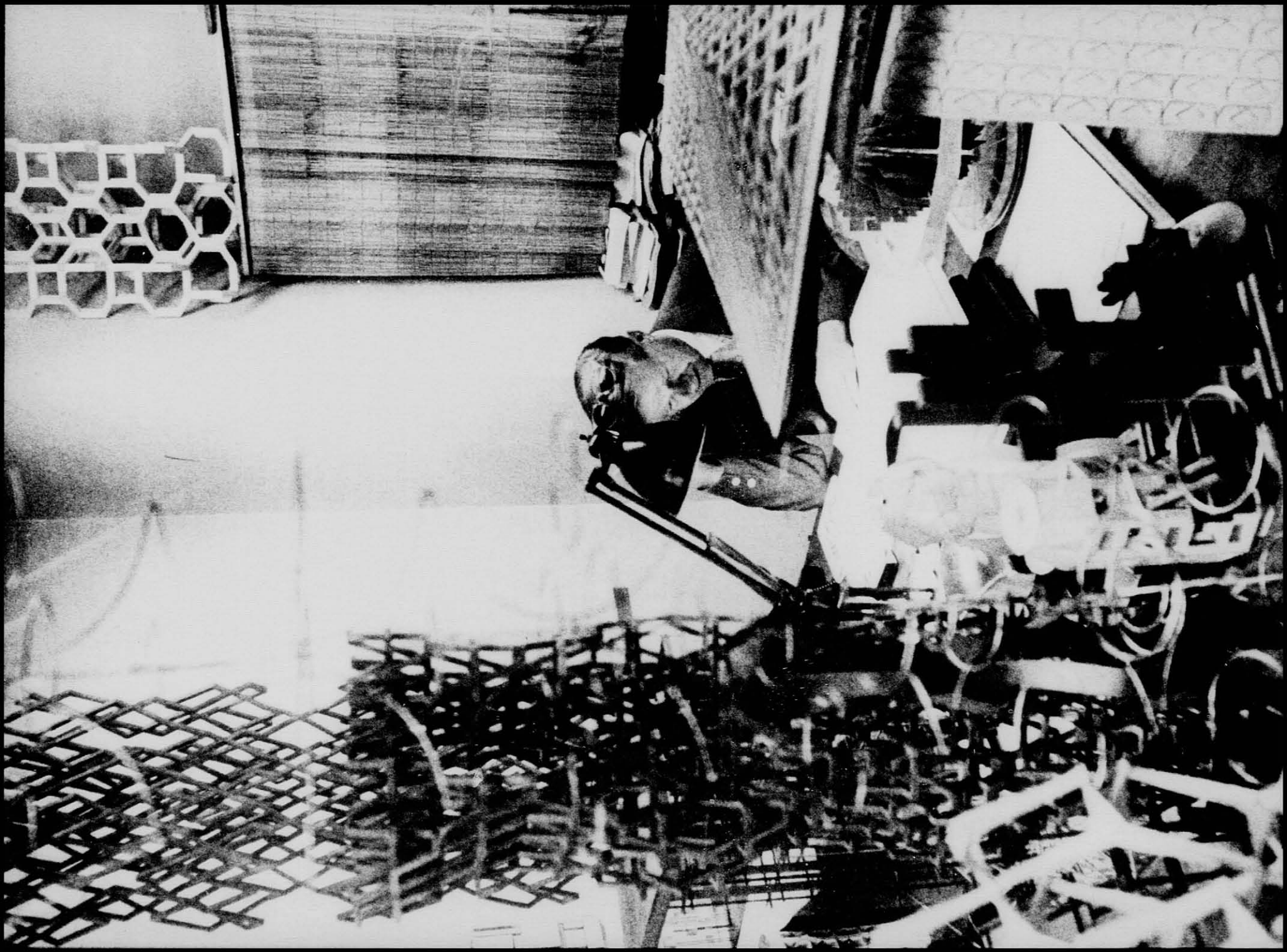
Any D.S.R. appointee may, by written permission from the Director of the Division (or his designate), apply for enrollment as a student in one subject only per term (but not thesis), either as auditor or for academic credit; he will be accepted for such enrollment if, in the opinion of the instructor in the subject, he is qualified to undertake it and if section size permits. For this type of enrollment he will be assigned to an appropriate Registration Officer and will pay, whether as a student or listener, the fee established at the Special Student rate and will be recorded as a Special Student. (For details, see "Fees" in Section 1 of this Catalogue.)

A D.S.R. appointee who at some previous time has held Regular Graduate Student status may, upon joint recommendation of a department Committee and the D.S.R. to the Dean of the Graduate School, be permitted to enjoy the status of Limited Graduate Student for the following purposes:

1. To undertake general doctor's or comprehensive Engineer degree examinations;
2. To undertake language examinations prescribed for advanced degrees;
3. To complete thesis presentation with or without thesis examination, and either with or without simultaneous enrollment on a degree list;
4. To enroll on a degree list and in one subject.

Not more than one of the preceding four aspects will be permitted in any single term, nor will the privilege of taking one subject apply to terms in which permission is given for registration under aspects 1, 2, or 3 above. Furthermore, no request for enrollment on a degree list will be entertained (except under 4) until all degree requirements other than thesis presentation have been satisfactorily completed. D.S.R. appointees pay the fees or tuition as prescribed for Regular Students, not those applying to students holding academic staff appointments.

By approval of a Graduate Registration Officer, credits recorded for subjects completed as a Special Student may be accepted in partial fulfillment of advanced-degree requirements.



*A statement by the Dean of the School of Architecture and Planning.*

Architecture and planning were initiated as professions concerned with the art of design as applied to the built-in physical environment. Architects worked with structures and spaces at a fairly intimate scale requiring close control over the means of construction, planners in the larger framework of urban form, with a technology that leaned increasingly on the social sciences.

These professions are now rapidly enlarging their roles in society. Architects perceive that buildings form only a part of the constructed and natural environment, all parts of which should have a balanced relationship that cannot be imposed arbitrarily, but must represent all the unfolding needs of man as a social animal that can be met in his immediate surroundings. City planners perceive that concern for urban form is at the edge of a larger problem, the viability of urban life in America. The environmental problems of modern cities have become so urgent and so interrelated that one cannot address them singly. Knowing how to create physical systems such as housing and transportation is of high importance, but more important still is to know whether and when investment in such systems can be justified as compared to other policies that may not

involve built-in systems. Urban planning is tending today toward a loose federation of disciplines united only by a complete involvement in the urban problem. These disciplines are concerned not only with concepts of urban form but with race and poverty, with the phenomenon of squatter urbanization, with the intervention of government in urban change, and with neighborhood participation in planning decisions.

Both architecture and planning are being profoundly influenced by the new information revolution, which opens up new possibilities for the ordering of complex data for use in design and in policy making. The School benefits enormously from its placement in a scientific university.

Reinforcing the importance of cultural and aesthetic insights, an important section in the School is concerned with a broad perspective of the visual arts. This includes the scholarly study of the history and criticism of art and architecture as well as studio experiences in several forms of direct visual expression. The presence of this nucleus attracts students from every part of the Institute and offers possibilities for undergraduate concentration in the visual arts.

The overriding challenge of architecture and planning today is not in individual, isolated works of design; it is

# Architecture

SCHOOL OF ARCHITECTURE AND PLANNING

in bending the total environment to make a cohesive and satisfying background for modern urban life, in shaping individual creativity to fit into an ongoing social process of great complexity and dynamism. That is why these professions are now seeking to understand all the forces that are brought to bear in giving form to the physical environment.

LAWRENCE B. ANDERSON

## THE UNDERGRADUATE CURRICULA IN THE SCHOOL OF ARCHITECTURE AND PLANNING

The S.B. curricula in the School of Architecture and Planning consist of a program of general education, emphasizing science, mathematics, and the humanities and social sciences (the General Institute Requirements), and a concentration in one of a number of programs appropriate to architecture, urban planning, and the visual arts (the Departmental Programs). The General Institute Requirements are given on page 47. The Departmental Programs are given by each department on the following pages.

Each student arranges his program of studies with the advice and consent of a Faculty Counselor. Typical Course Schedules are issued each term by the Registrar with the Class Schedules. R.O.T.C. subjects may be used according to the specifications in Section 2.

## Department of Architecture

Architecture is an art; only creative insight may achieve it. Yet technology is the means to architecture, and architecture satisfies wants related to many areas of human affairs. Thus it has become the American preference that schools of architecture be lodged in universities, where the art of design can be fortified by scholarship and research in humanities, science, and engineering.

Contained within an institution especially alert to technology's potential for improving human life, M.I.T.'s Department of Architecture is dedicated to the search for a physical environment which expresses our culture, which encompasses the scientific outlook, and which uses modern industrial methods and materials while giving full satisfaction to our hunger for aesthetic fulfillment.

### THE UNDERGRADUATE CURRICULA

The Department offers two undergraduate courses of study: Architecture (Course IV), leading to the degree of Bachelor of Science in Art and Design; and Architecture (Course IV-B), leading to the degree of Bachelor of Science.

Course IV provides four programs of concentration: Program 1 — Architecture; Program 2 — City Planning; Program 3 — Visual Design; and Program 4 — History, Theory and Criticism of Visual Arts. These four programs are designed to provide, within the general educational objectives of the Institute, a concentration in aspects of the design of the physical environment. Selection of one of these programs will prepare a student for graduate professional study in the corresponding area. The student should choose his program of concentration not later than the end of the second year.

Course IV-B is offered for students who find that their basic intellectual commitments are to subjects within the Department of Architecture but whose interests and intentions do not match with the specified programs in Course IV. They may, with the approval of the Department, plan a course of study that more directly suits their interests, yet includes the fundamental subject areas within the Department.

Students in the Department of Architecture may, upon consultation with a Faculty Advisor, exercise flexibility in scheduling completion of General Institute Requirements. Deferment of a portion of the General Institute Requirements in the first year will allow those who so choose to elect appropriate subjects of professional interest within the Department of Architecture and other departments of the Institute. It should be emphasized, however, that any program of studies that involves postponing first-year physics and mathematics will limit the possibilities of easy transfer from the Department of Architecture to those departments of the Institute that, within a four-year sequence, presuppose the completion of most of the science and mathematics portions of the General Institute Requirements by the end of the sophomore year. In addition, some advanced subjects in departments other than Architecture presume the knowledge acquired in fulfilling General Institute Requirements. Registration in subjects of interest in those departments may be precluded or postponed by deferment of General Institute Requirements.

Within the Course IV programs, the subject matter treated in first-year physics and mathematics is necessary to undertake the required subjects Structures I (4.30) and Engineering Materials (1.02).

### PROGRAMS FOR THE DEGREE: BACHELOR OF SCIENCE IN ART AND DESIGN

#### Architecture (Course IV)

1. ARCHITECTURE PROGRAM CURRICULUM		<i>Total</i>
GENERAL INSTITUTE REQUIREMENTS ( <i>see page 47</i> )		<i>units</i>
Specific science and humanities and social science subjects. <sup>2</sup>		132 <sup>1</sup>
ECONOMIC PRINCIPLES I (14.01T) is required in the upperclass humanities and social science program.		
The Science Distribution Requirement will be satisfied by 1.02 and 4.30, which are required in the Departmental Program, plus appropriate subjects ( <i>see page 50</i> ) totaling		12
Laboratory Requirement ( <i>see page 51</i> ).		12

#### DEPARTMENTAL PROGRAM

Required Subjects		
1.02	ENGINEERING MATERIALS	3 3 6

(continued)

# Architecture

## DEPARTMENT OF ARCHITECTURE

### Required Subjects (continued)

4.031	FORM AND DESIGN I	2	4	6
4.032	FORM AND DESIGN II	2	4	6
4.30	STRUCTURES I	3	3	6
4.402	BUILDING PROCESS	3	3	6
4.601T	TOPICAL STUDIES IN THE HISTORY OF ART	3	0	6
4.701	ARCHITECTURAL COMMUNICATION	4	2	2
6.00	INTRODUCTION TO COMPUTATION	2	2	2
11.50	URBAN SOCIAL STRUCTURE AND PROCESS	2	0	6
4.121	ARCHITECTURAL DESIGN	2	5	5
4.122	ARCHITECTURAL DESIGN	2	5	5
4.131	ARCHITECTURAL DESIGN	0	6	6
4.132	ARCHITECTURAL DESIGN	0	6	6
4.31	STRUCTURES II	2	2	4
4.32	STRUCTURES III	2	2	4
				<b>155</b>

### Restricted Electives

Two of the following subjects:

4.61T	ARCHITECTURE IN THE ANCIENT WORLD	3	0	6
4.62T	ARCHITECTURE 1400-1750	3	0	6
4.63T	ARCHITECTURE IN THE MIDDLE AGES	3	0	6
4.64T	ARCHITECTURE FROM 1750 TO THE PRESENT	3	0	6
				<b>18</b>

### Unrestricted Electives

Total units required for the S.B. degree **36**

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> The following may not be used for the humanities and social science requirement: Field 10 — subjects in the 4.6 series used in fulfillment of the Departmental Program.

## 2. CITY PLANNING PROGRAM CURRICULUM

GENERAL INSTITUTE REQUIREMENTS (see page 47) **Total units**

Specific science and humanities and social science subjects.<sup>2</sup> **132<sup>1</sup>**

ECONOMIC PRINCIPLES I (14.01T) is required in the upperclass humanities and social science program.

The Science Distribution Requirement will be satisfied by 1.02 and 4.30, which are required in the Departmental Program, plus appropriate subjects (see page 50) totaling **12**

Laboratory Requirement (see page 51). **12**

## DEPARTMENTAL PROGRAM

### Required Subjects

1.02	ENGINEERING MATERIALS	3	3	6
4.031	FORM AND DESIGN I	2	4	6
4.032	FORM AND DESIGN II	2	4	6
4.30	STRUCTURES I	3	3	6
4.402	BUILDING PROCESS	3	3	6
4.601T	TOPICAL STUDIES IN THE HISTORY OF ART	3	0	6
4.701	ARCHITECTURAL COMMUNICATION	4	2	2
6.00	INTRODUCTION TO COMPUTATION	2	2	2
11.50	URBAN SOCIAL STRUCTURE AND PROCESS	2	0	6
				<b>91</b>

### Restricted Electives

77 units to be chosen from the following:

4.67T	HISTORY OF URBAN FORM	3	0	6
11.01	COMMUNITY PLANNING DESIGN	Arr.		

11.11	COMPONENTS OF THE URBAN ENVIRONMENT	3	0	6
11.15	SITE PLANNING	1	2	5
11.60	CITY STRUCTURE AND ECONOMIC DEVELOPMENT	2	0	6
11.90	METHODS OF RESEARCH IN CITY PLANNING	2	0	6
17.21T	AMERICAN POLITICAL PROCESS	3	0	6
17.81	STRUCTURE OF URBAN LIFE	3	5	10
				<b>77</b>

### Unrestricted Electives

Total units required for the S.B. degree **360**

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> The following subjects may not be used for the humanities and social science requirement: Field 7 — 17.21T, 17.81; Field 10 — 4.601T.

## 3. VISUAL DESIGN PROGRAM CURRICULUM

GENERAL INSTITUTE REQUIREMENTS (see page 47) **Total units**

Specific science and humanities and social science subjects.<sup>2</sup> **132<sup>1</sup>**

ECONOMIC PRINCIPLES I (14.01T) is required in the upperclass humanities and social science program.

The Science Distribution Requirement will be satisfied by 1.02 and 4.30, which are required in the Departmental Program, plus appropriate subjects (see page 50) totaling **12**

Laboratory Requirement (see page 51). **12**

## DEPARTMENTAL PROGRAM

### Required Subjects

1.02	ENGINEERING MATERIALS	3	3	6
4.031	FORM AND DESIGN I	2	4	6
4.032	FORM AND DESIGN II	2	4	6
4.30	STRUCTURES I	3	3	6
4.402	BUILDING PROCESS	3	3	6
4.601T	TOPICAL STUDIES IN THE HISTORY OF ART	3	0	6
4.602T	INTRODUCTION TO MODERN ART	3	0	6
4.701	ARCHITECTURAL COMMUNICATION	4	2	2
6.00	INTRODUCTION TO COMPUTATION	2	2	2
11.50	URBAN SOCIAL STRUCTURE AND PROCESS	2	0	6
				<b>100</b>

### Restricted Electives

One nine-unit subject<sup>3</sup> in art history, in addition to 4.601T and 4.602T **9**

60 units of visual design subjects to be chosen from the following:

4.013	GRAPHIC COMPOSITION	2	4	6
4.022T	VISUAL DESIGN PROBLEMS II	1	4	4
4.023	VISUAL DESIGN PROJECTS	2	4	6
4.033	FORM AND COLOR I	2	0	4
4.034	FORM AND COLOR II	2	4	6
4.041	LIGHT AND COLOR I	2	4	6

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> Subjects in Field 10 may not be used for the humanities and social science requirement.

<sup>3</sup> Subject to be chosen in consultation with the student's Faculty Counselor.

4.051T CREATIVE PHOTOGRAPHY I	2	6	1
4.054 ADVANCED PHOTOGRAPHY	2	4	6
4.071T PAINTING	1	4	4
4.081 PLASTIC COMPOSITION	2	4	6
			69
<i>Unrestricted Electives</i>			36
Total units required for the S.B. degree			361

**4. HISTORY, THEORY, AND CRITICISM OF ART AND ARCHITECTURE PROGRAM CURRICULUM**

GENERAL INSTITUTE REQUIREMENTS (see page 47)	<i>Total units</i>	
Specific science and humanities and social science subjects. <sup>2</sup>	132 <sup>1</sup>	
ECONOMIC PRINCIPLES I (14.01T) is required in the upperclass humanities and social science program.		
The Science Distribution Requirement will be satisfied by 1.02 and 4.30, which are required in the Departmental Program, plus appropriate subjects (see page 50) totaling	12	
Laboratory Requirement (see page 51).	12	

**DEPARTMENTAL PROGRAM**

<i>Required Subjects</i>			
1.02 ENGINEERING MATERIALS	3	3	6
4.031 FORM AND DESIGN I	2	4	6
4.032 FORM AND DESIGN II	2	4	6
4.30 STRUCTURES I	3	3	6
4.402 BUILDING PROCESS	3	3	6
4.601T TOPICAL STUDIES IN THE HISTORY OF ART	3	0	6
4.701 ARCHITECTURAL COMMUNICATION	4	2	2
6.00 INTRODUCTION TO COMPUTATION	2	2	2
11.50 URBAN SOCIAL STRUCTURE AND PROCESS	2	0	6
4.602T INTRODUCTION TO MODERN ART	3	0	6
4.681T THEORY AND METHOD IN THE HISTORY OF ART AND ARCHITECTURE	3	0	6
			109

*Restricted Electives*

The student may elect to concentrate in either History of Painting and Sculpture (Group a) or History of Architecture (Group b). A reading knowledge of French or German is required by the end of the junior year.<sup>3</sup>

Design subjects chosen from the subjects listed in Programs 1 and 3<sup>4</sup> totaling at least

A minimum of 45 units chosen from Group a and Group b, at least one subject to be selected from the alternate group

*Group a. History of Painting and Sculpture*

4.603T PAINTING AND SCULPTURE IN THE MIDDLE OF THE NINETEENTH CENTURY	3	0	6
4.604T MODERN ART FROM POST-IMPRESSIONISM TO CUBISM	3	0	6
4.605T PAINTING IN THE TWENTIETH CENTURY	3	0	6
4.606T SCULPTURE IN THE TWENTIETH CENTURY	3	0	6
4.641T MODERN ARCHITECTURE IN GERMANY FROM 1895 TO THE BAUHAUS LANGUAGE <sup>5</sup>	3	0	6
	4	0	8

<i>Group b. History of Architecture</i>			
4.61T ARCHITECTURE IN THE ANCIENT WORLD	3	0	6
4.62T ARCHITECTURE 1400-1750	3	0	6
4.621T ORIGINS OF CONTEMPORARY ARCHITECTURE IN THE EIGHTEENTH CENTURY	3	0	6
4.63T ARCHITECTURE IN THE MIDDLE AGES	3	0	6
4.64T ARCHITECTURE FROM 1750 TO THE PRESENT	3	0	6
4.641T MODERN ARCHITECTURE IN GERMANY FROM 1895 TO THE BAUHAUS	3	0	6
4.65T STUDIES TOWARD A THEORY OF ARCHITECTURE	3	0	6
4.66T CRITICISM OF ARCHITECTURE	3	0	6
4.67T HISTORY OF URBAN FORM	3	0	6
21.454T <sup>5</sup> NEAR EASTERN ARCHAEOLOGY: THE FOUNDATIONS OF CIVILIZATION LANGUAGE <sup>3</sup>	3	0	6
	4	0	8
<i>Unrestricted Electives</i>			36
Total units required for the S.B. degree			370

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> Subjects in Field 10 may not be used for the humanities and social science requirement.

<sup>3</sup> Any student who demonstrates to his Faculty Counselor his ability to read art historical literature in either French or German will have satisfied this requirement and need not include language in his elective program.

<sup>4</sup> Subjects are to be chosen in consultation with the Faculty Counselor. The Department recommends that students concentrating in History of Architecture elect 4.121 and 4.122 to fulfill the design requirement.

<sup>5</sup> 21.454T, if taken as elective, may not be used in the Humanities Program.

**PROGRAM FOR THE DEGREE: BACHELOR OF SCIENCE Architecture (Course IV-B)**

The wide range of offerings under the Department of Architecture and the numerous possible relationships with the subjects of other departments may well suggest to a student a coherent program of study other than the four programs in Course IV. In order to meet this condition, the Department offers for a limited number of students a curriculum composed of the Institute core, departmental restricted electives, and planned electives selected by the student. Students desiring to follow this curriculum must submit to the Department, not later than the end of the fall term of the junior year, a statement of their educational goals and a list of the restricted and planned electives selected to achieve these goals. At an earlier date students should discuss their interests and intended programs with one or more of the faculty of the Department.

GENERAL INSTITUTE REQUIREMENTS (see page 47)	<i>Total units</i>	
Specific science and humanities and social science subjects. <sup>2</sup>	132 <sup>1</sup>	

(continued)

# Architecture

## DEPARTMENT OF ARCHITECTURE

### GENERAL INSTITUTE REQUIREMENTS (continued)

ECONOMIC PRINCIPLES I (14.01T) is required in the upperclass humanities and social science program.

Science Distribution Requirement (see page 50).	36
Laboratory Requirement (see page 51).	12

### DEPARTMENTAL PROGRAM

#### Restricted Electives

Design subjects of at least 12 units in the 4.0 or 4.1 series, 11 15, or equivalent	24
Technological subjects in the 4.3 or 4.4 series <sup>3</sup>	12
History subject in the 4.6 series	9
Subject in the Department of Urban Studies and Planning	8

53

#### Planned Electives

A coherent selection which, together with other parts of the student's program, is aimed at a well-defined educational goal. Each program must be approved by the undergraduate curriculum committee or the Department.

72

#### Unrestricted Electives

55

Total units required for the S.B. degree 360

<sup>1</sup>The requirement for the Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup>The following may not be used for the humanities and social science requirement: Field 10—subjects in the 4.6 series used in fulfillment of the Departmental Program.

<sup>3</sup>STRUCTURES I (4.30) is accepted as fulfilling this requirement, and will also be credited toward the Science Distribution Requirement, thereby providing 12 additional units of Unrestricted Elective.

### GRADUATE STUDY IN ARCHITECTURE

The Department offers graduate study programs at two levels: Bachelor in Architecture and Master in Architecture. B.Arch. is the degree awarded to students who complete a program, accredited by the profession, that is an essential step toward licensure for architectural practice. M.Arch. is a second professional degree awarded to students who extend their studies beyond the B.Arch. Both programs are designed as preparation for practice, although they may also attract students preparing for teaching, writing, or research.

#### ENTRANCE REQUIREMENTS FOR GRADUATE STUDY

Undergraduate preparation in architecture usually differs from that leading to advanced studies for scientific and engineering degrees. The following requirements are substituted for those in Section 3 of this Catalogue.

*Mathematics and Science.* Four semester subjects at college level in mathematics and/or the physical sciences.

*Humanities.* Six semester subjects in the humanities and/or the social sciences.

*Professional Preparation.* For the Bachelor in Architecture program: no professional preparation is required for admission. A Bachelor's degree or equivalent with a high academic standing from a recognized institution is required. When credit has been received for professional subjects taken elsewhere, advanced credit may be allowed upon evaluation and comparison with similar subjects at M.I.T. M.I.T. students who have completed the architecture program leading to the S.B. in Art Design, upon admittance, will have completed the equivalent of two years of professional preparation in architecture. For the Master in Architecture program: completion of the curriculum for the first professional degree in architecture in a department or school of architecture of recognized standing.

#### The Graduate Degrees

##### BACHELOR IN ARCHITECTURE

The degree of Bachelor in Architecture is awarded upon the satisfactory completion of an approved program of at least 164 units, of which 96 units must be in "A" subjects, and an acceptable thesis. Completion ordinarily requires two years of residence beyond the Institute's undergraduate degree of Bachelor of Science in Art and Design.

A substantial number of candidates are admitted with a Bachelor's degree from other institutions; those who have not yet studied in a department of architecture will usually require four years of residence to fulfill the requirements for the B.Arch. degree.

##### MASTER IN ARCHITECTURE

This program, open only to students who have already earned the first professional degree, is designed to promote study in depth; candidates with degrees from other institutions will be required to be in residence for two academic years, and to complete approved programs substantially greater than the minimal requirements stated below. Candidates with the Institute's degree of B.Arch., having already completed 96 units of "A" subjects, can fulfill the requirements for the degree M.Arch. upon the satisfactory completion of the following additional requirements: an approved program of 66 units, of which 42 units must be in "A" subjects including one term of architectural design, and an acceptable thesis.

## *Department of Urban Studies and Planning*

City planning is concerned with the physical environment of cities, the forces that affect this environment, and the effects this environment may have on society. In the last decade, the central focus has shifted from an emphasis on the public guidance and control of the physical form of communities, and questions of environmental quality, to a broader concern with issues of urban and regional development such as poverty, race, health, education, economic development, public participation and the distribution of power. Research and action are now focusing on questions such as the relation of social and economic planning to physical planning; the interaction of the spatial environment with the behavior, attitudes, and satisfactions of the user; the technical process of large-scale design; the formulation of national and local development policies for the management and programming of changes in the environment of cities and regions; the design and improvement of urban information systems; the fashioning of more comprehensive and more powerful analytical strategies for approaching land use, transportation and communication problems; and the reformulation of the basic urban and regional growth strategies now employed in the developing countries. The Department of Urban Studies and Planning seeks to increase understanding of these problems and to train professionals and scholars who can act as advisors, managers, or advocates in the processes of urban and regional development.

A student may choose to pursue a generalized program and develop competence as a general practitioner along the lines of the Department's long-established general work in urban and metropolitan land use planning and implementation. Or he may wish from the start to focus on some special areas. These possibilities should be kept in mind in considering the degree programs outlined in later sections.

### **OPPORTUNITIES FOR SPECIALIZATION**

*Social and Political Aspects of Urban Planning:* A special concentration, focusing on the social impact of urban development programs, is available: problems of race, housing and poverty; political participation in urban affairs; and

urban policy in the context of intergovernmental relations. This specialization includes Course work in the M.I.T. Department of Political Science.

*Economics and Planning:* Students may elect a doctoral program combining study in this Department with study in the Department of Economics. Achievement of a high level of scholarly competence in both fields is required. Planning students may also work out programs consistent with varying degrees of concentration in urban economics and other relevant Course work offered in both departments.

*City Design:* The Department offers special training in the field of city design — the spatial organization of activities and the shaping of the physical environment at city scale, with special reference to its esthetic qualities, its effects on psychological processes and immediate behavior. Our training and research in design at the city, rather than the project, scale is for the present a unique program. It seeks to develop a basic competence in city planning and in the method of design at that scale as well as a more special competence in understanding the visual consequences of city form.

*Transportation Planning:* This work deals with the relationships between transportation networks, the patterns and channels of movement of goods and people, and the organization of land uses. The program is closely linked to activities in urban and interurban transportation in M.I.T.'s other schools.

*Planning Problems of the Developing Countries of the World:* This specialization is for students interested in the problems of cities and regions in developing countries. Special consideration is given to migration and social change, the problems of squatters, the social and cultural transformation implied by urbanization and economic development and the various policy issues posed by these trends.

*Quantitative Methods in Urban and Regional Studies and Planning:* New problems and programs in urban affairs require the development of new quantitative approaches. Students entering

# Architecture

DEPARTMENT OF URBAN STUDIES AND PLANNING

with some mathematics background may be particularly interested in subjects and seminars in the design and use of information systems, the simulation of complex models (including demographic and metropolitan applications), probabilistic systems, decision theory, and optimal programming. The computer facilities in the Institute and the Department provide essential resources for this work.

## WORKSHOPS AND LABORATORIES

A basic teaching tool of the Department is the workshop. It focuses on hypothetical or pragmatic policy case studies, or problems which will incorporate innovative viewpoints in real situations.

In the spring of 1968 the Department inaugurated a Laboratory for Environmental Studies involving the participation of a large proportion of the departmental faculty, and, on occasion, faculty from other departments (Architecture, Political Science, Economics, Humanities, and the School of Management). The Laboratory receives some support from the M.I.T. Urban Systems Laboratory and the Harvard-M.I.T. Joint Center for Urban Studies, with whose work the teaching in the Department is closely linked, but its primary source of support lies in the contracts and grants it receives from foundations and agencies such as the Economic Development Administration (Department of Commerce) and the Department of Housing and Urban Development. Most of the faculty are engaged in research in the Laboratory and students also participate in most of the activities as research assistants.

The Laboratory's current activities fall into four primary areas of concern: (a) race and poverty — particularly development of policy and programs for dealing with the problems of ghettos in central cities; (b) psychological perception studies — development of techniques and models for the design of the spatial environment; evaluation of the impact of existing environments and of new designs; (c) developing countries — including studies of national policies for urban and regional development, studies of problems of migration and squatter settlements, and development of regional economic programming techniques; (d) information systems for urban analysis — exploiting the potential of the computer for a variety of purposes, including the development of an environmental data library (social, physical, economic and visual).

## THE UNDERGRADUATE CURRICULUM

### *Urban Studies and Planning (Course XI)*

It is expected that starting in the fall of 1970, a new undergraduate curriculum in urban studies will be offered in Course XI. For the first year, this program will be experimental and therefore open to a limited number of students.

The undergraduate program leading to the degree of Bachelor of Science in Urban Studies will be designed for students intending to work in the field of city and regional planning or in the general area of urban studies. It will furnish a basis for graduate work with an urban focus in several fields. There are also career opportunities for students who do not go on to graduate work.

Other undergraduate approaches to graduate work in urban studies include the city planning program in the Department of Architecture, and undergraduate curricula in Civil Engineering, Economics, Political Science, Management, and others.

## GRADUATE STUDY (COURSE XI)

The Department of Urban Studies and Planning offers graduate work leading to the degrees of Master in City Planning and Doctor of Philosophy. The Course is open to students with varying backgrounds; urban studies, architecture, landscape architecture, civil engineering, economics, sociology, law, and public administration all offer suitable preparation. Applicants from other fields are also accepted.

## ENTRANCE REQUIREMENTS FOR GRADUATE STUDY

Undergraduate preparation for city planning usually differs from that required for the scientific degrees. In place of the general requirements given in Section 3 of this Catalogue, the following are prerequisites for graduate study:

*Mathematics and Science.* Four one-semester college subjects in one or more of the fields of mathematics and the physical and natural sciences.

*Humanities.* At least six semesters of work in English, history, economics (or allied subjects), and other humanities subjects equivalent in scope to those included in the undergraduate curricula of the Institute.

*General.* A broad, sound general education, with competence in communication through oral, written, and graphic expression and through mathematics, is essential; previous specialization in some related field is also desirable.

Deficiencies in any of the above areas may be removed by taking comparable subjects at M.I.T.

### ***The Graduate Degrees***

The core knowledge expected of all graduate students includes the following elements:

1. A general understanding of contemporary urban society and its major components: social, economic, spatial, and political.
2. Skill in the techniques for analyzing urban and regional communities: their social and economic characteristics, spatial patterns, political structure, behavioral impact, and processes of change.
3. Skill in the synthesis of development policy, including the statement of the problem, the formulation of objectives, the generation and evaluation of alternative plans and policies, their implementation, and the monitoring and adjustment of action.

Subjects offered in this Department and listed under Descriptions of Subjects will usually provide the base for each student's specialization, as well as a resource for the required core of fundamental knowledge and skills. Students are also encouraged to take relevant subjects in other M.I.T. departments, and may cross-register at Harvard University for specialized subjects not available at M.I.T.

### **MASTER IN CITY PLANNING**

The typical program leading to the degree of Master in City Planning requires two to three years of study at M.I.T., depending both upon prior preparation and upon the specialization chosen.

No program of required subjects is prescribed. Each student, whether through previous experience, formal subjects, or independent study, is expected to acquire an understanding of a core of fundamental knowledge and skills, and to develop competence in some more specialized area. He sets his own program in collaboration with a faculty advisor in the light of his particular background and interests. His area may be in one of the fields described under Opportunities for Specialization, or may be in some other area related to urban or regional development in which this department, or other M.I.T. departments, can offer advanced work. An original thesis is required, occupying at least one term and often longer.

### **DOCTOR OF PHILOSOPHY**

Advanced students seeking research or teaching careers in city and regional planning or in urban studies may be accepted as candidates for the doctorate. Prerequisites are substantially the same as for the Master's degree. The general requirements for the Ph.D. degree are specified in Section 3 of this Catalogue.

Doctoral candidates must prepare for three general examinations, one covering basic planning fundamentals, the second on planning theory, and the third on the area of concentration chosen by each candidate. This area may be in any field related to city and regional planning in which this Department or other M.I.T. departments offer strong support.

Upon successful completion of examinations, the student is required to prepare a written doctoral thesis evidencing the capacity to do independent research.

No stated number of graduate subjects is required. Doctoral candidates who already hold the M.C.P. degree will require at least two terms of study in residence before beginning their theses. Other candidates may require up to six terms, depending on their preparation.

Doctoral study in city and regional planning may be associated with the research program of the Joint Center for Urban Studies of M.I.T. and Harvard University.

### **SPECIAL PROGRAM FOR URBAN AND REGIONAL STUDIES OF DEVELOPING AREAS (SPURS)**

This program provides an opportunity for a small number of unusually qualified persons to carry out a program of study and research for one academic year outside the regular degree requirements. The work of this group of Fellows is focused on the problems of urban and regional change within the broad context of national development. The main aim is to make it possible for some of the persons who will be shaping policy in the developing nations in the years to come to enhance their capacity to cope with these problems.

The program is designed to serve mature individuals who are now occupying or are likely to occupy significant positions in private or public organizations. They may be drawn from such varied fields as architecture, engineering, sociology or economics, from government or business, from any field in which there is a concern with problems of urban and regional development. Preference is given to persons from the developing countries, but some partici-

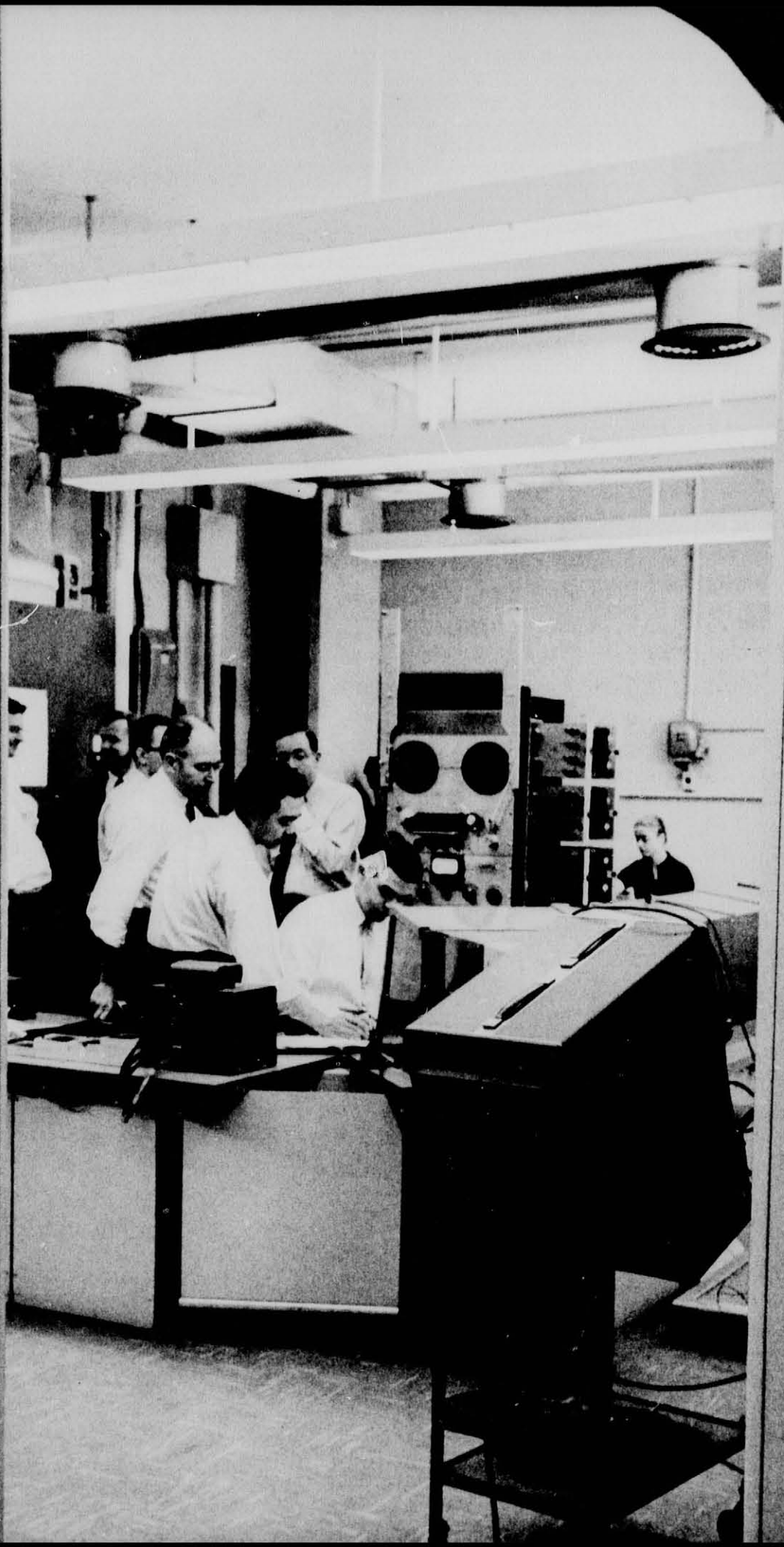
# Architecture

DEPARTMENT OF URBAN STUDIES AND PLANNING

pants come from Western Europe or the United States. The principal criteria for admission are the exceptional ability, experience and position of the individual. All applicants must have a thorough command of English.

The program is flexible. Fellows are encouraged to tailor their work to their own individual requirements. They would generally be permitted to select subjects offered at M.I.T. normally available to graduate students, subject to the approval of the instructor. Fellows may also pursue their own research or, when feasible, participate in ongoing programs.





## SCHOOL OF ENGINEERING 5.

*Dean Raymond L. Bisplinghoff describes the role of the engineer and M.I.T.'s program of education for leadership in engineering.*

It is the engineer who is bringing about the great revolution in technology. Largely by his efforts we are at last achieving the technical potential for the creation of a society free from want.

Increasingly the achievements of our engineering leaders derive more from a mature and imaginative exploitation of today's scientific knowledge than from ingenuity or tinkering, no matter how skillful these may be. Through a coupling of deep scientific skill with purposeful engineering motivation, engineers have provided, for example, a host of new machines and new materials; spectacular systems of transportation, communication, power and propulsion; and the tools for the automated mass production of consumer goods of many kinds. As engineers continue to enrich our society by conceiving, designing, building, and managing our great engineering and industrial systems, they are instigators of rapid change not only in engineering itself but in the economic, social, and cultural environment of the world.

Although engineers deal extensively with facts and scientific principles, they also must carry out their work as leaders of men. Their ultimate stature, therefore, often finds expression in those situations where judgment and wisdom weave the elements of scientific knowledge into the whole fabric of society.

In the future, the engineer will be called upon to participate with increasing frequency and in greater depth in programs that cut across a wide spectrum of disciplines and involve an increasing number of social and economic factors. The opportunities for the engineer to provide leadership in these areas are vast. Accordingly, the educational plan at M.I.T. interlaces a sequence of studies in science, engineering, and the humanities with involvement in research, in a manner that embraces all the elements of a truly liberal education.

Among M.I.T.'s 34,000 engineering alumni are many who have become independent professional consultants, college or university professors, or entrepreneurs responsible for their own businesses. The majority of them, however, are either on the staffs of industries, where they perform technical work of a highly varied and challenging character, or are members or leaders of management in industry. As the impact of engineering in world affairs accelerates, M.I.T. engineers in ever-increasing numbers have the distinction of serving as advisors to government on many important issues.

The various curricula within the School of Engineering are sufficiently general to assure that no student is confined to a narrow specialization. In fact, specialized knowledge is now of such quantity and its application is so sophisticated that it cannot be mastered in four, five, or even six years. Further-

# Engineering

SCHOOL OF ENGINEERING

more, the engineer and the scientist, working in concert, are setting such a pace in technological change that specialization is often outmoded several times within the span of a professional lifetime.

It is not enough merely to prepare an engineer to keep abreast of a particular contemporary technology. Accordingly, the goal of the School is to equip its students with an understanding of the basic sciences — mathematics, physics and chemistry — and of the engineering of science; and to develop in them a versatility of mind and an ability to learn anew so that, as professional engineers, they will work at the frontiers of their field and bring forth new technologies, the very nature of which may be essentially unknown during the period of their formal education.

The curriculum of the freshman year encompasses study of the basic sciences, mathematics, and humanities. In the sophomore year, the student normally continues these studies with subjects leading to the fulfillment of the Science Distribution, Laboratory, and Humanities requirements. While some technical and professional subjects that lead to a major field may begin in the sophomore year, the majority of these subjects are taken in the later years.

Mature professional education may begin during the senior year but finds its full expression only in the graduate years. The student who decides early in his program on the broad field of his major may enter a department at the beginning of the sophomore year. In most instances this student may elect, for about one-fourth of his sophomore studies, subjects that are a definite part

of his major program. On the other hand, the student who wishes to postpone his choice of department until the end of the sophomore year need not necessarily delay his graduation beyond four years, because any sequence of elective subjects he chooses to fill the elective time of the sophomore year will be credited to his total degree requirements.

The basis of choice among engineering fields should lie within — rather than outside — each student's mind and personality. When assessing the question of becoming identified with a particular engineering field during a period of study, a student is wise to choose the one which provides an immediate, potent source of motivation and inspiration rather than to attempt to foresee what his permanent area of professional activity may be. To find expression for one's gifts and to carry one's education as far as those gifts justify is the essential purpose of higher education.

The undergraduate programs of each department of the School of Engineering are built upon a strong scientific base to give knowledge of enduring value. Each program leads to a wide range of choice of a career and serves as preparation for continued on-the-job study following graduation, or further formal graduate study in a broad spectrum of fields. A student may thus safely follow his own intuition with the conviction that his training will equip him for the unknown future, whatever the details of his professional career may be.

RAYMOND L. BISPLINGHOFF

**THE UNDERGRADUATE CURRICULA  
IN THE SCHOOL OF ENGINEERING**

The S.B. curricula in the School of Engineering consist of a common program of general education emphasizing science, mathematics, and the humanities and social sciences (the General Institute Requirements) and groupings of subjects appropriate to particular engineering fields (the Departmental Programs). The General Institute Requirements are given on page 47. The Departmental Programs are given by each department in the following pages.

Each student arranges his program of studies with the advice and consent of a Faculty Counselor. Examples of Course schedules are issued each term by the Registrar with the Class Schedules. R.O.T.C. subjects may be used according to the specifications in Section 2.

# Engineering

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

## *Department of Aeronautics and Astronautics*

The engineer is sometimes described as a builder of bridges between science on the one hand and the needs of society on the other. The engineer practicing in the fields of aeronautics and astronautics bridges science with the specific social needs of transportation, national defense and the exploration of space. Aeronautics embraces the atmospheric flight of vehicles ranging from VTOL (Vertical Takeoff and Landing) aircraft, including helicopters, to the supersonic transport and hypersonic aircraft. Astronautics involves the flight of such vehicles as long-range ballistic missiles, satellites, and interplanetary spacecraft beyond the atmosphere in the vast airless regions of space. The objective of the education offered by the Department of Aeronautics and Astronautics is to prepare its graduates for leadership in the processes of research, development and operation as they relate to aeronautical and astronautical vehicles. To serve these objectives the Department curriculum, in addition to the Institute core offerings in humanities, science and mathematics, embraces the engineering sciences and technologies which are regarded as fundamental to contemporary aeronautics and astronautics. There is at the same time a strong emphasis on systems subjects, available as electives, which are superimposed upon the several disciplinary subjects and act as a means for giving the student an awareness of the relations among them and a feeling for the interconnected whole.

The interests and fields of specialty of the faculty of the Department range from the aeronautical and space sciences and technologies on the one hand to systems engineering on the other. This variety in background and interest makes it possible for the Department to offer a balanced education in aeronautics and astronautics with flexibility to meet student desires and to encourage maximum development of individual abilities. Engineering science electives are offered to those interested primarily in research, while professional engineering subjects are available to those attracted to engineering development and operations. Throughout the Department's offerings, the view is taken that it is less important for the student to learn spe-

cialized knowledge in detail than it is to acquire the attitudes of applying science to achieve engineering objectives; to learn how to explore new technical ideas, express and test them and examine their implications; and to develop a feeling for the innovations, compromises, judgments and attention to detail required for technological advancement. Every subject taught by the Department is regarded as an instrument to instill these attitudes in its students.

In order to deal effectively with the range of subjects underlying the processes of research, development and operations, the Department faculty is presently divided into five major divisions of instruction. Each division includes faculty members and subject offerings which are fundamental to both aeronautics and astronautics. The five divisions are the following: mechanics and physics of fluids; materials, structures and aeroelasticity; propulsion and space power; aeronautical and astronautical systems; instrumentation, control and guidance. Many faculty members work with more than one division, thereby promoting a broader understanding within the faculty of the conditions associated with the research, development and operation of flight vehicle systems. Because of the exceptionally stringent character of these conditions, the small design margins that separate success from failure make the problems of flight vehicle engineering among man's most difficult and challenging.

Progress in aeronautics and astronautics continues to be so rapid that effective education must deal not only with the circumstances of today but also those to be expected in the future. Faculty service with government and industry advisory committees and consulting on significant aerospace problems help fulfill the need for coupling education with current practice. Another means for insuring that faculty members continue to be well informed and retain leadership in their professional areas is active personal participation in research. An important characteristic of the Department is that, on the basis of his own free choice, each faculty member may be associated with research work in either academic facilities or laboratories

assisted by outside sponsorship. Experience and information gained from such research is generally incorporated first in graduate subjects and is then applied to the updating of all subjects offered by the Department. The laboratories also make it possible for undergraduates at all levels, including freshmen, for graduates, and for postgraduates to work with faculty members on a wide variety of advanced projects. Students frequently assist with laboratory work, carry out special projects, and use laboratory facilities; they have the advantage of advice from the laboratory staff on undergraduate and graduate theses. The laboratories also have funds to pay for service not associated with academic credit, so that students often can earn money toward academic expenses while gaining valuable professional experience.

The Department is organized for research into two divisions, each with several sections. The Aerospace Research Division includes the Fluid Dynamics Research Laboratory, the Aerophysics Research Laboratory, the Aeroelastic and Structures Research Laboratory, the Wright Brothers Wind Tunnel Facility, the Space Propulsion Laboratory, the Measurements Systems Laboratory, the Man-Vehicle Control Laboratory, the Gas Turbine Laboratory, the Flight Transportation Laboratory and various facilities used for individual research by faculty members. The Instrumentation Division includes the guidance systems section, the guidance component section, and the guidance test facilities sections.

The Aerospace Research Division has equipment for research in all regions of flight, from hovering to interplanetary operations. Gas dynamic research is carried out in the hypersonic wind tunnel (Mach number 7.5) and in the supersonic wind tunnel of the Aerophysics Research Laboratory. Fluid mechanics research occupies a low-speed, low-turbulence wind tunnel. Two larger low-speed wind tunnels are used for airplane and VTOL research. High-vacuum spheres and molecular-beam techniques are employed in the Fluid Dynamics Research Laboratory to simulate low-density space environments and study interactions of the environment with vehicle surfaces. Structural dynamics research, including blast and high-velocity impact effects, is carried on in the Aeroelastic and Structures Research Laboratory. Facilities for ion propulsion studies are available in the Space Propulsion Laboratory,

while the Gas Turbine Laboratory, manned jointly with the Department of Mechanical Engineering, conducts research on the aerodynamics of turbines, compressors, combustion, and mixing jets. The Measurements Systems Laboratory is engaged in research on interplanetary navigation systems and in research and flight-testing of systems for celestial observations from stations in the upper atmosphere. Simulator equipment is used for studying human reactions in the Man-Vehicle Control Laboratory.

The Instrumentation Division pioneers in the development of control and guidance equipment for aircraft, missiles, and space vehicles. Inertial guidance receives special attention, and the Laboratory is equipped with advanced facilities for research on all phases of control and guidance. Projects dealing with systems for helicopters, airplanes, submarines, missiles, satellites, and manned lunar craft are currently in progress and offer many kinds of student participation.

In addition to the research facilities described, a Projects Laboratory is maintained for the purpose of allowing students to carry out experiments which they themselves conceive and design. Students who have acquired reasonable levels of skill in the Projects Laboratory usually move into other laboratories of the Department.

Seminars on topics of historic and current general interest in aeronautics and astronautics, conducted by leaders in their fields, are held on Tuesday afternoons throughout the school year. Because of their educational value, seniors and graduate students are expected to join the staff in attending these seminars.

#### **THE UNDERGRADUATE CURRICULUM** *Aeronautics and Astronautics (Course XVI)*

Undergraduate study in the Department leads to the degree of Bachelor of Science in Aeronautics and Astronautics at the end of four years. The curriculum provides flexibility to meet the needs of careers in aerospace activity ranging from scientific research to responsible engineering direction of large enterprises. Each student elects an individual program tailored to his interests, built on firm grounding in science and on a broad base in the engineering sciences, from a wide selection of available subjects. With the advice of his Faculty Counselor, he plans an undergraduate program which is reviewed each term and which may be changed at any time.

# Engineering

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

The curriculum requirements for the Bachelor of Science degree are as follows:

**GENERAL INSTITUTE REQUIREMENTS** (see page 47) Total units

Specific science and humanities and social science subjects. 132<sup>1</sup>

The subjects 8.03, 16.20, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 50) and can be used to satisfy the Science Distribution Requirement.

The subject 16.62, which is required in the Departmental Program, appears on the list of Laboratory Subjects (see page 51) and can be used to satisfy the Laboratory Requirement.

**DEPARTMENTAL PROGRAM**

*Required Subjects*

16.001T	THERMODYNAMICS AND STATISTICAL MECHANICS	4	0	8
8.03	PHYSICS III	5	0	7
16.20	SOLID MECHANICS I	4	2	6
18.034	DIFFERENTIAL EQUATIONS	3	0	9
3.141	SCIENCE OF MATERIALS	4	3	5
6.14T	INTRODUCTION TO ELECTRONICS	4	2	6
16.01	DYNAMICS	4	2	6
16.62	EXPERIMENTAL PROJECTS	2	6	4
				96

*Restricted Electives*

16.02	AERODYNAMICS	4	2	6
<i>or</i>				
16.03	GASDYNAMICS			
<i>At least three subjects chosen from the following:</i>				
16.031	TOPICS IN FLUID MECHANICS	3	0	6
<i>or</i>				
16.11	AERODYNAMICS OF FLIGHT VEHICLES	4	0	6
16.201	SOLID MECHANICS II	4	0	6
16.30	PRINCIPLES OF AUTOMATIC CONTROL	3	0	9
16.40	PRINCIPLES OF FLIGHT GUIDANCE	3	0	9
16.53	ROCKET PROPULSION	3	0	6
<i>or</i>				
16.54	AIRCRAFT ENGINES	2	3	7
16.71	FLIGHT VEHICLE ENGINEERING	4	0	8
<i>or</i>				
16.73	SPACE SYSTEMS ENGINEERING	4	0	8

*Unrestricted Electives<sup>2</sup>*

40 to 48

92 to 84

Total units required for the S.B. degree 360

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> Schedules of students in Course XVI may always be arranged to leave available 24 units of unrestricted elective in the second year.

During the first two years, subjects elected by the student will be mainly in the areas of science and engineering science. If he wishes to specialize as fully as possible in his education in aeronautics and astronautics, he will choose subjects recommended by the Department, thereby gaining flexibility and elective freedom in his upper years. These subjects are in varied fields, in

keeping with the wide range of the Department's interests, so that this course of action is consistent with a desire for program diversity and breadth.

Usually a student begins to follow the program in aeronautics and astronautics in the fall of his second year. During that year, he is advised to take the first four subjects listed above, namely 8.03, 18.034, 16.001T and 16.20. He may also, with profit, elect 3.141, if he has not already done so as a freshman. Other desirable choices would include mathematics beyond 18.034, physics beyond 8.03, fields in continuous media, 16.09, or, from the above list, 16.01 or 6.14T.

A student who elects Course XVI at the end of his second year can arrange an acceptable program by using some of the elective freedom available in the upper years to satisfy the departmental subject requirements. However, such a program will be correspondingly limited in depth.

During the first two years and apart from science and engineering science subjects, many students will wish to obtain a broad view of the aerospace field or a deeper insight into one of its aspects under the tutelage of an experienced engineer or scientist. Undergraduate electives and seminars meet this need.

During the third and fourth years programs may be drawn from a wide range of subjects, depending on a student's interests. As a base, he may well use some of his elective freedom to take more than three of the six restricted electives listed above. He will still have opportunity to choose continuing subjects in the Department's varied fields of interest. Any student may elect to do a Bachelor's thesis in his fourth year.

**Aeronautics and Astronautics (Cooperative Course) (Course XVI-B)**

The cooperative program for Aeronautics and Astronautics undergraduates provides the opportunity to spend about seven months in an aerospace organization before the senior year. This length of industrial practice enables the student to advance to more interesting and professionally rewarding experience than can be gained in summer employment. The program permits completion of requirements for the Bachelor's degree in four years.

Students in the program become regular employees during their period of employment and are subject to the regulations of the company. Cooperating companies in the aerospace industry pay students at prevailing rates during

their period of employment. Students pay their own expenses while away from the Institute.

A student interested in the program should apply to the professor in charge for particulars and an interview and also should, with his Faculty Counselor, arrange a schedule which permits his absence from Cambridge during the second term of the third year. This should be done before January of the sophomore year since subject choices in the second term of the second year may be affected.

#### CURRICULUM IN THE COOPERATIVE COURSE (COURSE XVI-B)

The Cooperative Course leads to the degree of Bachelor of Science in Aeronautics and Astronautics. The curriculum requirements for this degree are the same as for Course XVI, except for the addition of required plant work in place of 8 units of elective:

16.85 INDUSTRIAL PRACTICE 0 8 0

#### GRADUATE STUDY IN AERONAUTICS AND ASTRONAUTICS

Graduate students in the Department of Aeronautics and Astronautics study and conduct research in the engineering and scientific aspects of many problems of flight transportation. Fields of endeavor may be fairly general; programs may be oriented to aeronautical or astronautical engineering or to aeronautics or astronautics, in which case there will be less emphasis on engineering applications. Major fields of specialization include:

Aerodynamics and gasdynamics  
Aeroelasticity  
Aeronautical and astronautical engineering  
Automatic control  
Flight guidance  
Flight transportation  
Fluid mechanics  
Instrumentation  
Physics of fluids  
Plasma physics and space sciences  
Propulsion  
Space mechanics  
Structures  
Vehicle design

Advanced study in the Department leads to the degrees of Master of Science in Aeronautics and Astronautics; Engineer in Aeronautics and Astronautics; Materials Engineer; Doctor of Science or Doctor of Philosophy.

#### *Entrance Requirements for Graduate Study*

In addition to the general requirements for admission to the Graduate School, all appli-

cants must have a strong undergraduate background in fundamentals of mechanics, thermodynamics, and electrical science. Additional undergraduate preparation is a prerequisite for specialization in particular fields. Some prerequisites may be completed early in a graduate program.

#### *The Graduate Degrees*

##### MASTER OF SCIENCE IN AERONAUTICS AND ASTRONAUTICS

The general requirements for the Master's degree are given in Section 3. To complete the requirements of at least 66 subject units, of which 42 units must be in "A" subjects, and an acceptable thesis generally takes one academic year. Two terms of advanced mathematics beyond DIFFERENTIAL EQUATIONS (18.034) or its equivalent must be included.

Although excessive specialization is undesirable, it is expected that most candidates for this degree will concentrate in a single professional field, not seeking the breadth of educational background implied by the Engineer degree.

##### ENGINEER IN AERONAUTICS AND ASTRONAUTICS

The general requirements for the Engineer degree are given in Section 3. The minimum program of 162 subject units and an acceptable thesis usually takes at least two years for completion. Subjects in a variety of professional specialties are required, so as to provide a broad foundation in both aeronautical and astronautical science and their engineering applications. The Department may accept a Master's thesis of superior quality for the Engineer's degree.

Requirements for admission to candidacy for the degree of Engineer in Aeronautics and Astronautics are more rigorous than for the degree of Master of Science in Aeronautics and Astronautics.

##### DOCTOR OF SCIENCE (OR PHILOSOPHY)

The general requirements for the doctor's degree are given in Section 3. To be recommended for this degree by the Department of Aeronautics and Astronautics, the student must complete an approved program, including a thesis. Such a program probes more deeply into a special field than the program for the Engineer degree and does not necessarily include the same breadth of engineering applications. Competence must be demonstrated by a Qualifying Examination designed to test the candidate's grasp of the principles of mathematics and physics and their application to simple situations.

# Engineering

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

A Minor program is required. A General Examination later tests the depth of the candidate's understanding of his major field of study. The thesis must demonstrate the student's ability to carry out independent original research of high quality on a problem of aeronautical or astronautical science or engineering.

## **SPECIALIZATION IN THE FIELD OF INSTRUMENTATION**

For the doctor's degree, the student is required to complete an approved program and a thesis in one of the interrelated fields of instrumentation which include automatic control; navigation and guidance of vehicles; optimum control principles and their application to various types of plants; information systems, and system components. This program involves study in and participation by the Departments of Aeronautics and Astronautics, Electrical Engineering, Mechanical Engineering, Mathematics, and Physics. It is administered, for registration purposes, by the Department of Aeronautics and Astronautics. Competence must be demonstrated by a Qualifying Examination designed to test the candidate's grasp of the principles of mathematics, physics and control theory. The General Examination includes both written and oral parts. The thesis must demonstrate the ability of the student to do original research of high grade on a problem of instrumentation or weapons systems engineering.

## **SPECIALIZATION IN THE FIELD OF MATERIALS ENGINEERING**

There has arisen in recent years a very strong interaction between the field of materials and flight vehicle development. It may be said that material properties impose limitations on either the performance or efficiency of most flight vehicles and their propulsion systems. Graduates who have preparation in the combined fields of aeronautics and astronautics and materials science are required in increasing numbers to deal with these important interdisciplinary problems.

Graduate students with undergraduate backgrounds in aeronautics and astronautics may pursue programs leading to the degrees of Materials Engineer or Doctor of Science or Doctor of Philosophy. The same general requirements for the completion of these degrees are applicable as for the corresponding degrees in Aeronautics and Astronautics.

Programs of study leading to the degrees of

Materials Engineer and Doctor of Science or Doctor of Philosophy are arranged on an individual basis, depending upon the preparation of the student. In general, such programs will involve a substantial number of subjects in the fields of metallurgy, physics, and chemistry in addition to subjects within the Department.

## **Language Requirement**

There is no language requirement for candidates for the Master of Science or Engineer degrees. A candidate for a doctoral degree is normally required to fulfill the departmental language requirement before his third year in residence. The language choice must have prior approval of his Graduate Registration Officer.

## **Financial Assistance for Graduate Study**

The Department offers several fellowships for full-time study in aeronautics and astronautics.

The fellowships, which allow students to pursue full-time programs of study, are described in Appendix A of this Catalogue.

The assistantship program provides a unique opportunity to progress toward a graduate degree through combined registration for academic subjects and research leading to the thesis. The research assistant works with a faculty supervisor on a specific research assignment. The experience gained in organizing work, in learning and applying new experimental techniques and analytical tools, and in technical writing, is invaluable in any career in engineering. In most cases, a student can be placed in the technical area in which he desires to concentrate his study and to carry on his thesis research.

The Department also offers a limited number of teaching assistantships.

## Department of Chemical Engineering

(Including the School of Chemical Engineering Practice)

Chemical engineers have contributed notably to the development of process industries such as chemicals and petroleum. These industries are now rapidly expanding in areas such as synthetic organics, microbiology, pharmaceuticals, plastics, petrochemicals, new metals, and atomic energy. The chemical engineer must be equipped to do more than handle present problems; he must understand the principles involved in new developments and be prepared to pioneer in unknown areas. The Department's primary aim is to cultivate its students' capacities for handling new problems with competence.

The Department of Chemical Engineering offers two undergraduate programs: Chemical Engineering (Course x), leading to the degree Bachelor of Science in Chemical Engineering; and Chemical Engineering (Course x-c), leading to the degree Bachelor of Science. The latter requires less study in chemistry and chemical engineering, resulting in additional elective time for those students who desire to take more subjects in other areas. In addition, there is a wide selection of graduate subjects and research leading to advanced degrees in Chemical Engineering and Chemical Engineering Practice. The interests and offerings of the staff range broadly over the fields of process engineering and applied chemistry and include specializations in engineering operations, applied chemistry, and fuel engineering. This breadth permits students considerable selectivity in advanced phases of undergraduate work and in graduate study.

The School of Chemical Engineering Practice involves one term of work under the direction of Institute faculty at the Practice School Stations. There each student has a unique opportunity to develop the ability to apply basic professional principles to the solution of practical problems in industry. Study at the field stations is generally included in a program for a Master's degree.

### THE UNDERGRADUATE CURRICULA

The undergraduate subjects provide basic studies in physics and mathematics, a major concentration in chemistry, and a strong core of chemical engineering. The four-year under-

graduate programs, designed to develop judgment, initiative, and responsibility, give each student considerable latitude in arranging a selection of subjects that will best fit his needs and develop his aptitudes. Those who expect to go on to Graduate School may therefore elect subjects which will strengthen their preparation for advanced work.

In addition to work in science and engineering, students take an integrated sequence of subjects in the humanities and social sciences. The chemical engineer's progress and accomplishments are not determined solely by technological competence; fully as important are his breadth of outlook and understanding of society.

The curriculum is designed to give undergraduates a sound basis for further developing their aptitudes and interests through industrial work, independent study, or graduate work.

In order to permit different undergraduate programs, a wide latitude of free choice of subjects within the chemical and chemical engineering areas is provided. Consequently, each student should plan, with the aid of his Faculty Counselor, a program which fits his interests and capabilities. It is especially important that he recognize early the extent of his interest in graduate work.

### PROGRAM FOR THE DEGREE: BACHELOR OF SCIENCE IN CHEMICAL ENGINEERING

#### Chemical Engineering (Course X)

The Course in Chemical Engineering leads to the degree of Bachelor of Science in Chemical Engineering. The curriculum requirements for the degree are given below:

GENERAL INSTITUTE REQUIREMENTS (see page 47)	Total units
Specific science and humanities and social science subjects.	132 <sup>1</sup>
The subjects 5.60, 10.12, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 50) and can be used to satisfy the Science Distribution Requirement.	
Laboratory Requirement (see page 51).	12

### DEPARTMENTAL PROGRAM

Required Subjects	
5.41T INTRODUCTION TO STRUCTURE, BONDING AND MECHANISM	4 0 8
5.60 CHEMICAL EQUILIBRIUM	4 0 8
5.62 PHYSICAL CHEMISTRY	4 0 8

(continued)

# Engineering

## DEPARTMENT OF CHEMICAL ENGINEERING

<i>Required Subjects (continued)</i>			
10.12	STAGED CASCADES IN CHEMICAL PROCESSING	3	3 6
10.13	CHEMICAL ENGINEERING THERMODYNAMICS	4	0 8
10.15	<sup>2</sup> THESIS REPORTS	0	4 0
10.26T	CHEMICAL ENGINEERING LABORATORY	0	10 0
10.301	MODES OF HEAT AND MASS TRANSFER	4	0 6
10.37	CHEMICAL KINETICS AND REACTOR DESIGN	3	0 6
18.034	DIFFERENTIAL EQUATIONS	3	0 9
	THESIS		12 117

### *Restricted Electives*

Chemistry or Biology (in addition to the above required subjects) at least **24**

Chemical Engineering (in addition to the above required subjects) at least **24**

Laboratory work (within the above categories of electives, at least 6 units in addition to the General Institute Laboratory Requirement, 10.12, 10.26T, and THESIS)

*Unrestricted Electives*<sup>3</sup> up to **51**

Total units required for the S.B. degree **360**

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> 10.15 is a "time-arranged" subject.

<sup>3</sup> Schedules of students in Course x may always be arranged to leave available 12 units of unrestricted elective in the second year. The Unrestricted Electives must be at least 48 units.

Electives in chemistry are normally selected from the following: a second term of organic chemistry (5.42); a further term of physical chemistry (5.63); a term of inorganic chemistry (5.03); and relevant laboratory subjects. Electives in chemical engineering normally include most of the following: engineering operations (10.302 or 10.311, and 10.312); structure and properties of non-metallic substances (10.21) and industrial chemistry (10.18).

Additional opportunity for experimental research, with considerable flexibility in scheduling, is provided in Experimental Research Problem (10.91), 12 units of which satisfy the General Institute Laboratory Requirement. Students with a strong interest in a professional minor may satisfy this interest by use of the scheduled free elective time.

The student who decides early to major in chemical engineering is encouraged to begin taking professional subjects right away. For example, 5.41T or 5.60 satisfies the Institute requirement in Chemistry. Both are required in the Departmental Program and either one or both may be taken in the freshman year. In the second year, the Chemical Engineering subjects (10.12 and 10.13), Physical Chemistry

(5.62), and additional mathematics may be taken. The student would then be in an excellent position for professional work in some depth in the third and fourth years.

Some students may wish to defer choice of major field until the end of two years; or they may decide upon chemical engineering early but still wish, because of strong secondary interest in other engineering or scientific areas, to exercise maximum freedom in the first two years. They will have 12 units of elective time in the first year and, if their second year includes two subjects in humanities and a third term of mathematics, 60 units will remain to be chosen. If two of the Science Distribution Subjects chosen are in the field of fluid mechanics, thermodynamics, chemistry, biology, chemical engineering (examples: 2.403, 3.00, 5.41T, 5.60, 7.01, 10.12), a student can generally complete the requirements for a degree in chemical engineering in two more years. This leaves 36 hours to his own choosing in the second year; but he will have sacrificed some of his elective freedom of the third and fourth years. He is advised to discuss his proposed program with a Course x Faculty Counselor as soon as he becomes interested in a degree in chemical engineering.

### MATERIALS SCIENCE AND ENGINEERING

A sound training in the fundamental physics and chemistry which underlie the useful macroscopic properties of materials, and their response to environment and manipulative processes, has in recent years become of great importance to the engineering community at large and to the chemical engineering profession in particular. The area of polymeric materials (plastics, elastomers, coatings, and adhesives) occupies an important place in the domain of chemical engineering, and the Department offers a strong teaching and research program in this field.

Recognizing that a growing number of the students who are motivated toward chemical engineering as a profession may wish to develop special competence in the fundamentals of materials science, the Department offers a program in Materials Science and Engineering.

This program involves a significant study in chemistry and chemical engineering and an integrated program of subjects in the materials area offered by the Departments of Physics, Chemistry, Metallurgy and Materials Science, and Mechanical, Civil, Nuclear, Electrical, and Chemical Engineering. Students interested in

this field should arrange with a Faculty Counselor a program that best fits their objectives.

**PROGRAM FOR THE DEGREE: BACHELOR OF SCIENCE  
Chemical Engineering (Course X-C)**

The degree allows a student to plan a program involving basic subjects in chemistry and chemical engineering, but instead of continuing in depth in these areas, he can arrange for study in other fields (such as other engineering disciplines, biology, biomedical engineering, economics, and management).

The student planning to follow this curriculum should discuss his interest in such a degree with a member of the faculty of the Department. No later than the first term of his junior year, he should submit to the Department a statement of his goals and a program of subjects which will achieve these objectives. The student will be assigned a member of the department faculty as his advisor.

	<i>Total units</i>
<b>GENERAL INSTITUTE REQUIREMENTS</b> (see page 47)	<i>units</i>
Specific science and humanities and social science subjects.	<b>132<sup>1</sup></b>
The Science Distribution Requirement will be satisfied by 5.60 and 10.12, which are required in the Departmental Program, plus appropriate subjects (see page 50) totaling	<b>12</b>
Laboratory Requirement (see page 51).	<b>12</b>
<b>DEPARTMENTAL PROGRAM</b>	
<i>Required Subjects</i>	
5.41T INTRODUCTION TO STRUCTURE, BONDING AND MECHANISM	4 0 8
5.60 CHEMICAL EQUILIBRIUM	4 0 8
10.12 STAGED CASCADES IN CHEMICAL PROCESSING	3 3 6
10.13 CHEMICAL ENGINEERING THERMODYNAMICS	4 0 8
	<hr style="width: 10%; margin-left: auto; margin-right: 0;"/> 48
<i>Restricted Electives</i>	
A coherent program of subjects, with at least 24 units in chemical engineering, in addition to those in the Departmental Program, designed to achieve a specific educational goal. The program is to be planned by the student in consultation with a designated Faculty Counselor in the Department of Chemical Engineering.	at least <b>100</b>
<i>Unrestricted Electives<sup>2</sup></i>	up to <b>56</b>
Total units required for the S.B. degree	<b>360</b>

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128, the Unrestricted Elective units being increased by 4.

<sup>2</sup> The Unrestricted Electives must be at least 36 units.

**GRADUATE STUDY IN CHEMICAL ENGINEERING**

Because of the breadth of the field of chemical engineering, the undergraduate Course must be devoted primarily to training in fundamentals; strictly professional subjects are necessarily ele-

mentary in character. Postgraduate study is therefore of particular importance and value to the chemical engineer.

The following advanced degrees are offered in chemical engineering: Master of Science in Chemical Engineering, Master of Science in Chemical Engineering Practice, Chemical Engineer, Materials Engineer, Doctor of Science or Doctor of Philosophy. Programs for the Master of Science degree are usually arranged as a continuation of undergraduate professional training on a more mature basis. Work for the Engineer and doctoral degrees is more specific in character, and the Department offers coordinated programs in eight fields: applied chemistry, biochemical engineering, biomedical engineering, catalysis and reactor engineering, engineering operations, fuel engineering, materials engineering and polymers and plastics. Special programs are developed for individual cases.

**Entrance Requirements for Graduate Study**

In addition to the general requirements for admission to the Graduate School set forth in Section 3 of this Catalogue, preparation in physical chemistry and organic chemistry equivalent to CHEMICAL EQUILIBRIUM (5.60) and PHYSICAL CHEMISTRY (5.62) and ORGANIC CHEMISTRY (5.41T, 5.42) is normally essential.

**Requirements for Advanced Degrees**

The general requirements for the various degrees are specified in Section 3. A Minor is required by the Department.

**Fields of Study**

The technology of chemical engineering in the process industries falls loosely into two categories: physical and chemical. While both types are encountered in many industrial problems, graduate subjects of instruction and research are logically grouped in the corresponding fields of engineering operations and applied chemistry. Most graduate students take some work in each field, and in the School of Chemical Engineering Practice the problem assignments involve fundamentals in both areas.

**ENGINEERING OPERATIONS  
(PROCESS ENGINEERING)**

The variety of graduate offerings provides opportunity for programs in heat transfer, fluid mechanics, and the separation processes based on mass transfer — subjects which are basic in

# Engineering

DEPARTMENT OF CHEMICAL ENGINEERING

process engineering. The topics include thermodynamics, applied mathematics, molecular transport properties, fluid mechanics and the interrelation of mass, momentum and heat transfer, distillation, mass transfer between phases, combustion, economic balance, and plant design. Opportunities for research of an advanced nature are available.

Relevant subjects offered by the Department include:

ANALYTICAL TREATMENT OF CHEMICAL ENGINEERING PROCESSES (10.33)  
CHEMICAL ENGINEERING THERMODYNAMICS (10.40)  
DISTILLATION (10.41)  
ION EXCHANGE (10.47)  
HEAT AND MASS TRANSFER (10.50)  
MECHANICS OF FLUIDS (10.52)  
CHEMICAL ENGINEERING DESIGN (10.53)  
ADVANCED TOPICS IN MASS TRANSFER (10.54)  
PRINCIPLES OF COMBUSTION (10.70)

Programs may also include advanced subjects in mathematics, instrumentation, fluid mechanics, metallurgy, and others offered in other departments.

## APPLIED CHEMISTRY

The Department offers a diversified program in applied chemistry, designed for the student who wants to broaden his competence in the chemical aspects of chemical engineering. This program provides subjects in industrial chemistry and chemical thermodynamics; in chemical kinetics and theory of rate-processes, with emphasis on heterogeneous and catalytic processes; and in the physical chemistry of ion-exchange, adsorption, and chromatography. The subjects listed under Materials Science and Engineering (below) also include several on applied chemistry. Much of the Department's research activity falls into these areas, and unique laboratory facilities are provided.

Relevant subjects offered by the Department include:

INDUSTRIAL CHEMISTRY (10.25)  
ION EXCHANGE (10.47)  
PROPERTIES OF GASES AND LIQUIDS (10.59)  
CATALYSIS (10.602)  
ELECTROCHEMISTRY (10.62)  
APPLIED CHEMICAL KINETICS (10.65)  
CHEMICAL ENGINEERING IN MEDICINE (10.56)

A well-rounded program in applied chemistry might also include subjects given by other departments in advanced organic, inorganic, or physical chemistry; in biochemistry, enzymology, or bacteriology; and in physical metallurgy, electrochemistry, corrosion, or ceramics.

## MATERIALS SCIENCE AND ENGINEERING

The Department maintains an active and diversified graduate research program in surface and

colloid chemistry, polymer chemistry, and polymer physics and offers a coordinated instructional program in these areas. Students whose interests lie in the direction of surface phenomena or polymeric materials thus have a rare opportunity to develop specialized skills in these areas in an atmosphere where the focus of attention is on the applied, as well as the basic, scientific aspects. Specific subjects offered are:

PHYSICS AND CHEMISTRY OF SURFACES (10.61)  
STRUCTURE AND PROPERTIES OF POLYMERS (10.64)  
SURFACE SCIENCE AND ENGINEERING (10.66)  
PHYSICAL CHEMISTRY OF POLYMERS (10.68)  
POLYMERIZATION PROCESSES (10.69)

Graduate research activities in these fields include topics such as the rheology of polymer solutions and particulate dispersions, molecular transport phenomena in polymers, structure and properties of microcrystalline thermoplasts, permselective membranes, chemisorption on semiconductors, fluid transport in microporous solids, crystal growth kinetics, and wetting processes. Collaboration between Chemical Engineering and many other departments in the supervision of these research projects brings an interdisciplinary approach to the entire program.

For students with strong interest in materials and an adequate background in chemistry or chemical engineering, the Department offers special graduate curricula leading to the degrees of Materials Engineer and Doctor of Science or Doctor of Philosophy. These curricula are designed to provide a properly integrated background in the science and engineering of the major classes of materials (metals, ceramics, and polymer) and also to specialize in some depth in a selected area of the field. Specific graduate programs are suggested by, and subject to the approval of, an interdepartmental committee on materials engineering. Further details may be obtained by consulting the Department Graduate Registration Officer.

## FUEL ENGINEERING

Among all the chemical reactions, combustion is the one most widely used — in chemical synthesis, chemical and metallurgical processing, and power production. An integrated program in this field would typically include subjects in heat, momentum and mass transfer, thermodynamics, kinetics, combustion, radiation, a seminar in combustion, and a research problem in fuel processing or combustion. The Department's Fuels Research Laboratory provides excellent facilities for research on a wide range

of problems, from small-scale studies of fuel processing or combustion kinetics to research in high-output combustion in rockets, ramjets, and gas turbines requiring use of the Laboratory's 2,000 kw compressors to simulate altitudes to 80,000 feet and flight Mach numbers to 2.5.

Subjects commonly taken are:

CHEMICAL ENGINEERING THERMODYNAMICS (10.40)  
 MECHANICS OF FLUIDS (10.52)  
 APPLIED CHEMICAL KINETICS (10.65)  
 PRINCIPLES OF COMBUSTION (10.70)  
 SEMINAR IN AIR POLLUTION CONTROL (10.72)  
 RADIATIVE TRANSFER (10.74)

### **SCHOOL OF CHEMICAL ENGINEERING PRACTICE**

In the School of Chemical Engineering Practice, selected groups of graduate students spend a term at two field stations located at the American Cyanamid Company plant in Bound Brook, New Jersey, and the Oak Ridge National Laboratory of the Atomic Energy Commission, in Oak Ridge, Tennessee. At each field station, the student groups operate under the direction of two members of the Institute staff. The facilities of the plant constitute their laboratory. The program's chief objective is to develop students' ability to apply theory to practical engineering accomplishment. Staff guidance emphasizes resourcefulness and effectiveness in cooperative effort under industrial conditions.

Quantitative aspects of chemical engineering are intensively studied in the Practice School. Plant investigations are carried out by the students on special phases of unit operations and on problems of industrial chemistry. Oral and written presentation of plans, results, and recommendations for action are stressed.

Bachelor's graduates of this Department ordinarily meet the requirements for the S.M. degree in Chemical Engineering Practice (Course x-A) in two terms. Starting in the September following graduation, students are at the field stations until the end of January, and then return to the Institute to complete the program for the Master's degree during the spring term. Practice School experience (10.82 and 10.83; or 10.86 and 10.87) may be substituted for the S.M. thesis in Course x. A similar Practice School field program starts in February and extends to early June.

For students who have graduated in chemical engineering from other institutions, the usual program of study for the Master's degree in Chemical Engineering Practice involves one or two terms at the Institute followed by the field

station work in the Practice School. Graduates in chemistry from other institutions normally require an additional term. Students are usually not admitted to the Practice School until they have spent at least one term at the Institute.

## *Department of Civil Engineering*

Creating the complex systems of constructed facilities needed for sound economic growth is the purpose of civil engineering. Billions of dollars are invested each year by industries and government throughout the world to meet the rapidly expanding demand for facilities for transportation, communication, energy, defense, water resources, urban development, housing, manufacturing, and distribution. Civil engineering is a principal instrument for focusing man's scientific and technological skills on this adaptation and control of our environment. Many specialists including teams of scientists, engineers, architects, and managers, contribute to these ventures, but the successful civil engineer must be responsible for bringing together many skills in achieving the most efficient solution. Reflecting this challenge, the program of the Department of Civil Engineering is based upon three broad and interrelated areas — the applied earth sciences, structures and materials, and civil engineering systems — each of which will be briefly described.

Where the earth scientist is primarily concerned with investigations of the earth, the oceans, and the atmosphere on a global scale, the civil engineer concentrates upon the near-surface aspects of the earth. The civil engineer seeks a basic understanding of the physics and chemistry of soils, liquids, and gases, and how their quality is modified by man's activities.

Many facility systems are primarily composed of structures. These often are large and extensive, requiring materials which perform for extended time periods under complex loads while exposed to the natural actions of the environment. Thus a fundamental understanding of the physics, chemistry, properties, structure, and behavior of materials is basic to civil engineering; new types of materials and structures, coupled with modern analytical and design tools such as computers and models, constitute another dimension in the profession.

The interaction of the many elements essential to the planning, design, construction, operation, and management of civil engineering projects is of controlling significance; these operations may now be formulated in terms of systems

which can be engineered for optimum functional modes. Modern developments in mathematical techniques, systems analysis, simulation, operations research, and computer methods make the synthesis of civil engineering systems a challenging new area for study and research.

The research program of the Department is both substantial and comprehensive and is supported by extensive experimental facilities. Access to the facilities of other groups within the Institute further extends this capability. In all such activities, both undergraduate and graduate students participate to the fullest degree, working together with faculty who are widely known for their research accomplishments.

### EDUCATIONAL FACILITIES

Areas of principal teaching and research interest within the Department are described below in terms of the departmental laboratories.

The *Hydrodynamics Laboratory* is a major unit for experimental research in fluid mechanics and has recently been enlarged to contain more than 40,000 square feet of laboratories, shops, and offices. Research equipment includes tanks, channels and basins for the study of waves, tides, and currents on coastlines and in estuaries and for the investigation of the mechanics of sedimentation and of water quality control. Specialized equipment exists for the study of cavitation, hydro-elastic vibrations, turbulence, stratified flows, thermal pollution, dispersion in porous media, surface runoff, and many other phenomena of vital importance in water resources engineering. In addition, of course, the Laboratory provides extensive supporting facilities for instrument development and calibration and for data recording, reduction and analysis.

The *Soil Research Laboratory* conducts applied and fundamental research on the engineering properties of soil and rock. Areas of concentration are earthquake engineering, behavior of jointed rock, fabric of clays, frost action, soil stabilization, stress-strain behavior of clays, lunar soil mechanics, and the measurement of soil properties for a variety of field projects involving buildings on the M.I.T. campus, braced subway excavations, highway embankments

and earth dams. A data acquisition system serves the experimental facilities, which include plane strain and high pressure triaxial apparatus, controlled loading consolidation cells, freezing units, X-ray diffraction apparatus, and equipment for dynamic testing. A models laboratory investigates the bearing capacity of cohesive soils, soil structure interaction during earthquakes, and provides students with models of earthdams and retaining walls. New field measurement devices and improved methods of field data acquisition and processing are being developed.

The *Structures Research Laboratory* is an educational research facility for the study of the behavior of structural elements and materials under both static and dynamic loads to help develop theoretical solutions, design parameters, and design procedures for structural systems. The Laboratory for Structural Models is equipped to fabricate and test complex scale models such as shells and space frames as well as more conventional structural designs. Much apparatus is available for generating loads and for sensing and measuring the stresses, strains, deflections, and accelerations which result in the models.

The *Materials Research Laboratory* staff includes civil, chemical, and mechanical engineers, metallurgists, and electronics specialists; its mission is research on materials which are useful to the practice of civil engineering. Among the latter are concrete and cementitious compounds, metallic reinforcements, metals, natural and synthetic polymers, glasses, asphalt and bituminous materials, wood, and various composites containing combinations of these. The research programs are directed toward understanding of composition-structure-property relationships, the control of properties for enhanced usefulness, and the experimental measurement of properties to facilitate best engineering design. As a consequence, considerable and varied equipment for the production, fabrication, and evaluation of materials is available, with new apparatus continually being developed. Cooperation exists with other similar groups in the Institute.

The *Civil Engineering Systems Laboratory* (CESL) is an intra-department laboratory which serves as a focus for all system-related activities in civil engineering. CESL is concerned with the application of systems methodology such as optimization, simulation, information systems, economic systems analyses, and decision theory to the solution of large-scale multidisciplinary

projects. As part of its research activities, the Laboratory is concerned with the practice of engineering and works closely with outside engineering organizations on actual engineering projects. The Department's IBM 1130 computer facility is maintained and operated by CESL. This facility contains on-line plotting devices and a scope for graphical computer input-output. The 1130 and remote consoles provide direct communication to the larger IBM System/360 Model 67 and IBM System/360 Model 65 in the M.I.T. Information Processing Center. A classroom has been equipped with closed-circuit television for group demonstration and lectures utilizing on-line computers. CESL has used these capabilities to develop a large number of computer-based information systems which are used in both engineering practice and engineering education.

#### INTERDISCIPLINARY PROGRAMS

By design, the curriculum of the Department presents many opportunities for interdisciplinary programs, both undergraduate and graduate, and only rarely do any two of them coincide exactly. For example, a student primarily but not exclusively interested in civil engineering may pursue valuable supplementary work in planning, architecture, management, computers, mathematics, economics, political science, and the life and earth sciences. Or, if his interests are more definitely technical, combinations with mechanical, electrical, nuclear, or chemical engineering are available. Well defined subject areas within the general domain of civil engineering may be followed by interdepartmental programs, including materials, transportation, construction management, structures, operations research, computers and information systems, water resources, building technology, and earth physics. In short, each student's educational and research program may be explicitly arranged to reflect best his personal motives and professional goals, whether they are intensive or extensive in nature.

#### THE INTER-AMERICAN PROGRAM IN CIVIL ENGINEERING

In cooperation with selected universities in Latin America, research programs on civil engineering problems are performed by small groups composed of M.I.T. and Latin American faculty and students; both undergraduate and graduate students of the Department may be eligible to participate in these activities. Each project extends over an appreciable time interval, thus

# Engineering

DEPARTMENT OF CIVIL ENGINEERING

affording opportunities for location field studies in Latin America where the social, economic, political, and technical factors involved in the problems may be observed. Experimental work, model studies, design evaluations, and other research activities are performed at the Institute, where the entire group is located during the major portion of the project.

The projects studied may be characterized as ones profiting from the use of modern technology and new scientific information in a research manner. The results of the work are presented in seminars in Latin America, to which interested local groups are invited.

## THE UNDERGRADUATE PROGRAM Civil Engineering (Course I)

The Department of Civil Engineering offers two undergraduate curricula for students seeking a strong base for careers in civil engineering or related fields. The first curriculum, which leads to the degree of Bachelor of Science in Civil Engineering, is designed for students interested in the technical and scientific aspects of engineering construction. The second curriculum, which leads to the degree of Bachelor of Science, is designed for students having a broad, well defined educational goal, the attainment of which requires a specially formulated course of study.

Each of these curricula provides sufficient flexibility to permit each student to develop his own special interests either within the Department or through subjects offered by other departments. Undergraduates are encouraged to participate in the research and development activities of the Department and in many cases can obtain degree credit for such work.

Often there are academic advantages to planning programs for the third and fourth years so as to dovetail with possible graduate study. Selected students may be admitted to a special program permitting them to work simultaneously toward undergraduate and graduate degrees. The undergraduate degree will be awarded upon completion of the requirements for that degree.

With the exception of two subjects in basic physics and mathematics, all core subjects are taught by faculty of the Department using examples drawn from their own experiences. However, the subjects in mechanics, materials, geology and mathematics are compatible, and when necessary interchangeable, with corresponding subjects offered by other departments.

## THE DEGREE: BACHELOR OF SCIENCE IN CIVIL ENGINEERING

The curriculum centers about a core which includes a firm grounding in mechanics, materials and physical geology; advanced mathematics including statistics and probability; study and use of computers as computational and information systems; and work in the three technical areas basic to construction — structures, fluids, and soils. The curriculum is capped by a "projects" subject in which students develop solutions to actual civil engineering problems drawn from the recent and current experiences of the senior faculty.

The curriculum also permits great flexibility with regard to scheduling. An entering student who has already decided upon a career in civil engineering is able to complete one-half of the Departmental Program by the end of his second year, thus permitting many professional electives during the third and fourth years. On the other hand, an undergraduate who wishes to delay his career decision will find it possible to compress as many as ten of the subjects of the Departmental Program into the third and fourth years.

## CURRICULUM FOR S.B. DEGREE IN CIVIL ENGINEERING

	<i>Total units</i>
<b>GENERAL INSTITUTE REQUIREMENTS</b> ( <i>see page 47</i> )	
Specific science and humanities and social science subjects.	132 <sup>1</sup>
ECONOMIC PRINCIPLES I (14.01T) is required in the upperclass humanities and social science program.	
The subjects 1.01, 8.03 and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects ( <i>see page 50</i> ) and can be used to satisfy the Science Distribution Requirement.	
Laboratory Requirement <sup>2</sup> ( <i>see the list on page 51</i> ).	12
<b>DEPARTMENTAL PROGRAM</b>	
<i>Required Subjects</i> <sup>3</sup>	
1.00 INFORMATION SYSTEMS	3 3 6
1.01 ENGINEERING MECHANICS	4 0 8
1.02 ENGINEERING MATERIALS	3 3 6
1.03 ENGINEERING ANALYSIS	4 0 8
1.04 STRUCTURAL ANALYSIS AND DESIGN I	3 3 6
1.05 FLUID DYNAMICS	3 3 6
1.06 SOIL MECHANICS	3 3 6
1.07 ANALYSIS OF UNCERTAINTY	3 1 5
1.08 GEOTECHNOLOGY	3 3 6
1.09 CIVIL ENGINEERING	0 6 12
8.03 PHYSICS III	5 0 7
18.034 DIFFERENTIAL EQUATIONS	3 0 9
	<hr/> 147
<i>Unrestricted Electives</i> <sup>4</sup>	69
Total units required for the S.B. degree	<hr/> 360

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> 1.10 CIVIL ENGINEERING LABORATORY is recommended but not required.

<sup>3</sup> Under special circumstances, substitution of subjects of similar content may be permitted by petition to the Department.

<sup>4</sup> Schedules of students in Course 1 may always be arranged to leave available 12 units of unrestricted elective in the second year.

**THE DEGREE: BACHELOR OF SCIENCE**

The core requirements of this curriculum are divided into required subjects and planned electives. The required subjects provide firm grounding in mathematics, in mechanics and materials, and in the use of computers as computational and information systems. By means of the planned electives, the student develops his own program for achieving a well defined educational goal. Under this program, for example, students interested in urban affairs or in transportation systems may develop sequences of planned electives in systems analysis, city planning, and political science.

Students planning to follow this curriculum must submit to the Department, no later than the end of the fall term of the junior year, a statement of their educational goal and a list of the planned electives to achieve this goal. Students should at an earlier date discuss their interests and intended programs with one or more of the faculty of the Department.

**CURRICULUM FOR S.B. DEGREE**

**GENERAL INSTITUTE REQUIREMENTS** (see page 47) Total units

Specific science and humanities and social science subjects. 132<sup>1</sup>

ECONOMIC PRINCIPLES I (14.01T) is required in the upperclass humanities and social science program.

The Science Distribution Requirement will be satisfied by 1.01 and 18.034, which are required in the Departmental Program, plus appropriate subjects (see page 50) totaling 12

Laboratory Requirement<sup>2</sup> (see the list on page 51). 12

**DEPARTMENTAL PROGRAM**

**Required Subjects<sup>3</sup>**

1.00	INFORMATION SYSTEMS	3	3	6	
1.01	ENGINEERING MECHANICS	4	0	8	
1.02	ENGINEERING MATERIALS	3	3	6	
1.07	ANALYSIS OF UNCERTAINTY	3	1	5	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
					57

**Planned Electives**

A coherent selection of at least eight subjects, at least three of which must be subjects in Civil Engineering, which is aimed at a well defined educational goal. The planned

electives are to be agreed upon between the student and a designated Faculty Counselor of the Department of Civil Engineering. at least 84

**Unrestricted Electives<sup>4</sup>** up to 63

Total units required for the S.B. degree 360

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> 1.10 CIVIL ENGINEERING LABORATORY is recommended but not required.

<sup>3</sup> Under special circumstances, substitution of subjects of similar content may be permitted by petition to the Department.

<sup>4</sup> The Unrestricted Electives must be at least 36 units.

**ELECTIVE SUBJECTS**

Undergraduate elective subjects offered by the Department include the following:

1.51	STRUCTURAL ANALYSIS AND DESIGN	3	2	5
1.60T	INTRODUCTION TO WATER RESOURCES		3	0 6

By the fourth year, students will have the prerequisites for a variety of graduate subjects offered by the Department in the applied earth sciences, hydrodynamics and water resources, soils, structures, materials, systems, transportation, and construction management. Descriptions of typical sequences of subjects in these areas may be obtained from Faculty Counselors.

Students wishing to work closely with a faculty member in his research may obtain permission to register for thesis or to enroll in Special Studies in Civil Engineering (1.99).

Students are encouraged to consider appropriate subjects offered by other departments as part of their elective programs.

**GRADUATE STUDY IN CIVIL ENGINEERING**  
**The Graduate Degrees**

The Department grants the following advanced degrees:

- Master of Science in Civil Engineering
- Civil Engineer
- Materials Engineer
- Doctor of Science
- Doctor of Philosophy

The general requirements for the various degrees are indicated in Section 3.

**Entrance Requirements for Graduate Study**

In addition to the admission requirements noted in Section 3, applicants must present evidence of appropriate training for graduate study in the areas of their interest, though this preparation need not have been in Civil Engineering. Normally students may make up deficiencies in prerequisites for graduate subjects while pursuing a program of graduate work; prerequisite subjects are indicated with the description of each subject in this Catalogue.

# Engineering

DEPARTMENT OF CIVIL ENGINEERING

## *Fields of Advanced Study*

The Department has integrated programs for graduate study in the following areas: the applied earth sciences, hydrodynamics and water resources, soil mechanics, structures and structural mechanics, materials, civil engineering systems, transportation systems, urban systems, engineering construction, and operations. Each of these is described briefly below. For major fields for doctoral theses, students should refer to the Civil Engineering list in Section 3 of this Catalogue. Fields other than those listed must be approved by the Department Graduate Registration Officer and by the Dean of the Graduate School.

### THE APPLIED EARTH SCIENCES

Extensive departmental involvement with the behavior of near-surface earth materials, the microstructure of natural dynamic processes, and the interactions of those with constructed facilities provide opportunities for new interdisciplinary research in the applied earth sciences. The activities in applied earth sciences are in the fields of fluid mechanics, soil mechanics, rock mechanics, and geology. The Department's work in these areas is described in more detail below under the headings Hydrodynamics and Water Resources, and Soil Mechanics.

### HYDRODYNAMICS AND WATER RESOURCES

Vital problems of civil engineering exist in the areas of hydrodynamics, hydrology and water resources design and development. Basic applications of fluid mechanics and of systems methodology are involved in hydraulic engineering, pollution abatement, coastal and ocean engineering, hydrologic analysis and water resources planning.

Modern developments in hydrodynamics deal with turbulence, boundary layers, free surface flow, wave motion, diffusion processes, sedimentation and flow in porous media.

The planning and development of water resources is treated from the standpoint of analysis and synthesis of hydraulic and hydrologic systems as well as of optimum integration of physical, economic and social factors.

Water quality is covered with regard to the effect of man's activities in utilizing and polluting water sources and to methods of restoring or maintaining desirable characteristics.

An extensive research program in the Hydrodynamics Laboratory is closely coupled with

the educational offerings and at present includes the following areas:

Transformation and shoaling of waves, tidal dynamics in estuaries and sea-level canals, interaction of submerged bodies and fluid interfaces, wave forces on offshore structures, mechanics of stratified flow, dispersion, circulation and mixing processes in lakes, rivers and estuaries, heat absorption and storage in lakes, thermal pollution, flow and dispersion in porous media, sediment transport and erosion of cohesive materials, resistance and turbulence phenomena in fluid suspensions, cavitation control on rough boundaries, analysis and synthesis of hydrologic systems, water distribution networks and regional development of water resource systems.

### SOIL MECHANICS

The civil engineer uses soil as a foundation material for a wide variety of structures, such as buildings, bridges, pavements, and retaining walls, and also uses it as a construction material for such things as embankments, dams, roads, and canal linings. The graduate program in soils emphasizes the development and evaluation of techniques for practical design, and is supported by major efforts in the analysis of deformation, stability, and flow problems, the measurement of the engineering properties of soil in the field and laboratory, including basic research on the physicochemical properties of soils, and the measurement and evaluation of the field behavior of soils during and after construction.

In addition to the comprehensive treatment of theoretical soil mechanics, soil properties, and applied soil mechanics, there are advanced subjects in soil dynamics, soil technology, engineering geology, and rock mechanics. These subjects, together with thesis research and other studies utilizing the unique laboratory facilities of the Department, offer students excellent opportunities to work closely with the faculty in the study of such problems as the behavior of embankments on soft ground, the behavior of deep braced cuts, the measurement and analysis of foundations of buildings on the M.I.T. campus, the use of theoretical and computer techniques to solve stress distribution, deformation, stability, and flow problems, the behavior of stabilized soils, the behavior of sand under vibratory and earthquake loading, the behavior of jointed rock masses, frost action, and the physicochemical behavior of clay-water systems.

**STRUCTURES AND STRUCTURAL MECHANICS**

The program offered in structures encompasses the range of activities involved in the design of complete systems such as buildings, bridges, towers, and various industrial facilities. It includes study in the theory of structural mechanics, in the conception and planning of structural systems, in advanced design techniques, and in the optimization of design with regard to the use of materials, construction costs, and operating efficiency.

The research program, in which students naturally become involved, closely parallels the academic subject offerings. In structural mechanics, current work includes theoretical developments in shell theory, the inelastic behavior of structures, and structural dynamics including design to resist earthquakes. The complete design process is being investigated through studies of probabilistic approaches to design, structural optimization, and the use of computers in design. New design techniques are being developed through the use of finite element methods for plates and shells, the use of model analysis for complex structures, and the creation of computer languages for structural design. In addition, new structural systems are being devised together with the construction techniques which will make them feasible.

**MATERIALS**

Civil engineers are the largest users of materials in any area of technology and the entire field of structural materials is undergoing rapid changes at the present time. These two facts impart unique characteristics to our teaching and research programs related to materials. On the one hand, the origin of properties, in terms of composition and internal structure, must be clearly understood. Equally important is the ability to utilize these properties, effectively, economically and imaginatively, to fulfill engineering needs. The property-composition-internal-structure relationships are treated in a number of fundamental subjects, some of which deal with broad classes or families of materials to illustrate the principles involved. Related to these subjects are research programs employing basic techniques and tools such as optical and electron microscopy, X-ray diffraction, single crystal studies and microstructural examinations; students acquire operational skill with the latter both through their Course work and in their research activities.

The application of materials to civil engineer-

ing needs, in a rational and quantitative fashion, represents the second main component of our effort. In this area are found subjects and research dealing with structural composites, fracture mechanics, viscoelasticity and rheology, mechanics of materials and the mechanical behavior of metals. Again, considerable reinforcement between teaching and research takes place and the most modern testing and computational equipment and techniques are employed.

Students are also given opportunity to pursue studies in materials engineering, under interdepartmental supervision, leading to the degrees of Materials Engineer or Doctor of Science or Doctor of Philosophy. There is no standard curriculum in this field, and each student arranges a program of study and research uniquely suited to his interests and professional goals.

**CIVIL ENGINEERING SYSTEMS**

Advanced study and research in civil engineering systems emphasizes the application of modern mathematical, computer, economic, and operations research techniques to problems in engineering management systems, urban systems, building systems, structural systems, water resource systems, and transportation systems. Particular attention is directed to new approaches to solving civil engineering problems at the project and operational system level. All areas of engineering including planning, analysis, design, construction, management and control are emphasized. Current research involves the development of computer-based information systems and the use of those systems in the solution of large-scale engineering projects. The program emphasizes how new systems approaches will affect and change conventional engineering procedures.

**TRANSPORTATION SYSTEMS**

The essential focus of teaching and research in transportation is on systems planning, especially multimode systems. The program builds upon basic knowledge of the properties of transportation systems components, and the ability to analyze interactions among these components and between the transportation system and its environment. The basic approach is that of rational decision making about engineered systems, using where appropriate such techniques of systems analysis as economics, mathematical optimization, and computer models. Close relation to an extensive body of research supports

# Engineering

DEPARTMENT OF CIVIL ENGINEERING

and stimulates the academic program. Subjects of instruction offered include fundamentals of transportation systems, transportation systems analysis, transport systems design, urban transportation systems, flight transportation, traffic flow theory, decision theory, system simulations, mathematical programming, network flow, economic analysis, probabilistic analysis, and substantive applications to highway, air, rail, and sea transport. The Transportation Systems Division works in close relation to the Civil Engineering Systems Laboratory and the Urban Systems Laboratory in both teaching and research. Collaboration is encouraged with other groups at the Institute whose interest is related to transportation.

## CONSTRUCTION AND OPERATIONS

Construction is the focal point of civil engineering, where all the specialists in civil engineering are drawn inevitably together and where the many diverse aspects of civil engineering — research, planning, analysis, and design — find their common purpose.

Several major research projects in the Department of Civil Engineering are centered around construction. The approach is to predict some aspect of the performance of a structure on the basis of theory and laboratory or field tests, or both; instrument the structure; observe the behavior of the structure during and after construction; and evaluate the performance of the structure and the techniques used for predicting the performance. The many students who work on the projects have the opportunity to learn firsthand about the problems of construction. The research leads to the improvement of old techniques or the development of new techniques of analysis, testing, and construction, and in this way not only advances the profession but has an immediate impact on the formal subjects taught in the Department.

## URBAN SYSTEMS ENGINEERING

A majority of civil engineering projects are located in metropolitan areas. Their design must therefore take into consideration not only the physical loads that will be imposed upon them, but also the strong interaction between these facilities and the complex economic and social forces of the urban environment.

Urban systems engineering applies modern computer-aided analytic techniques, tempered by an appreciation for relevant human issues, to the creative solution of urban civil engineering

problems. The academic program thus integrates three complementary lines of study: methods of systems analysis, an application area such as transportation or water resources, and the social, economic, and political aspects of the urban context.

Research in urban systems engineering is supported by the interdepartmental Urban Systems Laboratory and the Civil Engineering Systems Laboratory. The work is closely tied to the educational program and current developments are rapidly brought into the classroom. Last year, for example, students worked on the layout of a proposed quarter-billion-dollar municipal water supply network.

## Research Assistants

The research of the Department is an integral part of the study program, and approximately one hundred graduate students each year receive appointments as research assistants. In addition to the financial support so gained, such appointments provide valuable educational experience and outstanding thesis opportunities. Information about these appointments, and other forms of financial assistance, may be obtained by writing to the Head of the Department; but consideration for awards cannot be given before students have been assured of admission to the Graduate School.

## Department of Electrical Engineering

Starting from a relatively modest beginning about one hundred years ago, the field of electrical engineering has become one of great variety and scope. Its products and services directly influence the daily living of most of the world's population. Its generators, motors, and other energy-processing devices provide the large quantities of inexpensive power needed in the industrialized and developing modern world. Its instruments for detecting, observing, and measuring electrical signals give it a unique role in supporting the advance of all other branches of science and engineering. Its conceptual models of detection, communication, and automatic control have influenced the development of such fields as economics, industrial management, psychology, and linguistics. Most recently its digital computers have revolutionized experimental techniques throughout the natural and behavioral sciences, engineering, and management and have provided models and tools for the study of the brain.

In a field with the rapid rate of change of modern electric technology, no one can describe with confidence the devices and systems of 15 years hence. But it seems very likely that their development and understanding will require a knowledge of electromagnetic fields and waves, that their performance will be limited by considerations of mechanics and thermodynamics, and that they will exploit the quantum-mechanically based electrical and magnetic properties of matter. It also seems likely that the systems will handle signals in the presence of noise and that the mathematical apparatus for dealing with signals, noise, and stability will be useful. And finally, the computer will have become an all-pervasive component of organized society and of technology. The undergraduate and graduate curricula are based on such assumptions. In the undergraduate core curriculum, and in many of the subjects offered for graduate students, the emphasis is on the physical and mathematical principles and the techniques of applying them to real problems. In addition, however, elective subjects dealing with specialized techniques in a variety of fields are offered.

### THE UNDERGRADUATE CURRICULA

There are six undergraduate programs in the Department of Electrical Engineering: three in Course VI (Program 1 — Electrical Engineering, Program 2 — Electrical Science and Engineering, and Program 3 — Computer Science and Engineering); and in Course VI-A, the cooperative versions of these three programs. The three VI-A programs permit the student to combine study with industrial engineering practice. In any program, a student who is admitted to graduate work may combine the Bachelor's and Master's thesis and receive the Bachelor of Science and the Master of Science degrees simultaneously at the end of five years of study. The common objective of all of these programs is to provide the intellectual and practical foundations on which can be based a large number of interesting careers.

*Program 1* prepares students for industrial careers or graduate study in electrical engineering or allied fields. Through a proper selection of elective subjects, they may get a good start in a specialized branch of electrical engineering or they may prepare themselves for graduate study in engineering or in such fields as physics, mathematics, industrial management, and the social sciences.

*Program 2* is designed for students who are planning research-oriented or teaching careers. They are expected to study more deeply in the basic sciences (biology, mathematics, physics, etc.) in order to provide the necessary foundation for their future graduate study and research.

*Program 3* is designed to give students a background in the computer sciences on which to build careers in advanced computer systems development, in sophisticated applications of computers to technical or organizational problems, and in the further development of the computer sciences themselves.

Programs 1, 2, and 3 require two terms of mathematics and two terms of physics beyond the General Institute Requirements, introducing the student to differential equations, theory of functions of a complex variable, electricity and magnetism, and quantum mechanics. In

# Engineering

DEPARTMENT OF ELECTRICAL ENGINEERING

Programs 1 and 2 the physics and mathematics background is used in a group of six core electrical engineering subjects in linear circuits, electronics, electromagnetic fields and waves, signal analysis and transform theory, and statistical mechanics and thermodynamics. These core subjects use lecture demonstrations, small sections, carefully developed homework assignments, and individual weekly conferences with each student to make sure that the points brought out in the homework are fully mastered. Program 3 combines a part of the core curriculum of Program 1 with a series of subjects in programming linguistics, computation structures, information systems, algebraic foundations of computer science, and in formal systems and logic.

The Electrical Engineering programs allow the student to take a considerable number of unrestricted elective subjects without overload. Students may use these as they see fit: they may take additional humanities subjects, science subjects, or use them to get a start in specialized branches of electrical engineering. To provide students with a chance to specialize in several of the current disciplines of electrical engineering, and to bring them into contact with current graduate research in these areas, sequences of electrical engineering electives have been developed.

The different engineering disciplines which students may enter through these elective sequences are: control, computer science, digital systems, electronic materials and devices, electromagnetics and dynamics, communications, bio-engineering, and energy systems. Students should consult with their Faculty Counselors about these specialized elective sequences.

The Department of Electrical Engineering recommends that all undergraduates get some industrial experience during their program at M.I.T. There are two reasons for this recommendation. First, many aspects of the education of an engineer can be learned much more effectively and realistically on a job than by listening to lectures about them in the classroom. Second, most students get a great deal of pleasure from the discovery that the knowledge they have gained at M.I.T., which may have seemed rather abstract, does in fact help them to solve real and important engineering problems. This experience may be gained either through summer jobs or by participation in Course VI-A.

## PROJECT STUDY

The Department of Electrical Engineering is offering, beginning this year, the opportunity for an undergraduate to develop a close working relationship with an active research group. A series of elective subjects, 6.852-6.858, Project Study, has been established for this purpose. A student enrolls by permission of an Electrical Engineering faculty member to join his research group. Grading is Pass-Fail, but continued registration is subject to the approval of the faculty member. It is expected that an undergraduate student entering a research group will participate in several ways: by independent study of the literature of that specialized field, by assisting graduate thesis students in their research work, by undertaking investigations or engineering design problems assigned to him, by assisting students who enter the group after him, or by project work which may extend over several terms under the supervision of an individual faculty member.

## *Electrical Engineering (Course VI)*

### PROGRAM 1. ELECTRICAL ENGINEERING

This program leads to the degree of Bachelor of Science in Electrical Engineering. The curriculum, consisting of a core of required subjects and a number of elective subjects, allows a student to prepare himself for an industrial career or for graduate study.

Since the General Institute Requirements for Science Distribution subjects and Laboratory are met by the program, a total of 72 units of upperclass elective time is available which the student may use for a number of purposes. He may, for example, elect eight additional upperclass subjects in the humanities and social sciences. He may take a substantial minor program in industrial management. He may elect elementary foreign language subjects as well as advanced subjects in physics, mathematics, and electrical engineering, to prepare for a future doctoral program. He may take electives in transistor electronics, communications, control, computer systems, probability, and instrumentation to prepare for a career in the engineering of large-scale systems. He may explore fields such as biology, psychology, and linguistics, to develop an understanding of communications in a context which includes both men and machines.

The curriculum requirements for the Electrical Engineering Program are listed below.

**PROGRAM 1. ELECTRICAL ENGINEERING CURRICULUM (COURSE VI)**

**GENERAL INSTITUTE REQUIREMENTS** (see page 47) *Total units*  
 Specific science and humanities and social science subjects. **132<sup>1</sup>**  
 The subjects 6.01, 8.03, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 50) and can be used to satisfy the Science Distribution Requirement.  
 Laboratory Requirement (see page 51). **12**

**DEPARTMENTAL PROGRAM**

**Required Subjects<sup>2</sup>**

6.01	<sup>3</sup> INTRODUCTORY NETWORK THEORY	4	0	8
6.02	ELECTRONIC DEVICES AND CIRCUITS	4	0	8
6.03T	ELECTROMAGNETIC FIELDS AND ENERGY	4	0	8
6.04	ELECTRODYNAMICS	4	0	8
6.05	CIRCUITS, SIGNALS, AND SYSTEMS	4	0	8
6.08	STATISTICAL MECHANICS AND THERMODYNAMICS	4	0	8
8.03	PHYSICS III	5	0	7
8.04	PRINCIPLES OF QUANTUM PHYSICS	5	0	7
18.034	<sup>3</sup> DIFFERENTIAL EQUATIONS	3	0	9
18.05	<sup>5</sup> ADVANCED CALCULUS FOR ENGINEERS	3	0	9
	<sup>5</sup> THESIS		12	
				<b>132</b>

**Restricted Electives**  
*Departmental Laboratory*  
 Subjects selected from the list below (in addition to the General Institute Laboratory Requirement) **12**

6.215	<sup>4</sup> FEEDBACK CONTROL LABORATORY	Arr.		
6.272	DIGITAL SYSTEMS PROJECT LABORATORY	2	8	2
6.274	ADVANCED DIGITAL SYSTEMS PROJECT LABORATORY	2	8	2
6.70	ELECTRONIC COMPONENTS AND MEASUREMENTS	1	4	1
6.71	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1	4	1
6.711T	DIGITAL SYSTEMS PROJECT LABORATORY	3	7	2
6.712	BIOELECTRONICS PROJECT LABORATORY	2	8	2
6.714	ELECTRONIC LIGHT MEASUREMENTS PROJECT LABORATORY	2	8	2
6.715	POWER SYSTEMS PROJECT LABORATORY	2	8	2
6.716	PARTICLE OPTICS PROJECT LABORATORY	2	8	2
6.717	AUDIO FREQUENCY COMMUNICATIONS PROJECT LABORATORY	2	8	2
6.719	SEMICONDUCTOR DEVICES PROJECT LABORATORY	2	8	2
6.722	MODERN OPTICS PROJECT LABORATORY	2	8	2
6.723	IMAGE TRANSMISSION SYSTEMS PROJECT LABORATORY	0	12	0
6.81	<sup>4</sup> ELECTRICAL ENGINEERING LABORATORY	Arr.		
				<b>72</b>

**Unrestricted Electives<sup>4</sup>** **72**  
 Total units required for the S.B. degree **360**

<sup>1</sup> The requirement for the Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> Under special circumstances, substitution of subjects of similar content may be permitted by petition to the Department.

<sup>3</sup> Students may elect 6.001 ELEMENTS, SYSTEMS, AND COMPUTATION I (4-0-8) and 6.002 ELEMENTS, SYSTEMS, AND COMPUTATION II (4-0-8) in substitution for 6.01 and 18.034. Note that while 6.001 satisfies the Science Distribution Requirement, 6.002 does not satisfy the Science Distribution Requirement.

<sup>4</sup> Registration in 6.215 or 6.81 must consist of at least 6 units in order to satisfy a part of the Departmental Laboratory Elective Requirement.

<sup>5</sup> A thesis of at least 12 units is required. Not more than 30 units of thesis credit can be included in the minimum of 360 units required for the S.B. degree.

<sup>6</sup> Schedules of students in Course VI, Program 1, may always be arranged to leave available 12 units of unrestricted elective in the second year.

The above requirements are not rigid. Some variations are routinely permitted, while others are considered on an individual basis. Well-motivated substitutions of substantially equivalent subjects are usually approved. Students may request substantial changes in program which involve more than substitution in kind. Departmental approval will be granted in general only to well-prepared students, whose proposed programs are comparable to the curriculum listed above in breadth, depth, and integrated approach to a well-defined educational objective.

**PROGRAM 2. ELECTRICAL SCIENCE AND ENGINEERING**

This program in Electrical Science and Engineering is offered for a selected group of students who show sufficient interest and ability to make it likely that they will continue their education through the doctorate. The subjects parallel the subjects in Program 1 but are characterized by greater depth. Students are expected to strengthen their background in the fundamental — and engineering — sciences by suitable choice of electives. Since most students in this program will be doing thesis work in graduate school, 12 units of seminar are used to satisfy the departmental requirement of a thesis or project for the Bachelor of Science degree. However, a student may undertake a Bachelor's thesis instead of the seminar, if he wishes.

New subjects or approaches are likely to be tried out first in Program 2. The challenge of the program attracts an excellent student body, and it is expected that students will maintain high academic standards.

Students may apply for admission to Program 2 by interview at the end of the first year or during the first term of the second year. Transfer students or others well prepared in mathematics and physics who have completed the work of the second year of Program 1 may be admitted at the beginning of the third year.

# Engineering

DEPARTMENT OF ELECTRICAL ENGINEERING

Because they are likely to be engaged in a seven- or eight-year continuous educational program, Program 2 students are especially urged to gain some industrial experience, either through summer jobs or through Program 2 of Course VI-A described below.

Program 2 may lead to the degrees of Bachelor of Science and Master of Science in Electrical Engineering, awarded simultaneously at the end of the graduate year, if the student is admitted to the Graduate School. The curriculum requirements for the Bachelor of Science degree are given below.

## PROGRAM 2. ELECTRICAL SCIENCE AND ENGINEERING CURRICULUM (COURSE VI)

### GENERAL INSTITUTE REQUIREMENTS (see page 47)

Specific science and humanities and social science subjects. **132<sup>1</sup>**

The subjects 6.013, 8.03, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 50) and can be used to satisfy the Science Distribution Requirement.

Laboratory Requirement (see page 51). **12**

### DEPARTMENTAL PROGRAM

#### Required Subjects<sup>2</sup>

6.013	<sup>3</sup> INTRODUCTORY NETWORK THEORY	4	0	8
6.023	ELECTRONIC DEVICES AND CIRCUITS	4	0	8
6.033	ELECTROMAGNETIC FIELDS AND ENERGY	4	0	8
6.043	ELECTRODYNAMICS	4	0	8
6.053	CIRCUITS, SIGNALS, AND SYSTEMS	4	0	8
6.083	STATISTICAL MECHANICS AND THERMODYNAMICS	4	0	8
6.11	<sup>4</sup> PROJECT SEMINAR	2	0	4
6.12	<sup>4</sup> PROJECT SEMINAR	2	0	4
8.03	PHYSICS III	5	0	7
8.04	PRINCIPLES OF QUANTUM PHYSICS	5	0	7
18.034	<sup>3</sup> DIFFERENTIAL EQUATIONS	3	0	9
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	9

**132**

#### Restricted Electives

##### Departmental Laboratory

Subjects selected from the list of laboratory subjects given under Course VI, Program 1 (in addition to the General Institute Laboratory Requirement)

12  
— **12**

#### Unrestricted Electives<sup>5,6</sup>

Total units required for the S.B. degree **360**

<sup>1</sup> The requirement for the classes '70, '71, and '72 is 128 units, the Unrestricted Elective Units being increased by 4.

<sup>2</sup> Under special circumstances, substitution of subjects of similar content may be permitted by petition to the Department.

<sup>3</sup> Students may elect 6.001 ELEMENTS, SYSTEMS, AND COMPUTATION I (4-0-8) and 6.002 ELEMENTS, SYSTEMS, AND COMPUTATION II (4-0-8) in substitution for 6.013 and 18.034. Note that while 6.001 satisfies the Science Distribution Requirement, 6.002 does not satisfy the Science Distribution Requirement.

<sup>4</sup> An Undergraduate Thesis of at least 12 units may be elected in substitution for 6.11 and 6.12.

<sup>5</sup> Schedules of students in Course VI, Program 2, may always be arranged to leave available 12 units of unrestricted elective in the second year.

<sup>6</sup> Subjects in materials and probability—e.g., 6.13, 6.28, and 18.18—are particularly suitable adjuncts to this program.

The comments about variation in requirements following the Program 1 curriculum apply to Program 2 also. Well-conceived proposals by students in Program 2 embodying substantial changes have usually received departmental approval.

## PROGRAM 3. COMPUTER SCIENCE AND ENGINEERING

This program of studies provides a foundation in the structure of computer systems and languages and the allied mathematics, and in the ideas of circuits, electronic devices, and signals encountered in electrical systems. With this background, a student may enter into any of the rapidly evolving fields of activity based on the digital computer, such as system design, machine design and organization, artificial intelligence, design of programming languages and compilers.

For those students whose interests focus on the hardware aspects of computers (such as large-scale memories, logical design of digital circuits, specialized on-line computers), a program of studies involving more of the physical science subjects of Programs 1 or 2 coupled with a selection of subjects from Program 3, or with the large number of elective subjects dealing with computers, may be more appropriate. Such specially designed programs of study may be arranged with the help of the student's departmental Faculty Counselor subject to the approval of the Head of the Department.

The program leads to the degree of Bachelor of Science in Electrical Engineering. The curriculum requirements are listed below.

## PROGRAM 3. COMPUTER SCIENCE AND ENGINEERING CURRICULUM (COURSE VI)

### GENERAL INSTITUTE REQUIREMENTS (see page 47)

Specific science and humanities and social science subjects. **132<sup>1</sup>**

The subjects, 6.01, 8.03, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 50) and can be used to satisfy the Science Distribution Requirement.

Laboratory Requirement (see page 51). **12**

### DEPARTMENTAL PROGRAM

#### Required Subjects<sup>2</sup>

6.01	<sup>3</sup> INTRODUCTORY NETWORK THEORY	4	0	8
6.02	ELECTRONIC DEVICES AND CIRCUITS	4	0	8

6.05	CIRCUITS, SIGNALS, AND SYSTEMS	4	0	8
6.231	PROGRAMMING LINGUISTICS	3	2	7
6.232	COMPUTATION STRUCTURES	4	0	8
6.233	INFORMATION SYSTEMS	4	0	8
6.261	ALGEBRAIC FOUNDATIONS FOR COMPUTER SCIENCE	4	0	8
6.262	COMPUTABILITY, FORMAL SYSTEMS, AND LOGIC	4	0	8
8.03	PHYSICS III	5	0	7
8.04	PRINCIPLES OF QUANTUM PHYSICS	5	0	7
18.034	<sup>3</sup> DIFFERENTIAL EQUATIONS	3	0	9
18.05	<sup>4</sup> ADVANCED CALCULUS FOR ENGINEERS	3	0	9
	<sup>4</sup> THESIS		12	
				156

**Restricted Electives****Departmental Laboratory**

Subjects selected from the list of laboratory subjects given under Course VI, Program 1 (in addition to the General Institute Laboratory Requirement).

12  
— 12

**Unrestricted Electives<sup>5</sup>**

48

Total units required for the S.B. degree 360

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> Under special circumstances, substitution of subjects of similar content may be permitted by petition to the Department.

<sup>3</sup> Students may elect 6.001 ELEMENTS, SYSTEMS, and COMPUTATION I (4-0-8) and 6.002 ELEMENTS, SYSTEMS, AND COMPUTATION II (4-0-8) in substitution for 6.01 and 18.034. Note that while 6.001 satisfies the Science Distribution Requirement, 6.002 does not satisfy the Science Distribution Requirement.

<sup>4</sup> A thesis of at least 12 units is required. Not more than 30 units of thesis credit can be included in the minimum of 360 units required for the S.B. degree.

<sup>5</sup> Schedules of students in Course VI, Program 3, may always be arranged to leave available 12 units of unrestricted electives in the second year.

**Electrical Engineering (Course VI-A)**

The VI-A Program provides the student with a way of gaining industrial and research experience concurrently with his undergraduate studies, through a series of organized plant assignments interleaved with regular study at M.I.T. Students in the VI-A programs are likely to receive more professionally rewarding assignments than the typical summer job may provide, because of continuing liaison between each participating company and a professor in the Department. The students can also spend more time on the job because the subjects taken while on job assignments and the academic credit received for plant experience help meet the degree requirements.

Second-year students in good standing in any of the three programs of Course VI may apply. The interviews with the cooperating companies are held in the spring. Applications may be made in the VI-A office early in the spring term.

The Department cannot guarantee the acceptance of a student by one of the participating companies; however most, but not all, of the interested students are placed. The program terminates in four years if the student leaves M.I.T. with a Bachelor of Science degree; if he is admitted to the Graduate School, the program continues through the fifth year. Admission to the Graduate School is based on the student's scholastic record and personal qualifications.

Course VI-A students who elect to pursue graduate study at M.I.T. are required to perform four terms of industrial practice. Three industrial-practice terms are normally required during the undergraduate program; in special cases, however, students who plan to leave M.I.T. upon receipt of their Bachelor of Science degree may omit the third practice term. On entering the VI-A Program, a student must agree to stay with one company through his Bachelor's and/or Master's degree.

Taken together, the participating companies cover substantially the entire spectrum of electrical technology and the electrical industry. Although a student is associated only with one company for his plant work, his plant assignments are arranged to provide broad experience with the affairs and operating procedures of industry, and with the kinds of work in which engineers are engaged. The level of technical sophistication and responsibility at the plants is kept in step with each student's growing technical competence as he advances in his academic program.

The industrial companies—such as the AVCO Corporation, General Electric Company, General Radio Company, Honeywell, Inc., International Business Machines Corporation, Radio Corporation of America, and Raytheon Company—provide experience in testing, design, development, and research in various areas of electronics, power, communications, control, and computation fields. The American Electric Power Corporation provides experience related to the technical operation, system planning, administration, and supporting research of a large electric utility system. The Bell Telephone Laboratories afford the opportunity for experience in the development of communication apparatus, circuits, and equipment for the Bell Telephone System. The Air Force Cambridge Research Laboratories and the Naval Ordnance Laboratory provide opportunities to work with people from many technical disciplines, brought

# Engineering

DEPARTMENT OF ELECTRICAL ENGINEERING

together in a large laboratory concerned with basic and applied research in many fields.

While at the plants, students are subject to the usual company regulations. They receive regular financial compensation for their work. During the practice periods, classes in prescribed academic subjects are held two evenings a week. At the conclusion of the program, students are not obligated to accept employment with the company, nor is the company obligated to offer employment.

These programs lead to the degree of Bachelor of Science in Electrical Engineering for four years of study, and may lead to the degrees of Bachelor of Science and Master of Science in Electrical Engineering, awarded simultaneously at the end of the graduate year, if the student is admitted to the Graduate School. The curriculum requirements for the Bachelor of Science degree are given below.

## PROGRAM 1. ELECTRICAL ENGINEERING CURRICULUM (COURSE VI-A)

### GENERAL INSTITUTE REQUIREMENTS (see page 47) Total units

Specific science and humanities and social science subjects. 132<sup>1</sup>

The subjects 6.01, 8.03, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 50) and can be used to satisfy the Science Distribution Requirement.

Laboratory Requirement (see page 51). 12

### DEPARTMENTAL PROGRAM

<i>Required Subjects<sup>2</sup></i>					
6.01	<sup>3</sup> INTRODUCTORY NETWORK THEORY	4	0	8	
6.02	ELECTRONIC DEVICES AND CIRCUITS	4	0	8	
6.03T	ELECTROMAGNETIC FIELDS AND ENERGY	4	0	8	
6.04	ELECTRODYNAMICS	4	0	8	
6.05	CIRCUITS, SIGNALS, AND SYSTEMS	4	0	8	
6.08	STATISTICAL MECHANICS AND THERMODYNAMICS	4	0	8	
8.03	PHYSICS III	5	0	7	
8.04	PRINCIPLES OF QUANTUM PHYSICS	5	0	7	
18.034	<sup>3</sup> DIFFERENTIAL EQUATIONS	3	0	9	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	9	
	<sup>4</sup> THESIS			12	
	<sup>5</sup> INDUSTRIAL PRACTICE			18	
					<b>150</b>

#### *Restricted Electives*

##### *Departmental Laboratory*

Subjects selected from the list of laboratory subjects given under Course vi, Program 1 (in addition to the General Institute Laboratory Requirement). 12

**12**

#### *Unrestricted Electives<sup>5</sup>*

**60**

Total units required for the S.B. degree **366**

<sup>1</sup> The requirement for the Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> Under special circumstances, substitution of subjects of similar content may be permitted by petition to the Department.

<sup>3</sup> Students may elect 6.001 ELEMENTS, SYSTEMS, AND COMPUTATION I (4-0-8) and 6.002 ELEMENTS, SYSTEMS, AND COMPUTATION II (4-0-8) in substitution for 6.01 and 18.034. Note that while 6.001 satisfies the Science Distribution Requirement, 6.002 does not satisfy the Science Distribution Requirement.

<sup>4</sup> A thesis of at least 12 units is required. Not more than 30 units of thesis credit can be included in the minimum of 360 units required for the S.B. degree. Students who continue studies for the S.M. degree and receive the S.M. and S.B. degrees simultaneously may substitute 12 units of additional elective for the undergraduate thesis.

<sup>5</sup> Credit for Industrial Practice subjects is limited to a maximum of 27 units and a minimum of 18 units.

<sup>6</sup> Schedules of students in Course VI-A, Program 1, may always be arranged to leave available 12 units of unrestricted elective in the second year.

## PROGRAM 2. ELECTRICAL SCIENCE AND ENGINEERING CURRICULUM (COURSE VI-A)

### GENERAL INSTITUTE REQUIREMENTS (see page 47) Total units

Specific science and humanities and social science subjects. 132<sup>1</sup>

The subjects 6.013, 8.03, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 50) and can be used to satisfy the Science Distribution Requirement.

Laboratory Requirement (see page 51). 12

### DEPARTMENTAL PROGRAM

<i>Required Subjects<sup>2</sup></i>					
6.013	<sup>3</sup> INTRODUCTORY NETWORK THEORY	4	0	8	
6.023	ELECTRONIC DEVICES AND CIRCUITS	4	0	8	
6.033T	ELECTROMAGNETIC FIELDS AND ENERGY	4	0	8	
6.043	ELECTRODYNAMICS	4	0	8	
6.053	CIRCUITS, SIGNALS, AND SYSTEMS	4	0	8	
6.083	STATISTICAL MECHANICS AND THERMODYNAMICS	4	0	8	
8.03	PHYSICS III	5	0	7	
8.04	PRINCIPLES OF QUANTUM PHYSICS	5	0	7	
18.034	<sup>3</sup> DIFFERENTIAL EQUATIONS	3	0	9	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	9	
	INDUSTRIAL PRACTICE			18	
	<sup>4</sup> INDUSTRIAL PROJECT			12	
					<b>150</b>

#### *Restricted Electives*

##### *Departmental Laboratory*

Subjects selected from the list of laboratory subjects given under Course vi, Program 1 (in addition to the General Institute Laboratory Requirement). 12

**12**

#### *Unrestricted Electives<sup>5,6</sup>*

**60**

Total units required for the S.B. degree **366**

<sup>1</sup> The requirement for the Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> Under special circumstances, substitution of subjects of similar content may be permitted by petition to the Department.

<sup>3</sup> Students may elect 6.001 ELEMENTS, SYSTEMS, AND COMPUTATION I (4-0-8) and 6.002 ELEMENTS, SYSTEMS, AND COMPUTATION II (4-0-8) in substitution for 6.013 and 18.034. Note that while 6.001 satisfies the Science

Distribution Requirement, 6.002 does not satisfy the Science Distribution Requirement.

<sup>4</sup>The Industrial Project is taken in place of the Departmental undergraduate thesis requirement.

<sup>5</sup>Schedules of students in Course VI-A, Program 2, may always be arranged to leave available 12 units of unrestricted elective in the second year.

<sup>6</sup>Subjects in materials and probability — e.g., 6.13, 6.28, and 18.18 — are particularly suitable adjuncts to this program.

**PROGRAM 3. COMPUTER SCIENCE AND ENGINEERING CURRICULUM (COURSE VI-A)**

<b>GENERAL INSTITUTE REQUIREMENTS</b> (see page 47)	<i>Total units</i>
Specific science and humanities and social science subjects.	<b>132<sup>1</sup></b>
The subjects, 6.01, 8.03, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 50) and can be used to satisfy the Science Distribution Requirement.	
Laboratory Requirement (see page 51).	<b>12</b>

**DEPARTMENTAL PROGRAM**

<i>Required Subjects<sup>2</sup></i>	
6.01 <sup>3</sup> INTRODUCTORY NETWORK THEORY	4 0 8
6.02 ELECTRONIC DEVICES AND CIRCUITS	4 0 8
6.05 CIRCUITS, SIGNALS, AND SYSTEMS	4 0 8
6.231 PROGRAMMING LINGUISTICS	3 2 7
6.232 COMPUTATION STRUCTURES	4 0 8
6.233 INFORMATION SYSTEMS	4 0 8
6.261 ALGEBRAIC FOUNDATIONS FOR COMPUTER SCIENCE	4 0 8
6.262 COMPUTABILITY, FORMAL SYSTEMS, AND LOGIC	4 0 8
8.03 PHYSICS III	5 0 7
8.04 PRINCIPLES OF QUANTUM PHYSICS	5 0 7
18.034 <sup>3</sup> DIFFERENTIAL EQUATIONS	3 0 9
18.05 <sup>4</sup> ADVANCED CALCULUS FOR ENGINEERS	3 0 9
<sup>4</sup> THESIS	12
<sup>5</sup> INDUSTRIAL PRACTICE	18
	<b>174</b>

*Restricted Electives*

*Departmental Laboratory*  
Subjects selected from the list of laboratory subjects given under Course VI, Program 1 (in addition to the General Institute Laboratory Requirement).

12

*Unrestricted Electives<sup>6</sup>*

**12**  
**48**

Total units required for the S.B. degree **378**

<sup>1</sup>The requirement for the Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup>Under special circumstances, substitution of subjects of similar content may be permitted by petition to the Department.

<sup>3</sup>Students may elect 6.001 ELEMENTS, SYSTEMS, AND COMPUTATION I (4-0-8) and 6.002 ELEMENTS, SYSTEMS, AND COMPUTATION II (4-0-8) in substitution for 6.01 and 18.034. Note that while 6.001 satisfies the Science Distribution Requirement, 6.002 does not satisfy the Science Distribution Requirement.

<sup>4</sup>A thesis of at least 12 units is required. Up to 18 additional units of thesis may be used as elective. Students who continue studies for the S.M. degree and receive the S.M. and S.B. degrees simultaneously may substitute 12 units of additional elective for the undergraduate thesis.

<sup>5</sup>Credit for Industrial Practice subjects is limited to a maximum of 27 units and a minimum of 18 units.

<sup>6</sup>Schedules of students in Course VI-A, Program 3 may always be arranged to leave available 12 units of unrestricted electives in the second year.

**GRADUATE STUDY IN ELECTRICAL ENGINEERING**

The program of graduate education in the Department of Electrical Engineering has three aspects. First, a variety of classroom subjects in physics, mathematics, and fundamental fields of electrical engineering is offered to permit students to develop a strong theoretical background. Second, more specialized classroom and laboratory subjects and a wide variety of colloquia and seminars introduce the student to the problems of current interest in many fields of research, and to the techniques which may be useful in attacking them. Third, each candidate for any advanced degree conducts research, under the direct supervision of a member of the Faculty and reports his results in a thesis.

Three advanced degree programs are offered. A well-prepared student can obtain his Master of Science degree in one calendar year, including completion of a course of formal studies and the presentation of a satisfactory thesis. Students who need more classroom subjects before entering on thesis work, or who want to carry out a more substantial research or teaching program while gaining further graduate experience, may choose to complete their theses by the end of a two-year program and receive the Electrical Engineer and the Master of Science degrees concurrently. The doctoral programs take three years or more to complete. Doctoral candidates are expected to perform thesis research which is a significant contribution to knowledge and to participate in the educational program of the Department. Most doctoral students complete the Master of Science degree requirements in the course of their doctoral programs.

There are no fixed programs of study for these degrees. Each student plans his program in consultation with his Graduate Counselor, a member of the Faculty whose professional field is related to the student's interest. As the program moves towards thesis research, it usually centers in one of a number of areas, each characterized by an active research program. Areas of interest in the Department which have active research programs and related graduate subjects include:

# Engineering

DEPARTMENT OF ELECTRICAL ENGINEERING

Circuits and signals  
Communication and probabilistic systems  
Communications bio-engineering  
Computer science  
Electromagnetic theory and antennas  
Energy conversion devices and systems  
High-voltage radiation engineering  
Materials and devices  
Operations research  
Stroboscopic photography and underwater sound  
Systems science and control engineering

Besides the graduate subjects in Electrical Engineering, many students find it profitable to study subjects in other departments, such as Biology, Economics, Modern Languages and Linguistics, Management, Mathematics, Physics, and Psychology.

The informal seminar is an important mechanism for knitting together members of the various research groups. There are about 16 that meet every week. In these, graduate students, faculty, and visitors report their research in an atmosphere of free discussion and criticism. For the new graduate student, these open seminars are excellent places to learn about the various research activities in the Department.

Research laboratories of extraordinary range and strength are sponsored by the Department. The principle of close integration between regular graduate studies and these research laboratories has proven very effective, yielding educational values beyond those of formal study alone. The Department regards active research as a dominant influence in its graduate program, and each project is conceived and administered so that graduate students can and do have full opportunity to associate with it while retaining their scientific individuality and initiative. Some of the research projects are mentioned in the following paragraphs.

In the *Electronic Systems Laboratory* a program of research and development in control, computer technology and applications, and instrumentation is closely coupled with graduate study in these areas. Faculty, students and full-time staff are engaged in research on topics which include modern control theory; chemical-process control; high-speed vehicle control for ground and space environments; analytical and experimental studies of analog, digital, and analog-digital data-processing systems; logic design; the application of computers to electrical network and mechanical design; library information retrieval; research in man-machine communication devices and techniques for time-

shared computers; research in computer programming; and electronic and microwave sensing systems for the measurement of physical quantities and for exploratory purposes in the aerospace environment. Taken together, these research efforts provide excellent educational opportunities in system and circuit analysis and in the application of modern computational tools, design techniques, and circuit devices to a variety of dynamical systems.

The *Research Laboratory of Electronics* provides a basic research environment with participation of faculty and students from a dozen academic departments. Since the formation of the Laboratory in 1945, as an outgrowth of the M.I.T. Radiation Laboratory, the research program has evolved and broadened. At present, the activities of the Laboratory fall into three principal categories. These are general physics, plasma dynamics, and communication sciences. Among the research activities in general physics are: microwave, optical, and infrared spectroscopy, radio astronomy, molecular beam studies, microwave electronics, and lasers and coherent optics. The research in plasma dynamics includes basic studies of plasma physics and gaseous electronics, as well as applications such as controlled fusion for energy conversion, ion propulsion, and microwave devices.

The research in communication sciences involves studies of both living and man-made systems. The major areas of interest in communications bio-engineering include communications biophysics, neurophysiology, speech communication, linguistics, and cognitive information processing. Other communications studies include information processing and transmission, statistical communication theory, artificial intelligence, circuit theory, and computer research.

Both graduate and undergraduate students participate in the full range of activities mentioned above.

*Project MAC* is an interdepartmental research effort. It supports research in areas such as computer languages, heuristic programming, automata theory, and display systems for convenient man-machine interaction. Both an object of research and the principal research tool in this work is a time-shared computer system which is being developed to make as easy as possible the effective real-time interaction of many users with a powerful computer.

The *Continuum Electromechanics Group* is concerned with the fundamental processes resulting

from continuum electromechanical interactions and their engineering applications.

A group in the *High Voltage Research Laboratory* is concerned with the techniques of producing high-energy particles and radiation, and with their application to the needs of science, medicine, and industry.

A considerable segment of the departmental faculty is engaged in research in the area of solid-state science and engineering. Most of this work is carried on by groups affiliated with the *Center for Materials Science and Engineering*. The *Semiconductor Materials and Devices Groups* are concerned with problems which range from the fundamental physics of semiconductors to the engineering problems encountered in semiconductor device development and analysis, including some of those relating to integrated circuits and the allied use of computers. The *Microwave and Quantum Magnetics Group* is involved in the study of magnetism in relation to crystal structure, in the development of new magnetic materials, and in the utilization of these materials in high-frequency and microwave electromagnetic and acoustic devices. The *Mass Spectroscopy Group* is measuring electron ionization cross sections, studying charged particle optics, and developing new experimental techniques. The single crystals needed for much of the foregoing research are provided by a *Crystal Physics Group*, which has its own active research program concerned with problems of crystal growth and the study of crystal structure and crystal imperfections. The *Materials Theory Group* is concerned with the theoretical description of the electrical, optical, and transport properties of semiconductors. In addition, it deals with the basic aspects of magnetic materials and superconductors.

The *Power Systems Engineering Group* is studying a wide variety of problems pertinent to the generation and distribution of electrical energy. Some of the research projects are the use of an MHD instability for arc interruption, study of a superconducting field system for a high-power alternator, computer estimation of power network behavior based upon discrete (and incomplete) measurements, and prediction of sub-harmonic resonances in super-high-voltage transmission lines.

#### **Financial Aid**

Studies toward an advanced degree can be supported by personal funds, by an award such as the National Science Foundation Fellowship

which the student brings with him to M.I.T., by a fellowship or traineeship awarded by M.I.T., or by a graduate assistantship. Assistantships require participation in research or teaching in the Department or in one of the associated laboratories. Assistants may register for up to 24 units of scheduled classroom and laboratory work and may receive additional academic credit for their participation in the teaching or research program. Many assistants spend two years in a program which leads to the simultaneous award of the Master of Science and the Electrical Engineer degrees, and the Department encourages assistants to pursue such programs.

A brochure on *Research and Graduate Study in Electrical Engineering at M.I.T.*, describing research and teaching opportunities in detail, may be obtained from the Department.

#### **Entrance Requirements for Graduate Study**

The general requirements for admission are set forth in Section 3 of this Catalogue. Because the undergraduate backgrounds of our applicants are so varied (electrical engineering, physics, mathematics, computer science, biomedical engineering, for example), no specific admissions requirements can be listed. The background of each such applicant will be studied carefully to see that he has the principal prerequisites deemed necessary for his probable graduate program. Applicants with non-electrical engineering backgrounds are encouraged to communicate directly with faculty members in their proposed area of study for advice and further details. In any case superior achievement in undergraduate mathematics and physics is considered particularly important.

Every regular graduate student in electrical engineering is required to complete a written examination in February of his first year of graduate study. This examination is designed to explore the student's undergraduate preparation in his principal areas of interest; it is intended primarily to help the student evaluate his preparation and to help the faculty counsel him with respect to his graduate program. Special examinations will be arranged for those for whom the regular examination is inappropriate.

#### **The Graduate Degrees**

##### **MASTER OF SCIENCE IN ELECTRICAL ENGINEERING**

The general requirements for the Master's degree are given in Section 3. The Department requires that the program include at least four

# Engineering

DEPARTMENT OF ELECTRICAL ENGINEERING

formal graduate-level classroom and laboratory subjects.

Students working full time for the Master's degree can take as many as four classroom subjects per term. Students who have graduate assistantships can take as many as two classroom subjects in addition to their teaching or research assignments. The subjects are wholly elective and are not restricted to those given by the Department of Electrical Engineering; however, the program of study must be well balanced, emphasizing one or more of the theoretical or experimental aspects of electrical engineering. A research thesis is required.

All of the four undergraduate programs, previously described, may lead to the degrees of Bachelor of Science and Master of Science in Electrical Engineering, awarded simultaneously at the end of the graduate year.

## **ENGINEER DEGREE**

Able students who desire more extensive training than is possible within the Master's degree program are encouraged to study for the Electrical Engineer degree. The course of studies for this degree is elective, and a thesis is required. The program ordinarily requires at least four terms of graduate study beyond the Bachelor's degree level.

The general requirements for the Engineer degree are given in Section 3. The Department also requires that the program include at least eight formal graduate-level classroom and laboratory subjects.

## **DOCTOR OF SCIENCE OR DOCTOR OF PHILOSOPHY**

The general requirements for the Doctor's degree are given in Section 3.

Only students who have shown promise of performing truly creative work in either engineering or engineering science are encouraged to study for the Doctor's degree. Doctoral candidates are expected to perform thesis research which is a significant contribution to knowledge, and to participate in the educational program of the Department. Students entering on graduate work in the Department without significant research experience are usually required to qualify first for the Master's or Electrical Engineer degree; the quality of the thesis submitted for these degrees is a major component in the decision to admit a student to the doctoral program. For most students the written examination required of all electrical engineering graduate students during their first graduate year is

acceptable as the written part of the General Examination.

Each candidate for the doctorate in electrical engineering must demonstrate intermediate competence in speaking and reading one modern foreign language.

A Minor is required by the Department, and must have departmental approval.

## *Department of Mechanical Engineering*

As perhaps the broadest in scope of all the engineering fields, mechanical engineering is not identified with nor restricted to a particular technology, a particular vehicle, a particular device, or a particular system. It is in fact concerned with so many areas of modern technology that the tasks of the mechanical engineer are most interesting and varied.

We live in an era when technology is changing so rapidly that the education of an engineer must prepare him with a sound base for working in fields which perhaps do not even exist at the time he gets his degree. The greatest strength of the undergraduate curriculum in mechanical engineering, which combines a broad scientific training with project-oriented work in the laboratory and in design, is that it is ideally suited to the education of an engineer for the times in which we live.

The broad scope of mechanical engineering can best be exemplified by listing some of the areas in which active research is proceeding in the Department of Mechanical Engineering at the forefront of one or another technology. These research areas are listed within the three main divisions into which the Department is organized.

### *1. Mechanics and Materials*

Continuum mechanics: elasticity, plasticity, rheology  
Physics and mechanics of deformation and fracture in materials

Dynamics, vibrations, acoustics

Surface physics, wear, lubrication, friction

Manufacturing processes, machines, materials and systems

Fibers, polymers, textiles

### *2. Thermal and Fluid Sciences*

Thermodynamics, kinetic theory, statistical mechanics

Heat transfer, mass transfer

Gas-surface interactions

Aero-acoustics

Fluid mechanics, plasma dynamics

Combustion

Re-entry physics

Cryogenics

Power generation and transmission

Biomedical fluid mechanics

Air and water pollution

Water desalination

### *3. Systems and Design*

Modeling, analysis, synthesis and management of systems

Control system theory and design

Man-machine systems

Instrumentation and measurement systems

Electromechanics

Sensory aids and prostheses

Societal systems design: transportation, underdeveloped technologies, urban problems

Fluidics and fluid power control

Computer-aided engineering: computer graphics, information storage and retrieval

Power and propulsion systems

There can be only one firm foundation for a career as diverse and challenging as that faced by the mechanical engineer. Starting with mathematics, physics and chemistry, he must acquire some mastery in the engineering sciences: dynamics, materials, fluid dynamics, heat and mass transport, thermodynamics and statistical mechanics, systems analysis, and controls. With this he must experience the ways in which scientific knowledge can be put to use in the development and design of useful devices and processes. This is the art of engineering. To teach this art, largely by project-oriented work of creative nature, is the primary object of subjects in laboratory and design. Laboratory experience, which takes many forms, is intended to show how the experimental method is used in the solution of engineering problems. Design experience includes devising means to perform certain specified tasks, such as the design of a device or the synthesis of a system made up of parts having known characteristics.

A field of this width and diversification cannot be learned and mastered in all its details in four college years. The objective of our undergraduate program is to provide a broad intellectual horizon for the graduate and to inculcate such habits and skills of study that he will learn new science as it appears and take the initiative in applying it.

### **THE UNDERGRADUATE PROGRAMS**

Two undergraduate programs are available, one leading to the degree of Bachelor of Science in Mechanical Engineering (Course II), the other to the degree of Bachelor of Science (Course II-A).

#### **PROGRAM FOR THE DEGREE: BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING**

##### ***Mechanical Engineering (Course II)***

The requirements for the degree, Bachelor of Science in Mechanical Engineering, have been

# Engineering

DEPARTMENT OF MECHANICAL ENGINEERING

selected to provide a balanced background in mechanical engineering while allowing students who defer entering the Department until the end of the second year to graduate in the normal four-year period. Students with a satisfactory academic record who have averaged 45 units per term, who have met the General Institute Requirements in chemistry, mathematics, and physics, and who have also taken Differential Equations (18.034) can graduate in four years.

The core curriculum for the degree Bachelor of Science in Mechanical Engineering provides many alternatives for a student who enters the Department at the end of the first year. He may, for example, elect additional upperclass subjects in the humanities and social sciences. He may take a substantial minor program in industrial management. He may elect advanced subjects in physics, mathematics, and mechanical engineering, to prepare for future graduate work. He may arrange his electives so that, as early as possible, he can focus on professional subjects — in some relatively specific area, such as system dynamics and control. Or he may explore allied fields — for instance, biology, if he is interested in biomedical engineering.

The curriculum requirements for the Degree of Bachelor of Science in Mechanical Engineering are given below.

## GENERAL INSTITUTE REQUIREMENTS (see page 47) Total units

Specific science and humanities and social science subjects. 132<sup>1</sup>

The subjects 2.01, 8.03, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 50) and can be used to satisfy the Science Distribution Requirement.

The subjects 2.672 and 2.673, which are required in the Departmental Program, appear on the list of Laboratory Subjects (see page 51) and can be used to satisfy the Laboratory Requirement.

## DEPARTMENTAL PROGRAM

Required Subjects <sup>2</sup>				
2.01	MECHANICS OF SOLIDS	4	0	8
2.02	INTRODUCTION TO SYSTEM DYNAMICS	3	1	8
2.03	DYNAMICS	3	0	6
2.201	FLUID MECHANICS	4	0	8
2.30	MECHANICAL BEHAVIOR OF MATERIALS	3	2	4
2.60	APPLIED THERMODYNAMICS	3	0	6
2.672	EXPERIMENTAL ENGINEERING I	1	3	2
2.673	EXPERIMENTAL ENGINEERING II	0	4	2
2.731	ENGINEERING DESIGN	3	3	6
2.861	ENGINEERING DESIGN AND MANUFACTURE	4	4	4
8.03	PHYSICS III	5	0	7
18.034	DIFFERENTIAL EQUATIONS	3	0	9
	<sup>3</sup> THESIS			9
				132

## Restricted Electives<sup>2</sup>

### Materials

One of the following subjects:

3.13	MATERIALS SCIENCE I	4	3	5
3.141	SCIENCE OF MATERIALS	4	3	5

### Thermodynamics

One of the following subjects:

2.403	THERMODYNAMICS	4	0	8
2.42	ELEMENTS OF CLASSICAL AND STATISTICAL THERMODYNAMICS	4	0	8

24

## Unrestricted Electives<sup>4</sup>

Total units required for the S.B. degree

72

360

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> Substitution of subjects of similar content may be permitted by petition to the Department.

<sup>3</sup> To foster substantial research and design achievement, the Department permits up to 6 units of additional thesis credit, subject to approval of the student's Faculty Counselor.

<sup>4</sup> Schedules of students in Course II may always be arranged to leave available 24 units of unrestricted elective in the second year.

## RECOMMENDED ELECTIVE SUBJECTS

Each student is urged to consult the Department as soon as he has decided to enter Mechanical Engineering so that he can be assigned a Faculty Counselor. The student and his Faculty Counselor then can plan a program that will best utilize the 60 units of unrestricted electives available in the remaining three years. Although the selection of elective subjects is an individual decision, the faculty of the Department recommends the undergraduate elective subjects listed below according to fields of interest.

### Core Electives for All Students

8.04	PRINCIPLES OF QUANTUM PHYSICS
6.14T	INTRODUCTION TO ELECTRONICS
	or
2.13	ELECTROMECHANICAL FIELDS AND SYSTEMS

### Mechanics

2.06	VIBRATIONS
2.071	INTRODUCTION TO SOLID MECHANICS
2.652	EXPERIMENTAL STRESS ANALYSIS

### Manufacturing

2.862	MACHINE TOOL FUNDAMENTALS
-------	---------------------------

### Materials

2.398	RESEARCH IN MATERIALS
-------	-----------------------

### Fibers, Polymers, Textiles

2.901	POLYMER MATERIALS SCIENCE
*2.903	ELEMENTS OF TEXTILE MATERIALS AND PROCESSES
2.904	FIBER PROCESSING DYNAMICS

### Fluid Mechanics

2.202	GAS DYNAMICS
-------	--------------

### Heat Transfer

2.50	HEAT AND MASS TRANSFER
2.53	PROBLEMS IN HEAT

### Thermal Systems

2.611	ELEMENTARY INTERNAL COMBUSTION ENGINES
2.612	INTERNAL COMBUSTION ENGINES
2.614	INTERNAL COMBUSTION ENGINE LABORATORY
2.643	AIR CONDITIONING
2.644	ENVIRONMENTAL CONTROL — AIR CONDITIONING
2.646	REFRIGERATION

**System Dynamics and Control**

- 2.13 ELECTROMECHANICAL FIELDS AND SYSTEMS
- 2.14 CONTROL SYSTEM PRINCIPLES

**Design**

- 2.00 INTRODUCTION TO ENGINEERING SYSTEMS
- \*2.711 GEOMETRIC DESIGN
- 2.732 DESIGN CONCEPTS
- 2.733 SPECIAL PROBLEMS IN SYSTEMS AND DESIGN

**Laboratory**

- 2.654 PHYSICAL MEASUREMENT ANALYSIS
- 2.67 DESIGN AND EXPERIMENT

**Computer Modeling of Physical Systems**

- \*2.10 ELEMENTARY PROGRAMMING AND MACHINE COMPUTATION
- \*2.101 COMPUTER MODELS OF PHYSICAL AND ENGINEERING SYSTEMS I
- \*2.724 NOMOGRAPHY

**Mathematics**

- 18.05 ADVANCED CALCULUS FOR ENGINEERS
- 18.06 ADVANCED CALCULUS FOR ENGINEERS

**Biomedical Engineering**

- 2.74 TOPICS IN BIOMEDICAL ENGINEERING

\*Subjects with no prerequisites which are suitable for freshmen.

**PROGRAM FOR THE DEGREE: BACHELOR OF SCIENCE**

**Mechanical Engineering (Course II-A)**

Many students have a defined goal which can best be met by organizing a curriculum specifically tailored to that goal. Such a curriculum may be significantly different from that required for the degree of Bachelor of Science in Mechanical Engineering or, for that matter, different from that required for a degree in any specified field at M.I.T. For instance, some students may wish to have a substantial component of biology and physiology in their programs, to prepare for biomedical engineering. Others may wish to combine knowledge of solids with knowledge of electrical circuits and devices, or knowledge of fluids with knowledge of physical chemistry and reaction kinetics.

To meet such needs, the Department offers the degree of Bachelor of Science, with a significant part of the curriculum made up of "planned electives." These are to be chosen by agreement between the student and a departmental officer in such a manner that the complete curriculum is coherent and in pursuit of a clear objective.

Students who wish to study for this degree must so advise the Department by the beginning of the junior year in order that there be adequate opportunity for planning the complete curriculum.

The curriculum requirements for this degree are given below.

GENERAL INSTITUTE REQUIREMENTS (see page 47) Total units  
 Specific science and humanities and social science subjects. 132<sup>1</sup>  
 The subjects 2.01, 8.03, and 18.034, which are required in the Departmental Program,

appear on the list of Science Distribution Subjects (see page 50) and can be used to satisfy the Science Distribution Requirement.

Laboratory Requirements. 12

The subjects 2.672 and 2.673, which are among the restricted electives, appear on the list of Laboratory Subjects (see page 51) and can be used to satisfy the Laboratory Requirement.

**DEPARTMENTAL PROGRAM**

**Required Subjects**

2.01	MECHANICS OF SOLIDS	4	0	8
8.03	PHYSICS III	5	0	7
18.034	DIFFERENTIAL EQUATIONS	3	0	9
	THESIS			9
				45

**Restricted Electives**

Five of the following subjects:

3.141	SCIENCE OF MATERIALS			
	or			
3.13	MATERIALS SCIENCE I	4	3	5
2.02	INTRODUCTION TO SYSTEM DYNAMICS	3	1	8
2.03	DYNAMICS	3	0	6
2.201	FLUID MECHANICS	4	0	8
2.30	MECHANICAL BEHAVIOR OF MATERIALS	3	2	4
2.403	THERMODYNAMICS			
	or			
2.42	ELEMENTS OF CLASSICAL AND STATISTICAL THERMODYNAMICS	4	0	8
2.60	APPLIED THERMODYNAMICS	3	0	6
2.672	EXPERIMENTAL ENGINEERING I	1	3	2
2.673	EXPERIMENTAL ENGINEERING II	0	4	2
2.731	ENGINEERING DESIGN	3	3	6
2.861	ENGINEERING DESIGN AND MANUFACTURE	4	4	4
				at least 54

**Planned Electives**

A coherent selection of at least five subjects which, together with the remaining portions of the student's program, is aimed at a well-defined educational goal. The planned electives are to be agreed upon between the student and a designated Faculty Counselor of the Department of Mechanical Engineering.

at least 57

**Unrestricted Electives<sup>2</sup>**

up to 60

Total units required for the S.B. degree 360

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> Schedules of students may always be arranged to leave available 12 units of unrestricted elective in the second year. The Unrestricted Electives must be at least 48 units.

**Mechanical Engineering: Cooperative Program (Course II-B)**

Students who wish to gain industrial experience during their four-year undergraduate program may do so by electing to enroll in Course II-B. Experience in a wide variety of industries is available, in a great many geographical locations. Students interested in this program should contact their Faculty Counselor or the staff member in charge, preferably in the sophomore year.

# Engineering

DEPARTMENT OF MECHANICAL ENGINEERING

## CURRICULUM IN THE COOPERATIVE COURSE (COURSE II-B)

The Course degrees and curricular requirements are the same as for Courses II and II-A; however, in addition, provision is made for the students to be employed in the plants of the cooperative companies. The plant work is considered as equivalent to an 8-unit elective subject:

2.951 INDUSTRIAL PRACTICE	40 h.p.w.
2.952 INDUSTRIAL PRACTICE	0 8 0

### *The Advanced Undergraduate Program*

In the conviction that a gifted mind can be developed to its full potential when suitably challenged, the Department makes special provision for the education of its exceptional students. Selection of students for the Advanced Undergraduate Program is made at the end of the sophomore year. During their third and fourth years, these men undertake special programs of study designed on an individual basis, with many graduate subjects included. Students in this program have, at the end of the fourth year, an intellectual maturity and a technical knowledge surpassing that of most Master's candidates and are in a unique position to pursue further graduate work. While the emphasis of the program is on the conscious pursuit of excellence rather than on degrees, it is sometimes possible for students in the Advanced Undergraduate Program to acquire the Master's degree before the end of the fifth year.

Students in this program will normally be invited to become members of the Honors Course, described below.

### *The Undergraduate Honors Course*

Towards the end of the junior year an opportunity is offered to a limited additional number of students of superior ability to join an Honors Course group, which provides a coordinated schedule of studies through the senior and a graduate year.

The Honors Course leads to the degrees of Bachelor of Science and Master of Science in Mechanical Engineering, awarded simultaneously at the end of the fifth year of study. The program must satisfy all the requirements for both degrees, but only a single thesis is required.

## GRADUATE STUDY IN MECHANICAL ENGINEERING

The Department provides opportunities for graduate work leading to the following degrees: Master of Science in Mechanical Engineering, Master of Science in Textile Technology, Mechanical Engineer, Materials Engineer, Doctor of Science or Doctor of Philosophy.

### *Entrance Requirements for Graduate Study*

The general requirements for admission are those given in Section 3 of this Catalogue.

Students starting graduate study in mechanical engineering usually have received the equivalent of a Bachelor's degree in mechanical engineering at a recognized engineering school; however, in many cases they will have had their undergraduate preparation in some other branch of engineering or science. Generally, their background includes preparatory studies in some or all of the following areas: applied mechanics, fluid mechanics, dynamics, thermodynamics, electrical circuits, electromagnetic fields, and materials. The Department requirements for admission are not specific, since a capable student with a more general preparation has the opportunity to establish his background in mechanical engineering by taking the most advanced undergraduate subjects which his abilities and preparation will permit.

The fields of advanced study and research are those briefly listed on page 131. Well-equipped facilities are available in the following laboratories:

Acoustics and Vibrations Laboratory  
Atomic and Molecular Kinetics Laboratory  
Automotive Laboratory, Sloan  
Combustion and Propulsion Laboratory  
Computer  
Cryogenic Engineering Laboratory  
Energy Conversion Laboratory  
Engineering Projects Laboratory  
Environmental Control Laboratory  
Fibers and Polymers Laboratory  
Fluid Mechanics Laboratory  
Fluid Power Control Laboratory  
Gas Turbine Laboratory  
Heat Transfer Laboratory  
Man-Machine Systems Laboratory  
Materials Laboratory  
Materials Processing Laboratory  
Power Systems Engineering Laboratory  
Sensory Aids Center  
Stress Analysis Laboratory  
Surface Laboratory  
Vacuum Laboratory

### *The Graduate Degrees*

#### MASTER OF SCIENCE IN MECHANICAL ENGINEERING

The general requirements for the degree are given in Section 3 of this Catalogue.

The student working for the Master of Science in Mechanical Engineering follows a wholly elective program; his subjects are not

restricted to those given by the Department of Mechanical Engineering. The selection of individual subjects is restricted only by the condition that the program must be substantial and logical in the judgment of the faculty advisor. The program should be well balanced, emphasizing one or more of the analytical, economic, design, or experimental aspects of the field.

#### **MASTER OF SCIENCE IN TEXTILE TECHNOLOGY**

Candidates for the Master of Science in Textile Technology should have the training offered by the Institute (or equivalent training from another institution) in the fields of either chemical engineering, chemistry, mechanical engineering, business and engineering administration, or industrial physics. The program for the degree lasts from one to two years, depending upon preparation. Students who have graduated with high standing from technical or textile schools which offer less extensive preparation in science and engineering may be accepted for study, but should expect to spend at least two years to fulfill degree requirements.

#### **MECHANICAL ENGINEER**

In recent years there has developed a need for leaders possessing knowledge in depth in a number of areas associated with mechanical engineering. For those who desire to prepare themselves for engineering practice at a high professional level, the degree of Mechanical Engineer is awarded for a program of study which is more advanced than that for the degree of Master of Science. The requirements for the degree include an additional year of class work beyond the Master's degree together with satisfactory performance in a comprehensive examination. If the Master's degree was not taken at M.I.T., a thesis must be a part of the program. The general requirements for the degree are given in Section 3 of this Catalogue.

#### **MATERIALS ENGINEER**

Candidates interested in studying materials engineering in the Department of Mechanical Engineering should in general have training equivalent to that offered by the Institute in its undergraduate programs in any of several departments of engineering or science. The graduate program encompasses study in the areas of mathematics, physics, chemistry, electrical materials, continuum and dislocation mechanics, metallurgy, ceramics, elastomers, and plastics, as well as research. In general, two years are required for completion of the degree of Materials Engineer. General re-

quirements for the degree of Materials Engineer include a qualifying examination, as described for the Mechanical Engineer degree.

#### **DOCTOR OF SCIENCE OR DOCTOR OF PHILOSOPHY**

Admission to the doctoral program is granted only after the candidate has passed a qualifying examination; this should be taken as soon as possible after completing the Master's degree program. The requirements for the Doctor's degree include a Program of Advanced Study, a Minor program, a thesis in the field of Mechanical Engineering or in the field of Materials Engineering, and the language requirement specified for the doctorates on page 83 of the Institute degree requirements.

The program of advanced study and research may be selected in any field of science or engineering approved by the Department Committee on Graduate Studies. While no fixed number of units is prescribed, the usual program includes a substantial number of subjects in the student's area of principal interest, in addition to those taken to satisfy the requirements for the Master's degree; these, with the Minor program, usually require an additional two terms of work beyond the Master's degree. The Minor program must be approved by the student's doctoral committee.

The qualifying examination must be completed before any program of research is undertaken. The language requirements should be fulfilled as early as possible in the program, so that the student will be capable of reading the foreign scientific literature on his proposed thesis subject before starting the actual research.

For his thesis, each candidate undertakes a program of research which will contribute significantly to his major field of interest. The Program of Advanced Study and the thesis are under the supervision of a doctoral committee selected by the student and his thesis supervisor. The doctoral committee makes an annual evaluation of the candidate's progress and conducts a final examination based on the thesis. While no fixed number of units is prescribed, the research usually requires at least one year of registration.

Candidates entering this doctoral program following award of the Master's degree in textile technology must meet the foregoing requirements but with a thesis based on research in the field of fibrous materials.

# Engineering

DEPARTMENT OF METALLURGY AND MATERIALS SCIENCE

## *Department of Metallurgy and Materials Science*

The Department of Metallurgy and Materials Science is concerned with the principal engineering materials upon which modern civilization depends. These are the skeleton, or even the whole substance, of structures, machines and equipment, and mechanical and electrical devices. Modern society cannot satisfy its needs for materials from wood, cement, and crude metals alone. The mechanical, chemical, thermal, and electrical properties demanded of materials today require much greater sophistication in the selection, treatment, and assembly of a bewildering variety of substances designed for specific needs.

Fortunately, there is a key to the rational use and development of materials, simple or complex, which is the basic contribution of the metallurgist. It is an understanding of the relations between structure and properties and, equally important, the knowledge of how structure may be controlled to influence properties. Structure has many levels: atomic, electronic, crystal, and gross. Even the lack of crystalline structure, as in glasses and some polymers, the blending of gross structures, as in composites, and defects in crystalline structures, as in electronic materials, are important features in the development of properties.

The name of the Department has both historical and technical significance. There is more to metallurgy and materials science than structural chemistry and solid-state physics. The metallurgist is also an engineer who must prepare materials of very high purity and know how to blend or alloy them, how to change their structure by heat treatment, deformation, phase change, and joining. He must, in effect, design materials with the desired combinations of properties; this is one of the applied aspects of his work. Historically, the metallurgist takes his name from the oldest, most abundant, and most serviceable of all engineering materials. But today he must know the place of other materials, such as ceramics, plastics, and other non-metallics, in the scheme of things. The same methods which have been so vital in the development of an extraordinary array of metals and alloys have been just as fruitful in the evolution

of improved ceramics, plastics, and electronic materials.

Metallurgists and materials engineers must bring together many skills in coping with actual materials problems. Some specialize in the preparation of materials, for which a basic knowledge of chemistry and control systems is most helpful. Others are concerned with the elucidation of structure-property relations, for which a background in solid-state science is more useful. Still others deal with the manipulation of shape and properties, for which an understanding of the mechanics of materials is critical. The versatile man can apply his basic knowledge to any of these areas, whether in research, development, production, or management.

Because the field of materials is so broad, the Department has chosen to concentrate its activities in metals, ceramics, and electronic materials, though it should be emphasized that the appropriate knowledge and methods can be applied successfully to the technology of any material.

Metallurgy and materials science are of vital importance to modern industry. The design and operation of propulsion units such as gas turbines and rocket motors, of energy producers such as nuclear reactors, or energy converters such as magnetohydrodynamic and thermoelectric generators, and of electrical and mechanical devices are critically dependent on the availability of materials with the requisite blend of properties. Men with skills to design these materials are in great demand by industry and government. They find challenging opportunities in a large variety of positions in operations, development and research in the basic materials-producing industries, chemical and metallurgical, in the consumer industries, which make products ranging from automobiles to surgical instruments, and in the space and defense oriented industries.

### **THE UNDERGRADUATE PROGRAMS**

**PROGRAM FOR THE DEGREE: BACHELOR OF SCIENCE IN METALLURGY AND MATERIALS SCIENCE**

#### ***Metallurgy and Materials Science (Course III)***

The undergraduate program caters to the diverse needs of students who aim for a terminal degree and those who intend to pursue graduate

work, to those who are more inclined toward engineering application as well as those who prefer solid-state science. The decision to concentrate on the physics, chemistry, or engineering of materials may be reached by students as late as the sophomore year or even during the junior year.

For these reasons, the curriculum is flexible. Understanding of materials is developed from a foundation of physical and engineering science, a core of subjects in mechanics, thermodynamics, crystal structure, and structure-property relations. These essential subjects are taught within the Department, so that meaningful examples can be used to illustrate the material. However, appropriate substitutions of subjects taken in other departments are permitted.

The elective program, constituting more than 20 per cent of the student's time, is chosen, with the help of an advisor, to give depth in one or more technical areas such as the preparation and purification of materials, including the chemical process technology employed by steelmakers; the processing and fabrication of materials by deformation, heat treatment, and phase change; the study and control of structure-property relations in metallic and ceramic materials; and the physics of solid materials generally. Many graduate subjects are open to undergraduates having the necessary preparation.

Other choices under the elective program are, of course, possible. A student may focus his elective time on modern production or research management techniques in the materials industry, or he may simply prepare for later graduate study.

Participation in laboratory work by undergraduates is an integral part of both engineering and research experience. Some laboratories are associated with particular subjects, but, especially in thesis work, the undergraduate has access to the extensive facilities for graduate research in materials described in a later section.

The teaching facilities, some of which are located in the Center for Materials Science and Engineering, include an electron-optics laboratory with X-ray and electron diffraction equipment; electron microscopes and microanalyzers; laboratories for microscopic studies, heat treatment, and physical testing of materials; and complete test apparatus for the study of mechanical, thermal, electrical, and magnetic properties. In the ceramics laboratories most types of refractory as well as electrical ceramics and glasses can be

prepared or their properties studied. Facilities for the growth and characterization of metallic and non-metallic crystals are available in several laboratories. The chemical metallurgy laboratories contain equipment for the study of heat and mass flow and for thermodynamic and kinetic investigations at high temperatures. The materials processing laboratories are equipped for work on deformation, solidification, joining, and vapor deposition as processing techniques. Laboratories in surface chemistry, corrosion, and mineral processing are also open to undergraduates. Other services include a complete analytical laboratory and computation facilities with remote consoles.

The Course leads to the degree of Bachelor of Science in Metallurgy and Materials Science. The curriculum requirements for the degree are given below:

		<i>Total</i>
		<i>units</i>
<b>GENERAL INSTITUTE REQUIREMENTS</b> ( <i>see page 47</i> )		<i>132</i> <sup>1</sup>
Specific science and humanities and social science subjects.		
ECONOMIC PRINCIPLES I (14.01T) is recommended in the upperclass humanities and social science program.		
The subjects 3.00, 8.03, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects ( <i>see page 50</i> ) and can be used to satisfy the Science Distribution Requirement.		
Laboratory Requirement ( <i>see page 51</i> ).		<b>12</b>
<b>DEPARTMENTAL PROGRAM</b>		
<i>Required Subjects</i> <sup>2</sup>		
3.00	THERMODYNAMICS OF MATERIALS	4 0 8
3.01	THERMODYNAMICS AND STATISTICAL MECHANICS	3 0 9
3.02	CHEMISTRY OF MATERIALS	3 3 6
3.11	MECHANICS OF MATERIALS	4 0 8
3.12	PRINCIPLES OF CRYSTALLOGRAPHY AND X-RAY DIFFRACTION	4 3 5
3.13	MATERIALS SCIENCE I	4 3 5
3.15	MATERIALS SCIENCE II	4 3 5
8.03	PHYSICS III	5 0 7
18.034	DIFFERENTIAL EQUATIONS	3 0 9
	<sup>4</sup> THESIS	12
		<b>120</b>
<i>Restricted Electives</i>		<b>20 to 24</b>
<i>Physical Metallurgy</i>		
<i>One of the following subjects:</i>		
3.14	PHYSICAL METALLURGY I	4 3 5
3.144	PHYSICAL METALLURGY I	4 0 4
<i>Materials Processing</i>		
<i>One of the following subjects:</i>		
3.18	MATERIALS PROCESSING	4 3 5
3.188	MATERIALS PROCESSING	4 0 4
<i>Unrestricted Electives</i> <sup>1</sup>		<b>76 to 72</b>
Total units required for the S.B. degree		<b>360</b>

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> Substitution of subjects of similar content is permitted in some cases.

# Engineering

DEPARTMENT OF METALLURGY AND MATERIALS SCIENCE

<sup>3</sup>Schedules of students in Course III may always be arranged to leave available 12 units of unrestricted elective in the second year.

<sup>4</sup>Up to 6 additional units of thesis may be used as elective.

Students who decide during the first year at M.I.T. to study Metallurgy and Materials Science can facilitate their later progress by ensuring that their second-year subjects include additional mathematics and physics as well as 3.00 and 3.11, or their equivalents. The third and fourth years may then be devoted to study, in some depth and with adequate preparation, of areas such as physical metallurgy, the physics of solids, chemical metallurgy, or ceramics, through appropriate use of upperclass elective time.

Some students, on the other hand, do not wish to make a Course choice until the junior year or may wish to use their elective time to the fullest possible extent in the second year rather than in later years. Generally, it will still be possible to complete the Departmental Program and Institute Requirements in two more years, especially if one of the second-year Science Distribution Subjects is in thermodynamics or mechanics of solids; but elective freedom, particularly in the fourth year, will have been sacrificed. An inadequate preparation in physics will cause the most difficulty, though a schedule may still be arranged.

## PROGRAM FOR THE DEGREE: BACHELOR OF SCIENCE

### *Metallurgy and Materials Science (Course III-A)*

Many desirable educational goals exceed the bounds of a departmental program, particularly in a thoroughly interdisciplinary field such as materials science. The student may wish, for instance, to combine biology with materials science to satisfy his interest in biomaterials, or may have a strong interest in the role of materials in the humanities, ocean engineering and deep sea submergence, the exploration of space, transportation and communication, electronic devices and digital computers, energy conversion, environmental systems, and other fields; he may wish to emphasize such areas as polymers and polymer chemistry, concretes and cements or soils.

Generally, a curriculum may be set up to attain such goals. For this purpose the Department offers the degree of Bachelor of Science. If the student informs the Department of his intentions at the beginning of the junior year (or earlier), there is usually enough time for the

student and a Faculty Advisor to plan a coherent program with a list of planned electives, and submit it to the Department for approval. Such a program can be much more effective if the student's aims are discussed, as early as possible, with the appropriate faculty members, and the Department urges the student to do so.

<b>GENERAL INSTITUTE REQUIREMENTS</b> (see page 47)	<i>Total units</i>
Specific science and humanities and social science subjects.	<b>132<sup>1</sup></b>
ECONOMIC PRINCIPLES I (14.01T) is recommended in the upperclass humanities and social science program.	
Science Distribution Requirement.	<b>36</b>
The subjects 3.00, 8.03, and 18.034, which are among the restricted electives, appear on the list of Science Distribution Subjects (see page 50) and can be used to satisfy the Science Distribution Requirement.	
Laboratory Requirement (see page 51).	<b>12</b>

## DEPARTMENTAL PROGRAM

<i>Restricted Electives<sup>2</sup></i>			
<i>Six of the following subjects:</i>			
3.00	THERMODYNAMICS OF MATERIALS	4	0 8
8.03	PHYSICS III	5	0 7
18.034	DIFFERENTIAL EQUATIONS	3	0 9
3.01	THERMODYNAMICS AND STATISTICAL MECHANICS	3	0 9
3.02	CHEMISTRY OF MATERIALS	3	3 6
3.11	MECHANICS OF MATERIALS	4	0 8
3.12	PRINCIPLES OF CRYSTALLOGRAPHY AND X-RAY DIFFRACTION	4	3 5
3.13	MATERIALS SCIENCE I	4	3 5
3.15	MATERIALS SCIENCE II	4	3 5
3.14	PHYSICAL METALLURGY I	4	3 5
3.18	MATERIALS PROCESSING	4	3 5
3.16	PHYSICAL METALLURGY II	2	4 4
			<b>72</b>
<i>Planned Electives</i>			
At least six subjects which are selected by the student and Faculty Advisor; together with the restricted electives, these subjects should make up a program intended to attain the goal defined by the student.			at least <b>72</b>
<i>Unrestricted Electives<sup>2</sup></i>			
			up to <b>72</b>

Total units required for the S.B. degree **360**

<sup>1</sup>The requirement for Classes '70, '71, and '72 is 128, the Unrestricted Elective units being increased by 4.

<sup>2</sup>Substitution of subjects of similar content is permitted in some cases. If 3.00, 8.03, or 18.034 are used to satisfy the Science Distribution Requirement, the total for Restricted Electives will be reduced accordingly and the total for Unrestricted Electives will be increased accordingly. The Unrestricted Electives must be at least 36 units.

## GRADUATE STUDY IN METALLURGY, MINERAL ENGINEERING, CERAMICS, AND MATERIALS SCIENCE

The Department conducts a large and active fundamental research program on the structure and properties, preparation, and processing of materials, with emphasis on metals and ceramics. Graduate research is an important part of the

educational process, and interaction between graduate and undergraduate is encouraged through participation in research. Students are allowed to choose research projects for which they have enthusiasm and generally work with an individual faculty advisor. Most research projects result in significant findings which are published in the scientific literature. Graduate subjects of instruction, in this and other departments, allow the student to pursue areas in depth but also afford the opportunity for a broad view of the field of metals and materials. Though there are many individual research laboratories in the Department, there is much interaction and sharing of experimental facilities between them. Such interaction extends to laboratories of other departments, and joint projects are common. Interdisciplinary research is facilitated by the Center for Materials Science and Engineering, of which metallurgy is an important part.

#### STRUCTURE AND PROPERTIES OF MATERIALS

The detailed structure of materials may be related to their mechanical, thermal, optical, and electrical properties. The study of such relationships with mechanical properties is one of the principal concerns of the physical metallurgy laboratories. The methods of electron and X-ray diffraction and electron microscopy are used to examine microstructural lattice imperfections induced by plastic flow and phase transformations; a classic example is the investigation of strengthening mechanisms in steel. Thermodynamic techniques also contribute to such research and are extended to investigation of deformation, annealing, and radiation damage. The mechanism of flow and fracture at high temperatures is studied in the high-temperature metals laboratory which is also concerned with the properties of metal, metal-oxide alloys. Deformation and fracture characteristics of ceramics, including even ice, are investigated in the ceramics laboratories. The mechanical properties of anisotropic and composite materials are also of interest from the structural viewpoint. Dislocation interactions in materials at low temperatures can be studied by the modern techniques available. An electron optics group is concerned with developing new tools such as micro-X-ray diffraction and the application of the electron microprobe to produce Kossel line patterns. Kinetic processes are not neglected; for example, there is important research on

stress relief, recrystallization, flow and fracture, and diffusion under stress.

Work on electrical properties proceeds in various laboratories. The superconductivity of metals, alloys, compounds, and composites and the relationship of defect microstructures to superconducting properties are extensively studied. The surface characteristics of semiconductor compounds and the study of materials for thermionic emission are part of the research on electronic materials. Thermal, optical, and electrical properties of both crystalline and non-crystalline ceramic materials form one of the principal areas of research in ceramics. The structures and crystallization of certain polymers are also of interest. The effects of irradiation damage on spontaneous magnetization and the study of spin disorder in magnetic alloys are examples of work on magnetic properties.

Work on Fermi surfaces and fine X-ray structure studies are conducted by a group in the physics of solids.

#### PREPARATION OF MATERIALS

Much of the research in this area is concerned with establishing thermodynamic properties and studying the mechanism of interaction between substances. In the chemical metallurgy laboratories, studies are made of the thermodynamic properties of liquid and solid metals and alloys, utilizing such methods as high-temperature solution calorimetry, reversible electrochemical cells, measurement of vapor pressures, and equilibration between gases and condensed phases. There are also studies of diffusion in liquid alloys and salts, on the kinetics of reactions between gases and liquid metals, and of electrode kinetics in high-temperature systems.

Separation of materials is an important part of preparation, and in the mineral engineering laboratories there are studies of the mechanism of flocculation of wet solids, of the fragmentation of materials, and of surface chemistry, including contact angle hysteresis, the electrochemistry of solid-liquid interfaces, and the kinetics of leaching processes.

The reaction of materials with their environments extends to fundamental corrosion research, including the measurement of contact potentials and studies of polarization, passivity, the nature of surface films, and the mechanisms of oxidation and corrosion under stress.

Other laboratories, for example ceramics and materials processing, require specific materials

# Engineering

DEPARTMENT OF METALLURGY AND MATERIALS SCIENCE

prepared by powder methods, vacuum melting and deposition, and zone refining.

## PROCESSING OF MATERIALS

The processing of materials to influence shape and properties involves study of the fundamental processes of solidification, deposition, deformation, and joining.

Research on solidification is conducted on aqueous solutions, metals, and alloys. The detailed structures produced by directional and slow solidification, as in castings, and by rapid solidification, as in arc-deposition, are of particular interest. Deposition of materials from the vapor state and plasma spraying are also studied.

Research on deformation processing involves the fundamentals of flow, fracture, and fatigue as well as studies of friction and lubrication during deformation, plastic instability, and superplasticity.

Work on joining includes fundamental studies of heat flow and material properties in arc, electron-beam, and laser welding, of vapor processing and surface treatment, and of sintering and brazing.

## EQUIPMENT

The latest research equipment is available for studies in all of these areas. Facilities include all types of high-temperature furnaces in chemical metallurgy and ceramics, vacuum induction and vacuum arc-melting furnaces, electron beam melting apparatus, and zone refining and crystal growing equipment in materials processing. In physical metallurgy and electron optics, the latest electron microscopes, electron diffraction apparatus, equipment for metallographic examination, X-ray diffraction apparatus for structural analysis and fine-structure studies, X-ray fluorescent analyzers, and electron probe micro-analyzers are all available, in addition to specialized equipment. Equipment for testing mechanical properties at high and low temperatures under a variety of strain rates is available in physical metallurgy and materials processing. Materials can be deformed in many ways, and the heavier equipment includes rolling and forging apparatus. A completely equipped laboratory is available for fundamental solidification studies. The welding laboratory includes welding, plasma-arc melting, electron-beam, and laser apparatus. All the necessary equipment for electrochemical studies in the corrosion laboratory and counting equipment for tracer studies in mineral engineering are available.

More recent additions include ultra-high vacuum equipment, extensive metallic and semiconductor crystal-growing apparatus, equipment for Fermi surface studies, and a high-pressure laboratory.

The Department maintains an analytical laboratory, machine and instrument-making shops, a student machine shop, and remote computation consoles.

## Requirements for Graduate Study

The general admission requirements are those given in Section 3 of this Catalogue. Students whose undergraduate preparation is in metallurgy will generally be familiar with the principles of heat and fluid flow, thermodynamics, and materials science, with the emphasis on metallurgy. Those whose undergraduate preparation is in other branches of science and engineering and who wish to enroll for advanced degrees in the Department may find it advantageous to take some undergraduate subjects during their first year of graduate study.

It is expected that those who do graduate work in metallurgy will have studied the following subjects or their equivalents:

THERMODYNAMICS AND STATISTICAL MECHANICS (3.01)

MATERIALS SCIENCE I (3.13)

Graduate students whose preparation does not include the above subjects, or their equivalents, are expected to complete them in the early part of their graduate work.

Students who wish to do graduate study in ceramics generally have varied backgrounds, and there are no special requirements. However, all entering graduate students are required to register for CERAMICS (3.06) unless they have had similar training elsewhere.

For students in materials science, the general Institute requirements for admission, given in Section 3 of this Catalogue, are sufficient. Programs are arranged on an individual basis depending on the preparation and interests of the student. Students who have not taken the following subjects or their equivalents are expected to complete them as early as possible.

THERMODYNAMICS AND STATISTICAL MECHANICS (3.01)

MATERIALS SCIENCE I (3.13)

## The Graduate Degrees

The Department offers the following graduate degrees: Master of Science in Metallurgy; Master of Science in Ceramics; Metallurgical Engineer; Mineral Engineer; Doctor of Science or Doctor of Philosophy.

The graduate degree requirements are as set forth in Section 3 of this Catalogue. The Department requires that candidates for the doctoral degrees pass a qualifying examination before proceeding with their programs of study and research and satisfy a Minor requirement. Information on this examination and on the areas covered by the general examination is available from the Chairman of the Departmental Committee on Graduate Students.

***Assistantships and Fellowships***

The Department offers assistantships and fellowships for graduate study. Research and teaching assistantships are available in all of the fields in which the Department is active. Further information may be obtained from the Chairman of the Departmental Committee on Graduate Students.

## *Department of Naval Architecture and Marine Engineering*

The Department of Naval Architecture and Marine Engineering encompasses ocean transportation, naval engineering, and ocean engineering. It is concerned with all aspects of vehicles and structures operating below and just above the sea surface, as well as on it. Activities range from the application of the most advanced engineering science disciplines to the unusual and specialized problems encountered in such devices; through the synthesis of all the systems, components, and structures of which they are comprised; to the consideration of environmental effects; to fabrication and construction; and to the management of transportation enterprises. The unifying objective is that of optimizing the sea-based components of transport, utilization, and habitation systems, whether in their research, development, or production phases. In keeping with this purpose, the Department of Naval Architecture and Marine Engineering emphasizes both the application of scientific knowledge and the development of each student's ability to interpret and apply the rapidly expanding knowledge in all pertinent disciplines.

Among the specific interests of the Department is the development of vehicles, structures, and devices for undersea research and exploitation. Deep-submergence, hydrofoil, and air-cushion vehicles present intriguing and urgent problems in structural and hydrodynamic design, propulsion, control, and instrumentation. Large structures for the recovery of petroleum and mineral resources from the ocean floor also fall largely into the field of interest of naval architects. Interest in devices for oceanographic research is generated by the close alliance between physical oceanography and the environmental conditions to which other vehicles and structures are subjected. Challenging applications of operations research are to be found in the evaluation of environmental conditions, in design, and in management.

The educational program of the Department leads to a broad engineering and scientific competence, with a core content which includes application of fundamental principles to problems in ocean transportation, naval engineer-

ing, and ocean engineering. It is based on a wide-ranging foundation of fundamental engineering science and is an excellent background for almost any later special activities based on the physical sciences. A flexible curriculum, a departmental faculty with wide and continuing research and industrial experience, and unusually close faculty-student contact all contribute to a sound and effective education.

The Department offers programs at both the undergraduate and graduate level in Naval Architecture and Marine Engineering, including a graduate degree program in Ocean Engineering. A program in Shipping and Shipbuilding Management is offered as a combination of undergraduate and graduate study, or as a graduate program. In addition, a program in Naval Construction and Engineering is available to selected officers of the U.S. Navy, U.S. Coast Guard, and accredited foreign navies.

### **THE UNDERGRADUATE PROGRAMS** *Naval Architecture and Marine Engineering* *(Course XIII)*

This curriculum is intended for students interested in the technical aspects of the marine industry — naval architects, marine engineers, and those with more specialized interests such as hydrodynamics. It also serves as suitable preparation for (and may be integrated with) the graduate programs in Ocean Engineering and in Shipping and Shipbuilding Management. All take the same required subjects in mathematics, science, engineering fundamentals, and humanities, in addition to subjects in the various phases of vehicle design, construction, and marine engineering. In each of the latter, attention is focused on the flexible and creative application of science and engineering. A thesis — a report of an independent research or study project — is required of every student before he graduates. The elective part of the program, which for an average student comprises about six subjects (in addition to those normally taken in the first two years), can be made up of subjects of general or specialized interest within or outside the Department; or it may be chosen to satisfy well-defined objectives in special fields, such as design, ocean engineering, manage-

ment, hydrodynamics, and structural mechanics. Throughout the curriculum the emphasis is on developing logic and originality, so that graduates may make an orderly attack on any engineering problem.

The undergraduate curriculum is given below. Substitution for departmentally prescribed subjects is encouraged when appropriate to a student's educational objective and particularly when more effective sequencing of elective subjects can result. Sequencing of required and prerequisite subjects can be so arranged that whatever normal program has been followed at the Institute during the first two years, the departmental undergraduate requirements can be met in a total of four years by foregoing elective time in the upperclass years.

Within departmental subjects, emphasis is placed on the application of engineering and science to physical problems, with examples chosen principally from the fields of naval architecture, marine engineering, ocean transportation, and ocean engineering; design projects emphasize the underlying engineering principles. Throughout, attention is directed to the development of logic and originality, to the end that graduates may make an effective attack on any engineering problem. Further, since both naval architecture and marine engineering are based in the general field of mechanical engineering, students spend much of their class time in the Department of Mechanical Engineering.

This four-year Course leads to the degree of Bachelor of Science in Naval Architecture and Marine Engineering. The curriculum requirements for this degree are given below:

GENERAL INSTITUTE REQUIREMENTS (see page 47)		Total units
Specific science and humanities and social science subjects.		132 <sup>1</sup>
ECONOMIC PRINCIPLES I (14.01T) is required in the upperclass humanities and social science program.		
The subjects 2.01, 8.03, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 50) and can be used to satisfy the Science Distribution Requirement.		
Laboratory Requirement (see page 51).		12
<b>DEPARTMENTAL PROGRAM</b>		
<i>Required Subjects<sup>2</sup></i>		
2.01	MECHANICS OF SOLIDS	4 0 8
2.02	INTRODUCTION TO SYSTEM DYNAMICS	3 1 8
2.201	FLUID MECHANICS	4 0 8
2.403	THERMODYNAMICS	4 0 8
3.141	SCIENCE OF MATERIALS	4 3 5
8.03	PHYSICS III	5 0 7
13.00	INTRODUCTION TO MARINE HYDRO-DYNAMICS	3 1 8

13.20	ENERGY CONVERSION SYSTEMS AND COMPONENTS	4 0 8
13.30	SHIP STRUCTURAL ANALYSIS AND DESIGN	3 3 6
13.40T	INTRODUCTORY SHIP DESIGN	2 4 3
13.701	A SURVEY OF OCEAN ENGINEERING	1 0 1
18.034	DIFFERENTIAL EQUATIONS	3 0 9
18.05	ADVANCED CALCULUS FOR ENGINEERS	3 0 9
	THESIS	9
		152
	<i>Unrestricted Electives<sup>3</sup></i>	64
	Total units required for the S.B. degree	360

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> The Department encourages substitution of subjects of similar content after consultation with and concurrence of the Faculty Counselor.

<sup>3</sup> Schedules of students in Course XIII may always be arranged to leave available 12 units of unrestricted elective in the second year.

#### **Shipping and Shipbuilding Management (Course XIII-B)**

This five-year program is intended for students primarily interested in the business and management phases of the marine industry. Students entering professional work in this field must have a firm technical background; hence all the departmentally prescribed subject requirements of the Naval Architecture and Marine Engineering curriculum must be satisfied prior to graduation. According to their interests, students select areas of concentration in business and management and study undergraduate and graduate subjects in the Department of Economics and the Alfred P. Sloan School of Management.

The coordinated program of undergraduate electives and graduate study for Course XIII-B will be approved after consultation with and concurrence of the Alfred P. Sloan School of Management. Compliance with all regulations of the Graduate School is required.

Although students are not normally admitted to the program until application to the Department at the end of the third year, it will be found convenient to arrange elective programs throughout the undergraduate period of study with this end in view because interdepartmental requirements of graduate subjects in economics and industrial management make early use of elective time for prerequisites necessary. Completion of the prescribed program within five years can be accomplished only by the most effective use of elective time. Application for admission to the Graduate School must be accepted before the beginning of the fifth year. Satisfactory scores in the Admissions Test for Graduate Study in Business must be submitted.

This five-year program leads to two degrees: the Bachelor of Science in Naval Architecture

# Engineering

DEPARTMENT OF NAVAL ARCHITECTURE AND MARINE ENGINEERING

and Marine Engineering and the Master of Science in Shipping and Shipbuilding Management, awarded simultaneously at the end of the graduate (fifth) year. The undergraduate curriculum requirements are the same as for Course XIII, except that the 9 units of undergraduate thesis are allotted to additional professional subjects, and that concentration in Economics (Field 6) and Labor Relations (Field 8) of the humanities program is not permitted.

The graduate requirement is 72 units of graduate study plus a satisfactory thesis. Normally, students will fulfill prerequisites for required subjects by taking additional graduate subjects.

The graduate program in Shipping and Shipbuilding Management is described below.

## GRADUATE STUDY IN NAVAL ARCHITECTURE, MARINE ENGINEERING, OCEAN ENGINEERING, AND SHIPPING AND SHIPBUILDING MANAGEMENT

Graduate study may be pursued in one or more of the following areas: Naval Architecture, Marine Engineering, Ocean Engineering, Naval Engineering, and Shipping and Shipbuilding Management.

A program of graduate study in the Department is almost entirely under the control of the student, with assistance in his planning by his Graduate Registration Officer. An acceptable graduate program of 72 credit units plus an acceptable thesis leads to the degree of Master of Science in Naval Architecture and Marine Engineering or in Ocean Engineering; this program can usually be completed in one academic year if it is based on an undergraduate curriculum equivalent in scope and emphasis to that available in this Department. A two-year program leads to the degree of Naval Architect, Marine Mechanical Engineer or Ocean Engineer. Students with a less suitable undergraduate background will require more time; or they may follow a program leading to a Master of Science without specification, which requires equally high standards of academic performance.

To obtain the degree of Doctor of Science or Doctor of Philosophy usually requires a minimum of three years of graduate work if the thesis can be completed in one year. Specialization in any aspect of naval architecture, marine engineering, or ocean engineering is appropriate.

Subjects in this Department which are appropriate to the programs of civilian graduate students include the following areas:

HYDRODYNAMICS (13.02T, 13.03, 13.04T, 13.05T, 13.07T, 13.08)  
STRUCTURAL MECHANICS (13.11T, 13.12T, 13.13T, 13.151J)  
MARINE ENGINEERING (13.21, 13.22, 13.23, 13.24)  
MARINE STRUCTURES AND DESIGN (13.32, 13.34, 13.36, 13.39)  
OVER-ALL DESIGN (13.41, 13.42, 13.43, 13.47J)  
COMPUTER APPLICATION (13.51)  
MARINE SYSTEMS ANALYSIS (13.61, 13.62, 13.65)  
SPECIAL AREAS (13.71, 13.72)  
ACOUSTICS AND VIBRATION (13.80, 13.81, 13.82, 13.83, 13.84J)  
SPECIAL OCEAN ENGINEERING AREAS (13.92J, 13.93, 13.94)

Most other departments in the Schools of Engineering and Science offer subjects which are appropriate to graduate programs in Naval Architecture or Marine Engineering. Among such subjects are those in mathematics, physics, acoustics, dynamics, structures, mechanics of fluids and solids, controls, oceanography, random processes, decision theory and optimization techniques, electrical engineering, nuclear engineering, materials, gas turbines, internal combustion engines, thermodynamics, and heat transfer.

### *Entrance Requirements for Graduate Study*

In addition to the general requirements for admission described in Section 3 of this Catalogue, the undergraduate preparation should be equal, in quality, quantity, and breadth of coverage to the Institute's undergraduate curriculum in Naval Architecture and Marine Engineering. Successful study in an acceptable program of graduate work requires a competence substantially equivalent to that represented by this curriculum in each of the following areas:

Strength of materials  
Dynamics  
Fluid mechanics  
Heat engineering  
Engineering materials  
Naval architecture  
Ship structures  
Power and propulsion  
Design

If undergraduate preparation has been significantly less intensive in any of these areas, the deficiencies must be removed prior to the award of any of the degrees implying specification. This may be accomplished concurrently with graduate work if the deficiencies are not extensive. Undergraduate subjects so required are not acceptable to the Department in partial fulfillment of the advanced degree requirements. Somewhat less broad undergraduate work is appropriate for candidates for the degree of Master of Science without specification, if accompanied by correspondingly increased com-

petence in areas pertinent to the proposed graduate program.

#### ***Departmental Requirements for Advanced Degrees***

The program of studies for an advanced degree must meet the general requirements specified in Section 3 of this Catalogue and must be acceptable to the Departmental Committee on Graduate Students.

Unless special approval is given by this Committee, candidates for any graduate degree are expected to include in their programs at least one term of advanced mathematics beyond the requirements of the Department's undergraduate curriculum. The program for an S.M. degree must include a minimum of 72 subject units plus a thesis acceptable to the Department. A minimum of 48 of the 72 units must be "A" subjects. The S.M. degree thesis should represent the equivalent of a half term of full-time work.

A program for an Engineer degree ordinarily includes two subjects in the area of economics, industrial management, or political science, and at least 12 units of comprehensive design, such as DESIGN OF A WATERBORNE VEHICLE (13.42), or the equivalent. A single thesis will generally be acceptable for both the Master of Science and Engineer degrees, provided it is appropriate to the specifications of both degrees. Additional departmental requirements applicable to each of the S.M. and Engineer degrees are available from the Department Graduate Office.

In addition to the Institute requirements for the doctoral program, the Department requires the successful completion of qualifying examinations before a student is admitted to a doctoral program. The programs of students must be acceptable to the Departmental Committee on Graduate Students, both as to depth in the major area and broadness in collateral areas. Details of the examination and other special departmental requirements, including those for the doctoral thesis, may be obtained from the Department Graduate Office.

The Department interprets the field of naval architecture and marine engineering rather broadly in connection with the requirements for a degree with or implying such specification. Thus a program for a degree with specification usually includes considerable work in other departments, such as mathematics, aeronautics and astronautics, or civil or mechanical engineering. The thesis may be in another depart-

ment if it is directly applicable to naval architecture or marine engineering.

#### ***Assistantships and Graduate Scholarships***

A limited number of teaching and research assistantships are available in the Department each year. These are awarded on the basis of both qualification and need. Departmental policy is that each assistant is expected to devote a minimum of 20 hours per week to his official duties; these duties contribute directly to the assistant's educational program. In accord with this policy, maximum registration for an assistant is limited to 36 units per term if there is no thesis registration. If an assistant is registered for thesis, the maximum number of subject units will be reduced in accordance with the anticipated thesis load. An exception to this policy will be permitted when thesis research directly contributes to the official duties of the assistant.

M.I.T. fellowships and scholarships, and National Science Foundation grants awarded on recommendation of the Department are available. In addition, some industrial fellowship aid is available, generally to students who are graduates of this Department or who have completed some graduate work in the Department. Fellowships are also awarded each year by the Society of Naval Architects and Marine Engineers. These latter are valid for study at any institution of the recipient's choice and are usually awarded to applicants who have previously evidenced strong interest in the field of naval architecture and marine engineering or in the shipping industry, either through their education or their professional work. Prospective students are invited to communicate with the Head of the Department regarding any of these educational and financial opportunities. Applications for the Society of Naval Architects and Marine Engineers Graduate Fellowships are made directly to that Society. Inquiries for the fall term should be made late in the preceding fall term.

#### ***Naval Construction and Engineering (Course XIII-A)***

This Course was originally set up at the request of the United States Navy to provide appropriate academic background for officers who would later supervise the design and construction of combat vessels. In addition to general engineering and science and a core program of naval architecture and marine engineering subjects especially arranged for Course XIII-A,

# Engineering

DEPARTMENT OF NAVAL ARCHITECTURE AND MARINE ENGINEERING

each student follows one of several specialized curricula in aspects of, or applicable to, naval construction and engineering.

In addition to full-time study at the Institute for eight terms, the Course includes appropriate experience during the summer after the second year.

The Course leads to the degree of Naval Engineer or Master of Science in Naval Architecture and Marine Engineering. For programs leading to the Naval Engineer degree, a Master of Science degree is awarded simultaneously upon recommendation of this Department or of the Department represented by the student's specialty.

Admission to the Course requires undergraduate preparation equivalent to that offered by the U.S. Naval and Coast Guard Academies.

## *Shipping and Shipbuilding Management (Course XIII-B)*

The educational objectives of the five-year program in Shipping and Shipbuilding Management, previously described, may also be achieved by post-baccalaureate study. In addition to satisfaction of departmental requirements for the undergraduate curriculum in Naval Architecture and Marine Engineering, students select areas of concentration in management, operations, or control. They study undergraduate and graduate subjects in the Department of Economics, the Alfred P. Sloan School of Management, and the Department of Naval Architecture and Marine Engineering. They may also broaden their experience by electing advanced subjects offered by other departments at the Institute.

Requirements for admission to the graduate program in shipping and shipbuilding management are the same as for other graduate study in the Department, as stated above, with the addition that scores in the Admissions Test for Graduate Schools of Business must be submitted. Students entering the program at the graduate level should expect to devote two years to completing requirements for the degree of Master of Science in Shipping and Shipbuilding Management, in view of the prerequisites necessary. The graduate subjects required for the degree are established after consultation with and concurrence of the Alfred P. Sloan School of Management. All general requirements of the Department for the award of advanced degrees as specified above must be satisfied.

## *Department of Nuclear Engineering*

The Department of Nuclear Engineering provides advanced technical education for students interested in developing the peaceful applications of nuclear reactions and plasma physics. In keeping with M.I.T.'s traditional role in other branches of knowledge, the Department aims to educate the individuals who will make the key scientific and engineering advances in these fields. Although the technological problems of power generation by neutron-induced fission of heavy elements in nuclear reactors and fusion of light particles in thermonuclear plasmas receive primary emphasis in the Department, the totality of its interests is best described as the engineering physics of low-energy charged and neutral particles.

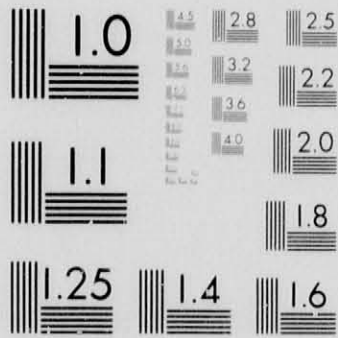
Fission reactors are used to produce heat and electricity, to propel submarines and ships, and to transmute elements and produce radioisotopes. The most important development now occurring in the fission field is the rapid growth in the number and capacity of electric generating stations using nuclear fission reactors as heat sources. Nuclear power is already economically competitive with power from coal, oil, or gas in many regions of the United States and in many foreign countries. One challenging task facing today's nuclear engineers is reducing the capital cost of nuclear power stations and extending the life of nuclear fuels so that nuclear plants will become the most economic way of generating electricity in ever-widening regions of the world. These cost reductions can be realized by intelligent interpretation of the performance of today's reactors, by development of improved methods for designing tomorrow's reactors, and by conceiving new and better types of reactors than any now in use.

Another assignment to challenge nuclear engineers is the development of economic breeder reactors which will derive their energy from fission of abundant uranium-238 or thorium instead of from the relatively scarce isotope uranium-235, which is the principal fissionable material in presently operating reactors. Breeder reactors will provide an energy resource capable of supplying the needs of the world for millions of years.

Fission reactors find widespread use in research on the interaction of radiation and matter and in the production of radioisotopes and the transmutation of elements. Also, the large amount of energy obtainable per unit mass of fissile fuel and the fact that air is not needed to sustain the fission reaction make fission reactors especially valuable in submarine and space applications.

The Department's interest in plasma physics originated in investigations of the problem of controlled fusion of light elements in a thermonuclear plasma. Development of a practical and economic means of producing power from controlled fusion would provide the world with another practically inexhaustible source of energy. These interests have now broadened to include fundamental studies of plasmas, and other applications. For controlled nuclear fusion with its requirement for confining a large volume of gas at a temperature of many millions of degrees without appreciable loss, further basic studies are certainly necessary before questions of feasibility can be answered. In addition, the same principles lead to much-needed understanding of astrophysical and ionospheric phenomena, magnetohydrodynamic energy conversion, ion propulsion, direct-conversion thermionic diodes, and high-power gas lasers. The latter two topics are applications of particular present interest in the Department. Students of the Department concentrating on applied plasma physics are therefore trained not only to advance knowledge of controlled fusion and of the plasma field as a whole, but also to apply the fundamental science in other contexts of more immediate practical significance. In these plasma activities, the Department is an active participant in M.I.T.'s broad, interdepartmental program of research and instruction in plasma physics and its varied applications.

Paralleling its work on these two important nuclear reactions, the Department of Nuclear Engineering offers two principal options for graduate study and research, the fission technology option and the applied plasma physics option. In each option, programs are available leading to the degrees of Master of Science in



MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

M. I. T. ANNUAL CATALOGUES AND BULLETINS

1969/70

93  
OF  
95

# Engineering

DEPARTMENT OF NUCLEAR ENGINEERING

Nuclear Engineering, Nuclear Engineer, and Doctor of Science or Doctor of Philosophy.

The Department of Nuclear Engineering does not offer undergraduate degrees. It does, however, offer jointly with a number of M.I.T. departments five-year programs leading to a joint Bachelor of Science in an undergraduate department and a Master of Science in Nuclear Engineering. The M.I.T. departments currently participating in these programs are Civil Engineering, Electrical Engineering, Mechanical Engineering, and Physics.

In these programs attention is focused on the technology of the fission reaction and plasma phenomena and on aspects of physical sciences and engineering which contribute importantly to the efficient development of these fields, as, for example, low-energy nuclear physics, plasma physics, nuclear materials, and high-flux heat transfer. The Department follows a broad interdisciplinary approach, making use of important segments of physics, chemistry, and metallurgy and drawing on the techniques of chemical, civil, electrical and mechanical engineering where relevant to the solution of nuclear engineering problems. The programs in nuclear engineering at M.I.T. are open to students with undergraduate training in these and related fields. They aim to teach the basic principles of nuclear technology and applied plasma physics and to show each student how his field of undergraduate specialization may be applied to problems in these fields. The programs should interest graduate students who wish to specialize in nuclear engineering as well as graduate students or advanced undergraduates in other departments who wish to obtain some familiarity with nuclear developments or plasma applications.

## RESEARCH FACILITIES

The Department's educational program is supported by a number of outstanding experimental facilities for advanced research in nuclear engineering.

### THE M.I.T. RESEARCH REACTOR

The M.I.T. Research Reactor operates at a power of 5,000 kw. It is fueled with U-235 and cooled and moderated by heavy water. Completed late in the spring of 1958, it is one of the finest university research reactors in the world. It provides first-hand experience in the design, performance, and operation of nuclear reactors and serves as a source of radiations for

use in laboratory instruction on radiation detection and measurement methods. A variety of research projects make use of the intense sources of neutrons and gamma rays produced by the reactor. Areas of research in which the reactor is being used include: neutron physics, cross-section measurements, reactor physics, solid-state studies based on neutron diffraction, radiochemistry, physics of neutron-capture processes, activation analysis, research with short-lived radioisotopes, radiation-catalyzed chemical reactions, radiation-induced biological effects, radiation therapy, and studies of radiation effects on materials.

### EXPERIMENTAL PLASMA FACILITIES

The Department utilizes extensive experimental facilities for production and confinement of large volumes of highly ionized plasmas and for studies of plasma turbulence, particle motions, and other phenomena. High-power lasers and other equipment are available both for plasma diagnostics and for study of basic physical interactions. Experimental apparatus for thermionic conversion studies is also available. The Department has facilities to support a unique program of controlled fusion engineering studies and has its own well-equipped graduate laboratory for instruction in plasma laboratory techniques.

Most of the research on plasmas and controlled fusion is done in M.I.T.'s Research Laboratory of Electronics. This Laboratory is an association of faculty and graduate students from many departments, and it includes groups active in all aspects of plasma research.

### OTHER RESEARCH FACILITIES

The Department has a well-equipped nuclear instrumentation laboratory, a 3.5 MeV pulsed Van de Graaff accelerator, a 14 MeV neutron source, and two subcritical natural-uranium reactors, one moderated by water and the other by graphite. Laboratory space and shop facilities are available for research in all areas of nuclear engineering. M.I.T.'s IBM Type 7094 and 360/65 digital computers are used extensively in research and graduate instruction. The Department has its own liquid helium refrigeration unit.

### UNDERGRADUATE PREPARATION FOR NUCLEAR ENGINEERING

An undergraduate degree in physics, chemistry, or metallurgy or chemical, civil, electrical, or mechanical engineering furnishes suitable preparation for graduate study in nuclear engineer-

ing. Optimum undergraduate preparation would include the following material:

*Physics:* At least two years, including mechanics, heat, light, electricity, and magnetism and an introduction to wave mechanics and modern physics, equivalent to M.I.T. subjects 8.01, 8.02, 8.03, and 8.04. Students electing the applied plasma physics option should have more advanced preparation in electricity and magnetism, including facility with Maxwell's equations, preferably equivalent to M.I.T. subject 8.07.

*Mathematics:* At least two and a half years, including ordinary and partial differential equations, vector analysis, matrix algebra, orthogonal functions, Bessel and Legendre functions, Fourier and Laplace transforms, and an introduction to functions of a complex variable, equivalent to M.I.T. subjects 18.01, 18.02, 18.034, 18.05 and 18.06.

*Chemistry:* One year of general, inorganic, and physical chemistry, including the periodic table, valence, oxidation-reduction potentials, equilibrium constants, and heterogeneous equilibrium, equivalent to M.I.T. subjects 5.01 and 5.60.

*Engineering Fundamentals:* Elementary theory of elasticity, thermodynamics of power cycles, and heat transfer, equivalent to M.I.T. subjects 2.01, 2.403 and 2.50.

Prospective graduate students should make every effort to take these subjects before starting graduate study. Students deficient in one or more of them may make up their deficiencies after admission to graduate study, but they will need more time to complete the graduate program.

Students who expect to apply for admission to the graduate Course in Nuclear Engineering should discuss their undergraduate programs with the Department's Registration Officer, preferably before the end of their junior year. Applicants for admission are advised, but not required, to take the Graduate Record Examination.

#### GRADUATE STUDY IN NUCLEAR ENGINEERING (COURSE XXII)

Details of the requirements for graduate degrees are given in the following paragraphs.

##### MASTER OF SCIENCE IN NUCLEAR ENGINEERING

The object of the Master's degree program is to give the student as good a general knowledge of either the fission or the applied plasma aspects of nuclear engineering as can be gained in one year of full-time graduate study. This will provide a good foundation either for productive work in the nuclear field or for more advanced graduate study.

The general requirements for this degree are listed in Section 3 of this Catalogue. Subjects recommended for candidates for the Master of Science in Nuclear Engineering who elect the fission technology option are:

NUCLEAR REACTOR PHYSICS I (22.21)  
 NUCLEAR REACTOR PHYSICS II (22.22)  
 NUCLEAR REACTOR ENGINEERING (22.231)  
 NUCLEAR REACTOR PHYSICS LABORATORY (22.41)  
 NUCLEAR PHYSICS FOR ENGINEERS I (8.721T)  
 NUCLEAR PHYSICS FOR ENGINEERS II (8.722T)

Depending on the student's particular interests, additional subjects should be selected from:

ECONOMICS OF NUCLEAR POWER (22.27)  
 NUCLEAR PLANT DYNAMICS (22.242)  
 NUCLEAR REACTOR DESIGN (22.26)  
 NUCLEAR ENGINEERING FOR SPACE APPLICATION (22.232)  
 NUCLEAR CHEMICAL ENGINEERING (22.31)  
 NUCLEAR REACTOR OPERATIONS (22.42T)  
 RADIATION SHIELDING (22.54)  
 PLASMAS AND CONTROLLED FUSION I (22.61)  
 METALLURGY FOR NUCLEAR ENGINEERS (22.71)  
 RADIATION AND RADIOISOTOPE APPLICATIONS (22.81)

Subjects recommended for candidates electing the thermonuclear plasma option are:

NUCLEAR REACTOR PHYSICS I (22.21)  
 PLASMAS AND CONTROLLED FUSION I (22.61)  
 PLASMAS AND CONTROLLED FUSION II (22.62)  
 ENGINEERING PHYSICS OF PLASMA AND PARTICLE DEVICES (22.63)  
 PLASMA LABORATORY (22.65)  
 NUCLEAR PHYSICS FOR ENGINEERS I (8.721T)  
 NUCLEAR PHYSICS FOR ENGINEERS II (8.722T)

Other studies may be chosen in accordance with the student's inclination and preparation.

Students with full undergraduate preparation normally need one full year to complete the requirements for the Master of Science degree.

##### NUCLEAR ENGINEER

The program of study leading to the Nuclear Engineer degree is intended to provide a broader knowledge of nuclear engineering than is possible in the Master's program and to develop competence in engineering application or design. The general requirements for the Engineer degree are given in Section 3 of this Catalogue.

The program of 162 units plus thesis must be approved by the Department and should provide a broad education for creative work in the field of nuclear engineering.

This program includes the completion of a substantial engineering design and/or construction project, the record of which will generally form an Engineer's thesis. A suitable Master's thesis may be accepted partly or wholly in place of the Engineer's thesis, and either thesis may be augmented by work done while registered for SPECIAL PROBLEMS IN NUCLEAR ENGINEERING (22.90).

# Engineering

DEPARTMENT OF NUCLEAR ENGINEERING

## DOCTOR OF SCIENCE OR DOCTOR OF PHILOSOPHY

The program of study leading to these degrees aims to give a comprehensive knowledge of nuclear engineering and to develop competence in advanced engineering research.

General requirements of the Institute for the doctorate are given in Section 3 of the General Catalogue and in the Graduate School Manual. The specific requirements of the Department of Nuclear Engineering are presented here. The four principal parts of the doctoral program are the Major program leading to the General Examination, the Minor program, the language requirement and the doctoral thesis. Upon a satisfactory completion of this program, the student will ordinarily receive the degree of Doctor of Science unless he requests the degree of Doctor of Philosophy. The requirements for both degrees are the same.

The object of the Major program is to give the student good general knowledge of nuclear engineering, together with detailed familiarity with the specific field in which he intends to undertake research. To this end, before the student may start his doctoral research, he is required to pass a general examination demonstrating adequate undergraduate preparation in physics, chemistry, mathematics and engineering fundamentals and comprehensive knowledge at the graduate level of his chosen field in nuclear engineering.

Graduate subjects on which all candidates for the doctorate are also examined include:

NUCLEAR REACTOR PHYSICS I (22.21)  
NUCLEAR PHYSICS FOR ENGINEERS I (8.721T)  
NUCLEAR PHYSICS FOR ENGINEERS II (8.722T)  
PLASMAS AND CONTROLLED FUSION I (22.61)

Candidates for the doctorate who elect the fission option must also be familiar with the content of:

NUCLEAR REACTOR PHYSICS II (22.22)  
NUCLEAR REACTOR ENGINEERING (22.231)  
NUCLEAR REACTOR PHYSICS LABORATORY (22.41)

Candidates who elect the applied plasma physics option should also be familiar with the content of:

ELECTROMAGNETIC THEORY (8.311T)  
PLASMAS AND CONTROLLED FUSION II (22.62)

and the basic subjects relevant to their particular interest (e.g., fusion plasma research or plasma kinetic theory). The faculty should be consulted when deciding upon a reasonable study program. The doctoral examination will also

include elective questions on other related subjects.

The object of the Minor program is to broaden the student's knowledge. The Minor consists of completing satisfactorily two or more related subjects, totaling at least 24 credit units, in a field other than nuclear engineering and of a more advanced character than would have been required for the student's undergraduate degree. The Minor program should be arranged in consultation with the student's registration officer, and have his approval. Graduate level subjects taken at other schools may be used to satisfy the Minor requirement if the registration officer judges them to be equivalent to M.I.T. graduate subjects.

Doctoral research may be undertaken either in nuclear engineering or in a related field in another department. Appropriate areas of research include: reactor statics and dynamics, cross-section measurements, neutron diffraction studies, nuclear metallurgy, feedback control, heat transfer, nuclear instrumentation, shielding, transport theory, nuclear chemistry, direct conversion of nuclear heat to electricity, chemical and biological effects of radiation, effect of radiation on reactor materials, fuel cycles for nuclear reactors, solvent extraction of metals, isotope separation, treatment of radioactive wastes; plasma physics, magnetohydrodynamics, fusion energy recovery, charged particle transport theory, plasma propulsion, plasma production and confinement, thermionic energy conversion, and gas laser technology.

## FIVE-YEAR PROGRAMS WITH OTHER DEPARTMENTS

The five-year programs leading to a joint Bachelor of Science in Civil Engineering, or Electrical Engineering, or Mechanical Engineering, or Physics, and a Master of Science in Nuclear Engineering are helpful to students who, early in their undergraduate studies, decide to pursue a graduate degree in nuclear engineering.

Students desiring to enter such a program must meet the graduate admission requirements of the Department of Nuclear Engineering. They must submit their applications for admission at the end of their junior year. If admitted, the student's program will be arranged between the registration officers of the two participating departments. For further information, interested students should contact either their undergraduate department or the Department of Nuclear Engineering.

## *Center for Advanced Engineering Study*

The M.I.T. Center for Advanced Engineering Study was established in order to provide ways for experienced professional engineers and scientists to attain and maintain the competence needed for continued leadership in an age of unparalleled technological change. The Center adds a new dimension to the activities of M.I.T. by offering educational programs which are designed to enable experienced engineers and scientists from industry, government, and educational institutions to acquire the understanding and skills needed to open technical frontiers.

### *Programs of the Center*

The programs of the Center include the Practicing Engineer Advanced Study Program described below, the Systematic Policy Analysis Program, five- to ten-week programs in specialized areas of science and engineering, interdisciplinary projects concerned with the potential contributions of new and advanced technological developments to important and complex problems, and participation in continued education programs offered on the premises of industrial and government organizations.

### *The Practicing Engineer Advanced Study Program*

The Practicing Engineer Advanced Study Program is planned to enable practicing engineers and scientists to work in depth in technological areas pertinent to their professions. The program of each participant is tailored to his needs. It is thus possible to accommodate the technical manager who wishes to understand those developments that bear directly on his problems, the man who seeks competence in depth at a technological frontier, and the man who desires to strengthen and expand his technological base.

Members of the Program are affiliated with the Center for one or more terms; a two-term sequence is recommended. Each member is associated with a faculty member who acts as his sponsor for the Program and helps arrange activities divided between formal classroom study, tutorial or research study, and other M.I.T. opportunities best suited to the member's needs and background.

The entire offering of M.I.T. undergraduate and graduate subjects, seminars, and colloquia are available. Subjects may be selected from those offered by the Schools of Engineering, Science, Architecture and Planning, Management, and Humanities and Social Science. Participation in ongoing research work may be carried out, and self-study programs with informal tutorial assistance can be arranged. The program of each participant can be largely tailored to his specifications provided it represents a serious intellectual commitment commensurate with his background and professional aims.

### SEMINARS AND SPECIAL SUBJECTS

Members of the M.I.T. Faculty conduct weekly seminars in the Center for Advanced Engineering Study during the fall and spring terms; these seminars are planned especially for members of the Practicing Engineer Advanced Study Program. The following special subjects of broad interdisciplinary interest are also offered within the Center for members of the Program:

COMPUTER SYSTEMS (1.156)  
PROBABILITY THEORY AND RANDOM PROCESSES (6.579)

Special sections of the following subjects are offered for the participants in the Advanced Study Program:

ELEMENTS OF SYSTEMS ANALYSIS (1.146)  
ENGINEERING SYSTEMS ANALYSIS (1.147)

Special sections of the following subjects are offered for participants in the Center's Systematic Policy Analysis Program. However, these subjects are also open to the Advanced Study Program participants.

PRINCIPLES OF SYSTEMATIC POLICY ANALYSIS (17.331)  
READING SEMINAR IN SOCIAL SCIENCE (Case Studies in Analysis) (17.711)  
READING SEMINAR IN SOCIAL SCIENCE (Quantitative Techniques) (17.712)  
INTRODUCTION TO MATHEMATICAL MODELS IN THE SOCIAL SCIENCES (17.731)  
STATISTICS FOR THE SOCIAL SCIENCES (17.732)

Before the fall term starts, participants in the Practicing Engineer Advanced Study Program may attend *CALCULUS REVISITED*, an optional six-week review offered by the Center to provide

# Engineering

CENTER FOR ADVANCED ENGINEERING STUDY

an opportunity to strengthen mathematical skills before entering the mainstream of activities of the Center. This review is an intensive development of the first two years of a modern approach to calculus. The point of view adopted is that of the technical professional who intends to apply mathematics to his problems. The aim is to provide the real understanding that supplies the basis for more advanced work and for continued self-development as well as for proficiency.

## DEGREES AND GRADES

A certificate will be awarded following satisfactory completion of the Program. Participants who fulfill the requirements of the Graduate School are eligible for advanced degrees. Grades will be recorded for those M.I.T. subjects which are taken for credit.

The Program fee, payable to M.I.T., is \$1,800 for the fall or spring term, \$3,600 for the two-term school year, \$1,400 for the regular summer term, and \$700 for CALCULUS RE-VISITED. The costs of the program are substantially greater than this fee. Initially, each man accepted as a participant will be awarded, from the grant to begin the Program provided by the Alfred P. Sloan Foundation, a scholarship which will supplement the Program fee in meeting M.I.T.'s costs.

The personal and family costs incident to living in Greater Boston for participation in the Program will vary among the men according to their personal circumstances. A personal budget for the year in Greater Boston should include (1) living costs; (2) the extra costs involved in moving; (3) the cost of books and other study materials.

## ADMISSION REQUIREMENTS

The primary requisites for admission are evidence of serious intent, intellectual maturity, and the technical background needed for participation, with appropriate guidance, in regular M.I.T. subjects and other scholarly activities at the Institute. Participants will be selected by an M.I.T. committee drawn from faculty members working in areas in which the candidate proposes to study. Application forms are available from the Director of the Center. Applications for the fall term should be received before July 1, for the spring term before December 1, and for the summer term before May 1.





## SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

# 6.

*The Dean of the School of Humanities and Social Science describes its many activities in serving M.I.T. Courses and granting M.I.T. degrees.*

The School of Humanities and Social Science consists of five departments, with a faculty of about 125 in the three professorial ranks. Three of these departments are in the social sciences — Economics, Political Science, and Psychology. The two humanistic departments, on the other hand, are multidisciplinary in their scope. Thus the Department of Humanities embraces the fields of history, literature, music, and philosophy, while the Department of Foreign Literatures and Linguistics is concerned with language skills, literature in foreign languages, and the more technical field of linguistics.

The faculty of this School has three complementary missions. In the first place, it is responsible for much of the general education required of every undergraduate at M.I.T., regardless of his area of specialization. In this role, the Department of Humanities teaches a required sequence of two interdisciplinary term subjects to all freshmen; and the members of that Department are then joined by social scientists in offering a limited number of rather broadly disciplinary subjects in the sophomore year. Some of these freshman and sophomore subjects are also available in sections taught exclusively in French and German. Later, all of the faculties of the School meet their share of juniors and seniors, since these

upperclassmen are required to elect four additional terms in the humanities or social sciences, including typically a sequence of three terms in a single field chosen from ten available areas. The curriculum for the first two years and the ten fields for subsequent study are described in Section 2 of this Catalogue.

A second mission of the School involves curricula leading to the degree of Bachelor of Science. There are currently such programs in the Department of Economics, the Department of Political Science, and the Department of Humanities. Those in Humanities involve essentially a second major in some branch of either science or engineering, while those in Economics and Political Science are specified as single majors. There is always, however, ample opportunity for each student through the use of free electives to combine a considerable amount of science or engineering with his chosen field of social science if he is so inclined. Even when the student uses his free electives otherwise, there remains of necessity a substantial amount of mathematics and science in his program, as a highly desirable complement to his social science major. In this respect, all of the School's undergraduate degree programs differ substantially from curricula in similar fields at most other institutions.

There are other differences of perhaps greater import. The view is overwhelmingly accepted at M.I.T. that science and engineering are important not only for their own sake but also as

# Humanities

SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

vital components of modern life and culture. For our own students no less than for all others at the Institute, these disciplines are to be embraced and mastered rather than feared. In other words, no matter what the extent of our students' involvement with science and engineering subjects, the same rigor is expected of them as of their fellow students who are majoring in a field of science or engineering. This is so both for those technical fields that are professionally complementary to study within our own School and also for those aspects of science or engineering that serve only to fill out our own students' general education. Far from regarding scientific study as antithetical to the humanistic or social-scientific, we feel that the essential unity of serious study in any area should be recognized. Accordingly, we hope that our programs are particularly well fitted to prepare the right kind of young man or woman for living in the modern world.

The student whose formal education is completed with his four-year degree should find that the preparation for modern life afforded by our Courses in economics, political science, or humanities is unique and effective. Alternatively, he should also find himself well prepared for further study in a law school, medical school, or graduate school of business, as well as in a graduate department in the area of his own major in the humanities or social science. And finally, if he has planned his program suitably, he should also find it possible to continue in graduate work in

his selected field of science or engineering. Thus our curriculum is an unusually flexible and open-ended one.

The School of Humanities and Social Science accepts with enthusiasm as the third part of its mission a responsibility to contribute to an expansion of the frontiers of knowledge. It does so both through the research and creative scholarship of its faculty and, in a growing number of fields, through programs of graduate study leading to the doctorate. These activities are prized not only for their own sake but also as contributing to the quality of undergraduate instruction. Few members of the faculty of this School are not engaged in research and publication, ranging from individual efforts to the large group engagement of the Center for International Studies, which is also a part of the School. Doctorates can be earned through research and study in fields of economics, political science, psychology, linguistics, and philosophy.

The extent of the graduate work and research is perhaps the feature which most distinguishes the School of Humanities and Social Science at M.I.T. from those to be found in other technological institutions. The extent to which the members of this faculty are in close contact with the faculties of science and engineering is perhaps what most distinguishes it from those of non-technological institutions. We believe this to be a happy pair of circumstances, which make every part of our student offering richer.

ROBERT L. BISHOP

**THE UNDERGRADUATE CURRICULA  
IN THE SCHOOL OF HUMANITIES AND  
SOCIAL SCIENCE**

The S.B. curricula in the School of Humanities and Social Science consist of a program of general education, emphasizing science, mathematics, and the humanities and social sciences (the General Institute Requirements), and a concentration in one of the humanities or social science disciplines, combined with a group of subjects in science or engineering (the Departmental Programs). The General Institute Requirements are given on page 47. The Departmental Programs are given by each department on the following pages.

Each student arranges his program of studies with the advice and consent of a Faculty Counselor. Typical Course Schedules are issued each term by the Registrar with the Class Schedules. R.O.T.C. subjects may be used according to the specifications in Section 2.

## Department of Economics

Economics is the scientific study of economic institutions and systems. It is a useful study in an intellectual sense because it trains students to think carefully and logically about complex social phenomena. By such knowledge it is possible to understand the impact on economic systems and institutions of broad social and economic developments or of new economic policies and the response of these units to them. The growing awareness of these interactions on the part of scientists and engineers makes the study of economics especially relevant at M.I.T.

### THE UNDERGRADUATE CURRICULUM

#### *Economics (Course XIV)*

The Course leading to the degree of Bachelor of Science in Economics combines a rigorous and complete training in technical economics with opportunities for a broad and balanced undergraduate education. Students may select programs that emphasize the relation of economic ideas to technology by concentrating their full time in science and engineering; they may choose programs that focus on economics and other social sciences; or they may undertake to relate economics to history, philosophy, or literature. The successful completion of the degree prepares students for graduate study in economics, industrial relations, business administration, law, and related fields, or for careers in teaching, local government, national government, unions, and business.

The aims of the degree program are: (1) to give the student a firm grounding in modern economic theory, (2) to provide a basic descriptive knowledge of the U.S. and world economy, (3) to develop in the student a capability for quantitative research and independent thought. These aims roughly correspond to the requirements of theory, electives, and statistics and research. The choice of electives also provides an opportunity for students to go into a single field or problem in depth.

The requirements allow substantial freedom for the student, both in designing his program within economics and in balancing it with subjects in other disciplines. The large amount of unrestricted elective time exists to encourage

students to shape a program close to their own needs and interests.

Students who have taken 14.01T and 14.02T by the end of their second year can follow a program which permits considerable depth in electives in the third and fourth years. The most satisfactory plan is to take intermediate economic theory (14.04 and 14.06) in successive terms of the third year, and to complete introductory statistics before the end of the third year. This satisfies prerequisites for all subjects, including the required economic research seminar (14.39T), which prepares the student for thesis research.

The Department does not specify any science distribution subjects, but strongly recommends that all students take some subject in computer techniques and, especially if professionally interested in economics, further work in mathematics.

		<i>Total units</i>
<b>GENERAL INSTITUTE REQUIREMENTS (see page 47)</b>		
	Specific science and humanities and social science subjects. <sup>2</sup>	132 <sup>1</sup>
	Science Distribution Requirement (see page 50).	36
	Laboratory Requirement (see page 51).	12
<b>DEPARTMENTAL PROGRAM</b>		
<i>Required Subjects</i>		
14.01T	ECONOMIC PRINCIPLES I	3 0 6
14.02T	ECONOMIC PRINCIPLES II	3 0 6
14.04	INTERMEDIATE MICROECONOMIC THEORY	4 0 8
14.06	INTERMEDIATE MACROECONOMIC THEORY	4 0 8
14.381	STATISTICAL METHOD	3 0 6
14.39T	ECONOMIC RESEARCH SEMINAR	2 0 7
	THESIS	9
		69
<i>Restricted Electives</i>		
	Elective subjects in economics	36
	A coherent program in a field related to economics but outside the Department as agreed on between the student and the Faculty Counselor. Subjects which also satisfy the General Institute Requirement may be used with a corresponding increase in unrestricted electives.	24
		60
	<i>Unrestricted Electives</i>	51
	Total units required for the S.B. degree	360

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> Subjects in Field Six (Economics) and Field Eight (Labor Relations) may not be used for the humanities and social science requirement.

**GRADUATE STUDY IN ECONOMICS**

The Department of Economics offers work leading to the degrees of Master of Science in Economics and Doctor of Philosophy.

**Entrance Requirements for Graduate Study**

In place of the general requirements for admission given in Section 3 of this Catalogue, the Department specifies the following prerequisites for graduate study in economics. A student whose deficiencies are of minor extent will be permitted graduate registration while taking appropriate subjects to remove them.

*Mathematics.* One full year of college mathematics, including at least one term of calculus. Students may remove a deficiency in mathematics by completing a special one-term subject, MATHEMATICS FOR ECONOMISTS (14.101).

*Science.* One full year of college work in science. A deficiency in science may be removed by completing any suitable one-term subject in science at the Institute.

*Humanities and Social Science.* At least six semester subjects in English, history, and other humanities or social science subjects equivalent in scope to those included in the undergraduate curriculum of the Institute. These subjects should be in other than the candidate's own professional field.

*Professional Subjects.* An undergraduate major in economics is considered desirable for graduate study in economics. Qualified students who have majored in a related field may be admitted, however, if their programs have included an appreciable amount of economics.

**Graduate Subjects**

The following subjects are given by the Department primarily for graduate students in economics:

*Economic theory:*

14.121, 14.122, 14.123, 14.124, 14.125, 14.132, 14.151, 14.451, 14.452.

*Economic history:*

14.731, 14.732, 14.733, 14.734.

*Monetary and fiscal economics:*

14.462, 14.463, 14.471, 14.472, 14.474.

*Economic development:*

14.282, 14.771, 14.772, 14.773, 14.774, 14.782.

*Industrial organization and policy:*

14.231, 14.271, 14.272, 14.282.

*Statistics and econometrics:*

14.371, 14.372, 14.373, 14.374, 14.381, 14.383, 14.384, 14.386.

*International economics:*

14.581, 14.582, 14.584, 14.586.

*Labor economics and public policy:*

14.671J, 14.672J, 14.674J, 14.691J, 14.692J.

*Urban economics:*

14.572J, 14.573J, 14.574J.

**Master of Science in Economics**

Most graduate students in the Department are Ph.D. candidates. Under special circumstances, however, admission may be granted to candidates for the S.M. degree.

The general requirements for the Master's degree are given in Section 3. Subjects strongly recommended are:

ECONOMIC ANALYSIS (14.121, 14.122)

THEORY OF INCOME AND EMPLOYMENT (14.451)

ECONOMIC GROWTH AND FLUCTUATIONS (14.452)

Additional subjects may be selected in line with the student's interests. The program of study must be well balanced, however, and meet with the approval of the student's Registration Officer.

**Doctor of Philosophy**

A candidate for the doctorate must prepare himself in five fields, four of which are covered by the General Examination. Economic theory, including both micro- and macroeconomics, is required as a field for all students. Among the four elective fields are advanced economic theory, monetary economics, fiscal economics, industrial organization, international economics, economic development, Soviet economics and comparative economic systems, urban economics, labor economics, economic history, and statistical theory and econometrics. If statistics and economic history are not among the candidate's five fields of concentration, he must also take one graduate subject in each of these areas.

No stated number of graduate subjects in the Department of Economics is required, but ordinarily the candidate will need two full academic years of work to prepare himself adequately for his General Examination and to meet the other pre-thesis requirements.

The doctoral thesis must be written in residence. As a rule it represents at least one year's research.

The Department has no general foreign language requirements. When a foreign language is essential for full access to the literature in the field of the student's major interest (for example, European Economic History, Communist Economics) or to his thesis research, a language requirement will be imposed by the Department upon the recommendation of the Thesis Supervisor or the Graduate Registration Officer.

# Humanities

DEPARTMENT OF ECONOMICS

Such a requirement will be administered by the Department of Foreign Literatures and Linguistics, and can be met by satisfactory course work at other schools, at M.I.T., or by examination.

Students interested in developing professional competence in the economics and planning problems of the city may combine study in the Department of Economics with study in the Department of Urban Studies and Planning. Depending on background, candidates can expect to take two and a half academic years of work to prepare for the General Examination.

## *Department of Foreign Literatures and Linguistics*

The Department of Foreign Literatures and Linguistics offers subjects for undergraduate and graduate students in several foreign languages and literatures and in linguistics. It also provides a program leading to the degree of Doctor of Philosophy.

### UNDERGRADUATE SUBJECTS

The Department provides instruction on several levels in German, French, and Russian. Introductory subjects aim first at familiarity with the spoken language, emphasizing pronunciation, and second at minimum essentials for a reading knowledge. The intermediate level provides for a continuation of speaking and the development of a broad reading vocabulary. The texts cover fiction, drama, and historical or descriptive works to introduce students to the genius, institutions, and social organization of the countries in question. Advanced subjects are conducted largely in the foreign language and stress analysis of the form and content of the literature of each country. A specially equipped language laboratory provides facilities for hearing and speaking languages at all levels.

Undergraduate subjects in linguistics are offered to explore the structural and semantic relationships of language and to examine problems in linguistics and search for possible solutions. There is an active program of research, in which tools and concepts of science and engineering are applied to the study of language.

Special freshman and sophomore humanities subjects provide reading and lectures in French and German, allowing students to use and improve their knowledge of the language while simultaneously satisfying the humanities requirement. These subjects are open to graduates of American secondary schools with three or more years of unusually good achievement in French or German.

A two-term sequence on Dante provides both language study and literary analysis. Four advanced subjects in Spanish literature are offered for undergraduates with an adequate background in Spanish.

The Department's subjects are open as electives to all qualified students throughout the

Institute and are acceptable as freshman electives. There is, however, no undergraduate degree program in foreign literatures or linguistics at M.I.T.

In choosing language subjects, students should bear in mind that credit towards graduation will not be given for repeating work offered for admission.

### GRADUATE SUBJECTS

For departments which have a foreign language requirement, two-term subjects in French, German, Russian, and Spanish, *open to graduate students only*, are designed to help develop intermediate competence in the reading of both technical and general materials. There are parallel two-term subjects in the same languages, *also open to graduate students only*, which aim to develop intermediate competence in the listening, speaking, and reading skills. Here again, the materials studied are both technical and general. These subjects carry no credit.

### *The Doctoral Program in Linguistics (Course XXIII)*

The program of studies leading to the degree of Doctor of Philosophy aims to give a comprehensive knowledge of modern linguistics, with particular emphasis on its experimental, quantitative, and theoretical aspects. To enter the program, each student must satisfy the Institute requirements for admission to the Graduate School and have done well in his previous academic work. He must be formally accepted by the Department of Foreign Literatures and Linguistics as a candidate for the degree.

### DOCTOR OF PHILOSOPHY

In place of the general requirements for admission given in Section 3 of this Catalogue, the Department specifies the following prerequisites:

*Mathematics.* One full year of college mathematics.

*Science.* One full year of college work in science.

*Languages.* Competence in two languages in addition to English is required, competence being defined as at least three years of formal study or the equivalent.

# Humanities

DEPARTMENT OF FOREIGN LITERATURES AND LINGUISTICS

*Humanities.* At least six semester subjects in literature, history, philosophy, or other humanities subjects equivalent in scope to those included in the undergraduate humanities curricula of the Institute.

A student with high academic rating who is deficient to a minor extent in one or more of the above requirements may be permitted graduate registration while fulfilling them at the Institute by taking appropriate subjects.

Subjects required of all doctoral candidates are as follows:

STRUCTURE OF ENGLISH I (23.731)  
LINGUISTIC STRUCTURE (23.752T)  
INTRODUCTION TO LINGUISTICS II: PHONOLOGY (23.762)  
SURVEY OF GENERAL LINGUISTICS I (23.781T)  
SEMINAR IN LANGUAGE ACQUISITION (23.702)

Before the student may start his doctoral research he is required to pass a comprehensive General Examination demonstrating competence in general linguistics, linguistic theories and methods, practical linguistic analysis, and the relation between linguistics and some adjacent field such as electrical engineering, mathematics, philosophy, physics, or psychology.

A Minor in one of the above related fields is recommended, though many other fields may also be suitable. The general requirements for the Ph.D. degree are indicated in Section 3 of this Catalogue.

## *Department of Humanities*

In its efforts to achieve a balanced curriculum for all undergraduates, M.I.T. provides both a required and an elective program in history, literature, philosophy, history and philosophy of science, music, and drama in the Department of Humanities.

In addition, the Department of Humanities offers three undergraduate programs which combine the basic subjects in science and engineering with a concentrated program in the humanities; these programs are Humanities and Engineering (Course XXI-A) and Humanities and Science (Course XXI-B, Programs 1 and 2). A graduate program in philosophy leading to the Ph.D. degree is also offered.

### THE UNDERGRADUATE CURRICULA

#### *Humanities and Engineering (Course XXI-A)* *Humanities and Science (Course XXI-B,* *Program 1)*

These two undergraduate Programs in Humanities and Engineering and in Humanities and Science offer a kind of education from which students may go on to graduate study in science, engineering, and humanities; or into teaching, law, linguistics, medicine, business, and a variety of other fields.

Because of their flexibility, these programs provide for choice of electives, especially in the third and fourth years. A student may devote more than half of his studies to humanities and the remainder to science or engineering, developing special interests in any combination of the two subject areas. Both Programs lead to a Bachelor's degree at the end of senior year; a student may continue for a fifth year to earn a second Bachelor's degree in the particular field of science or engineering which he studied as an undergraduate. In some cases the fifth year may lead to a Master's degree.

Built on the base provided by the Institute's general requirements in mathematics, physics, chemistry, and humanities, each of these Programs provides a curriculum of unusual scope and balance. One part is the undergraduate curriculum of one of the science or engineering

departments, shortened through the omission of certain of the more specialized or technical subjects. The other part consists of study in the humanities, chosen by each student with the advice of his Faculty Counselor from the various disciplines of the Department of Humanities and the Department of Foreign Literatures and Linguistics. The student chooses one field for concentration: literature (English, American, French, German, Russian, and comparative literature); history and history of science; philosophy; or music. In addition, study combining psychology and humanities is available.

In the fourth year members of Course XXI-A and Course XXI-B, Program 1, participate in a Humanities Seminar, interdisciplinary in character, which examines a single topic from the several perspectives of the students' previous study under the guidance of the Humanities department faculty and visiting professors. Each student also receives instruction in the writing of a thesis.

#### *Humanities and Science* *(Course XXI-B, Program 2)*

This new program, first offered to the class of 1969, provides a concentration or a major in history, literature, philosophy, and music. Like the other branches of Course XXI, it is based on the regular Institute requirements in science and in humanities, but provides a study of the humanities in greater range and depth. The required curriculum consists mainly of eight or nine subjects in a chosen field plus four subjects from related fields of humanities, social science, foreign literatures, linguistics, or visual arts. Depending upon the field of specialization, a seminar devoted to advanced study is required in the junior or senior year and a thesis in the fourth year. Students whose accomplishment is high should be able to qualify for graduate study in their fields in major universities; the Program could also be elected by students who wish to pursue a humanities discipline in greater depth than is ordinarily provided in Courses XXI-A and XXI-B, Program 1. A generous number of electives makes it possible to continue work in science, engineering, humanities, or

# Humanities

DEPARTMENT OF HUMANITIES

other fields taught in the Institute, allowing the student to increase the concentration in the discipline chosen or to broaden intellectual interests by studies in fields outside of his concentration. Faculty Counselors in each of the disciplines will help students to arrange suitable programs following both their main lines of interest and future professional objectives.

Course XXI-A leads to the degree of Bachelor of Science in Humanities and Engineering, and both Programs of XXI-B lead to the degree of Bachelor of Science in Humanities and Science. The curriculum for the first year is shown on pages 47-50; the curriculum requirements for the degrees in both Courses are summarized below.

## HUMANITIES AND ENGINEERING (COURSE XXI-A)

	<i>Total units</i>
<b>GENERAL INSTITUTE REQUIREMENTS</b> ( <i>see page 47</i> )	
Specific science and humanities and social science subjects.	<b>132<sup>1</sup></b>
Science Distribution Requirement ( <i>see page 50</i> ).	<b>36</b>
Laboratory Requirement ( <i>see page 51</i> ).	<b>12</b>

### DEPARTMENTAL PROGRAM

#### Required Subjects

21.07 HUMANITIES SEMINAR	2 0 8	
THESIS	14	<b>24</b>

#### Restricted Electives

Elective subjects restricted to one of the Humanities disciplines, e.g., history, literature, philosophy, music, etc.	54	
Elective subjects restricted to one of the engineering curricula	48	<b>102</b>

#### Unrestricted Electives

Total units required for the S.B. degree	<b>360</b>
--	------------

<sup>1</sup>The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

## HUMANITIES AND SCIENCE (COURSE XXI-B)

### CURRICULUM OF PROGRAM 1

	<i>Total units</i>
<b>GENERAL INSTITUTE REQUIREMENTS</b> ( <i>see page 47</i> )	
Specific science and humanities and social science subjects.	<b>132<sup>1</sup></b>
Science Distribution Requirement ( <i>see page 50</i> ).	<b>36</b>
Laboratory Requirement ( <i>see page 51</i> ).	<b>12</b>

### DEPARTMENTAL PROGRAM

#### Required Subjects

21.07 HUMANITIES SEMINAR	2 0 8	
THESIS	14	<b>24</b>

#### Restricted Electives

Elective subjects restricted to one of the humanities disciplines, e.g., history, literature, philosophy, music, etc.	54	
---	----	--

Elective subjects restricted to one of the science curricula or to psychology	48	<b>102</b>
---	----	------------

#### Unrestricted Electives

Total units required for the S.B. degree	<b>360</b>
--	------------

<sup>1</sup>The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

## CURRICULUM OF PROGRAM 2

	<i>Total units</i>
<b>GENERAL INSTITUTE REQUIREMENTS</b> ( <i>see page 47</i> )	
Specific science and humanities and social science subjects.	<b>132<sup>1</sup></b>
Science Distribution Requirement ( <i>see page 50</i> ).	<b>36</b>
Laboratory Requirement ( <i>see page 51</i> ).	<b>12</b>

### DEPARTMENTAL PROGRAM

#### Restricted Electives

##### One of the following:

(a) <i>History</i>		<b>118 to 135</b>
21.071 HISTORY SEMINAR	2 0 8	
THESIS	14	
Elective subjects in History	72	
Elective subjects in a second discipline of humanities, social science, visual arts, foreign literatures, or linguistics	36	
		<b>132</b>

##### (b) *Literature*

21.393 INDEPENDENT STUDY I	3 0 6	
21.394 INDEPENDENT STUDY II	3 0 6	
Elective subjects in Literature	72	
Elective subjects in a second discipline of humanities, social science, visual arts, foreign literatures, or linguistics	36	
		<b>126</b>

##### (c) *Philosophy*

21.072 <sup>T</sup> PHILOSOPHY SEMINAR	2 0 8	
Elective subjects in Philosophy	72	
Elective subjects in a second discipline of humanities, social science, visual arts, foreign literatures, or linguistics	36	
		<b>118</b>

##### (d) *Music*

THESIS	14	
Elective subjects in Music	81	
Elective subjects in a second discipline of humanities, social science, visual arts, foreign literatures, or linguistics	36	
		<b>135</b>

#### Unrestricted Electives

Total units required for the S.B. degree	<b>360</b>
--	------------

<sup>1</sup>The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

**Science and Mathematics Teaching Program**

Students who wish to register for the Science and Mathematics Teaching Program conducted in cooperation with the Harvard University Graduate School of Education should consult the Head of the Department of Humanities.

**THE DOCTORAL PROGRAM IN PHILOSOPHY**

The program of studies leading to the degree of Doctor of Philosophy is designed to provide comprehensive training in modern philosophy, emphasizing particularly its analytical and scientific aspects. An arrangement is also available whereby selected students may pursue a program in the philosophy of a special science — linguistics, mathematics, physics, psychology — while taking graduate work in that science. To enter the program, the student must satisfy the Institute requirements for admission to the Graduate School and have done well in his previous academic work. He must be formally accepted as a candidate for the degree by the Department of Humanities.

**DOCTOR OF PHILOSOPHY**

Students planning to avail themselves of the arrangement to work on the philosophy of a special science must meet the requirements for admission to graduate study in that science. For all other students, the Department specifies the following prerequisites in place of the general requirements for admission given in Section 3 of this Catalogue:

*Mathematics.* One full year of college mathematics.

*Science.* One full year of college work in science.

*Humanities.* At least six term subjects in literature, history, or other humanities subjects equivalent in scope to those included in the undergraduate humanities curriculum of the Institute.

A student with high academic rating who is deficient to a minor extent in one or more of the above requirements may be permitted graduate registration while fulfilling them at the Institute.

Before the student may start his doctoral research he is required to pass preliminary examinations demonstrating competence in history of philosophy, philosophy of science, logic, ethics, social and political philosophy, theory of knowledge, philosophy of mind, and philosophy of language.

Candidates for the doctorate are encouraged to take a Minor in a field other than philosophy. Possibilities include linguistics, mathematics,

physics, psychology, and other humanities or social sciences. There is no general language requirement for the doctorate, save in those cases where competence in one or another foreign language is needed to carry on research for the dissertation.

# Humanities

DEPARTMENT OF POLITICAL SCIENCE

## Department of Political Science

Political science is the systematic study of conflict and interdependence among people as members of society. As such, it explores the roles of man in political conflict situations, the distribution and use of power, and political relations and behavior in groups and institutions. Instruction in the Department aims at providing the professional competence that enables students to analyze, understand, and propose operative solutions to political conflicts of consequence to the national society and international community. Undergraduate and graduate subjects seek to equip each student with skills now available to assemble and structure empirical observations about politics — including opinion surveys, political gaming, and computer simulation. Instruction focuses also on contemporary political conditions, born of sustained technological advance, rapid population increase, and changing economic circumstance as reflected in substantive areas of political science. Finally, within a rapidly expanding and increasingly rigorous discipline, emphasis falls on encouraging the general intellectual attributes of the scholar. Hence the stress is upon empirical and interdisciplinary research to ensure the widest possible grounding in knowledge relating to political behavior.

### THE UNDERGRADUATE CURRICULUM

#### *Political Science (Course XVII)*

Students concentrating in political science acquire knowledge and skills necessary for understanding political behavior with special emphasis on the increasing range of problems that involve the activities of governmental agencies and political groups in matters of direct concern to science and technology.

There is no rigid program of subjects of instruction in the political science curriculum. Each student's program is worked out with the aid of his Faculty Counselor. A student normally takes three or four subjects in some field that interests him particularly and one or two subjects in several other fields. One field of possible concentration, for example, is international relations, where the introductory sub-

ject INTERNATIONAL RELATIONS (17.51T) is followed by a subject on PRINCIPLES AND PROBLEMS IN AMERICAN FOREIGN POLICY (17.52T) and SEMINAR IN INTERNATIONAL POLITICS (17.53T). Students in the comparative government field may focus on the United States to include, among other subjects, POLITICAL PSYCHOLOGY (17.15T), THE AMERICAN POLITICAL PROCESS (17.21T), COMPARATIVE POLITICAL SYSTEMS (17.24T), and SEMINAR IN CONTEMPORARY URBAN SOCIOLOGY (17.82). In the field of public policy, appropriate subjects are POLITICAL PARTIES (17.28T), POLITICS OF NATIONAL ECONOMIC CONTROL (17.26T), BUREAUCRACY (17.27T), GOVERNMENT, POLITICS, AND TECHNOLOGY (17.42T), and STRUCTURE OF URBAN LIFE (17.81). Other fields cover political communications, politics of developing nations, and U.S. defense policy, including subjects such as EVOLUTION OF STRATEGIC NUCLEAR SYSTEMS (17.31T) and EVOLUTION OF FORCES FOR LIMITED WAR (17.32T).

Each student majoring in political science writes a thesis on a subject that particularly interests him. Students have opportunities for field study with local political organizations or governmental units. As the student progresses into his senior year, he typically takes some reading seminars and graduate subjects in political science.

The Course leads to the degree of Bachelor of Science in Political Science; the curriculum requirements are given below.

	<i>Total units</i>
<b>GENERAL INSTITUTE REQUIREMENTS</b> (see page 47)	
Specific science and humanities and social science subjects <sup>2</sup>	<b>132<sup>1</sup></b>
Science Distribution Requirement <sup>3</sup> (see page 50).	<b>36</b>
Laboratory Requirement (see page 51).	<b>12</b>
<b>DEPARTMENTAL PROGRAM</b>	
<i>Required Subjects</i>	
THESIS	9
<i>Restricted Electives</i>	
Elective subjects in political science	<b>90</b>
<i>Unrestricted Electives</i>	<b>81</b>
Total units required for the S.B. degree	<b>360</b>

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> Subjects in Field Seven (Political Science) may not be used for the humanities and social science requirement.

<sup>3</sup> 1.00 INFORMATION SYSTEMS (3-3-6) and 18.10 APPLICATIONS OF PROBABILITY AND RANDOM VARIABLES (3-0-9) are suggested.

### GRADUATE STUDY IN POLITICAL SCIENCE

The Department of Political Science offers work leading to the degrees of Master of Science in Political Science and Doctor of Philosophy.

#### *Entrance Requirements for Graduate Study*

In place of the general requirements for admission given in Section 3 of this Catalogue, the Department specifies the following prerequisites for graduate study in political science:

*Mathematics.* One full year of college mathematics, including at least one term of calculus.

*Science.* One full year of college work in science.

*Humanities and Social Science.* At least six semester subjects in English, history and other humanities or social science subjects equivalent in scope to those included in the undergraduate curriculum of the Institute. These subjects should be in other than the candidate's own professional field.

Students may remove a deficiency in mathematics by completing a special one-term subject, INTRODUCTION TO MATHEMATICAL MODELS IN THE SOCIAL SCIENCES (17.731); and one other term of mathematics in a subject such as STATISTICS FOR THE SOCIAL SCIENCES (17.732). A deficiency in science may be removed by completing any suitable one-term subject in science at the Institute. A student whose deficiencies are of minor extent will be permitted graduate registration while taking appropriate subjects to remove them.

#### *Graduate Subjects*

The following subjects are given by the Department primarily for graduate students in political science and related fields:

##### *Political Communication and Behavior:*

17.111, 17.112, 17.121, 17.122, 17.131, 17.151, 17.161, 17.162, 17.163T, 17.191, 17.192.

##### *Comparative Politics:*

17.211, 17.213, 17.222, 17.223T, 17.224, 17.225, 17.226, 17.232, 17.241T, 17.242T, 17.243, 17.244, 17.261, 17.262, 17.263, 17.264, 17.265, 17.266, 17.267, 17.271, 17.275, 17.282.

##### *Defense Policy:*

17.311, 17.312, 17.322, 17.331, 17.332, 17.342, 17.352.

##### *Science and Public Policy:*

17.412, 17.413, 17.422, 17.431, 17.442, 17.443J.

##### *International Politics and Foreign Policy:*

17.511, 17.513, 17.514, 17.516, 17.518, 17.521, 17.522T, 17.523.

##### *Political and Economic Development:*

17.611T, 17.612, 17.621, 17.623, 17.631, 17.652.

##### *Political Analysis:*

17.721, 17.722, 17.723, 17.724, 17.725, 17.731, 17.732, 17.733, 17.734, 17.735, 17.736, 17.737, 17.738.

##### *Urban Studies:*

17.811, 17.812J, 17.813, 17.814, 17.818J.

##### *Special reading subjects:*

Students may arrange with individual instructors to take special reading subjects in fields of their particular interest which are not otherwise covered.

### MASTER OF SCIENCE IN POLITICAL SCIENCE

Most graduate students in the Department are Ph.D. candidates. Under special circumstances, however, admission may be granted to candidates for the S.M. degree.

The general requirements for the Master's degree are given in Section 3. Subjects are wholly elective and are not restricted to those given by the Department. The program of study must be well balanced, however, and meet with the approval of the student's Advisory Board.

### DOCTOR OF PHILOSOPHY

A candidate for the doctorate must prepare himself for a General Examination covering three approved fields. In addition, he is examined on the general area of political analysis including political theory and research methods. Established fields include: political communication and behavior, comparative politics, defense policy, science and public policy, international politics and foreign policy, political and economic development, concepts and methods, and urban studies.

Approved combinations of some of these fields together with economics, industrial management, sociology, social psychology, or science and engineering fields may be acceptable. A program in Urban Politics and Planning is offered jointly with the Department of Urban Studies and Planning; a program in formal analysis of complex systems is offered jointly with the Social Relations Department at Harvard University.

# Humanities

DEPARTMENT OF POLITICAL SCIENCE

Programs of study logically combining advanced work in some scientific or engineering fields with political science will be welcomed. A candidate's qualifications must indicate promise of ability to develop fruitful new lines of inquiry on problems touching the relationship of government, human behavior, science, technology, and the political process. Guided field research and close working ties with faculty members engaged in major research activities are stressed.

## *General Requirements for Doctoral Candidates*

No stated number of graduate subjects in the Department of Political Science are required, but ordinarily the candidate will need two full academic years of work to prepare himself adequately for his General Examination and to meet the other pre-thesis requirements.

The doctoral thesis must be written in residence. As a rule it represents one year's research and emphasizes personal gathering, assembly, and interpreting of source data often collected in the field.

Candidates are required to fulfill the language requirement as described in Section 3. The language or languages will ordinarily be chosen from German, French, or Russian; however, other languages may be substituted when they have sufficient professional significance for the individual candidate.

## *Department of Psychology*

Psychology, the study of behavior, has grown in recent years with unforeseen rapidity. New avenues of approach have been opened by convergent developments of methods in the natural and social sciences and in mathematics, raising the hope that man, who has achieved considerable mastery over the world around him, might also come closer to an understanding of himself.

Psychology at M.I.T. stresses its connections with basic science and concentrates its efforts on the search for new knowledge in three distinct but interrelated areas: the study of relationships between brain and behavior (physiological psychology), the study of perception and learning (general experimental psychology), and the study of origins of individual behavior and of the interaction among individuals in groups (developmental and social psychology). Accordingly, instruction in psychology on all levels (undergraduate, graduate, and postdoctoral) is organized to fall into these three areas which border on such diverse fields as biophysics, neurophysiology, philosophy, and sociology, as well as linguistics and other communication sciences.

Programs of research on these three principal themes (those of brain and behavior, perception and learning, and early development and social interaction) proceed in the Institute's Psychology Laboratories in close contact with the teaching program. The M.I.T. Psychology Building contains machine shops and electronic shops, a specialized research library, and facilities for brain research (electrophysiology, experimental surgery, and neurochemistry), for comparative studies of animal behavior, for observations on perception and memory in man in normal and abnormal states, and for the study of early stages in the acquisition, by children, of language, logic and social values.

### **UNDERGRADUATE SUBJECTS**

Psychology subjects at the undergraduate level begin with **INTRODUCTORY PSYCHOLOGY (9.00T)**, which is the prerequisite for all of the subsequent undergraduate subjects. The remaining subjects fall into the three areas covered by the Department: physiological psychology, general experimental psychology, and social-developmental psychology. There is at present no under-

graduate major in psychology at M.I.T., but undergraduate psychology subjects are open to all undergraduates as electives and can serve in fulfilling the undergraduate requirements for electives in the humanities and social sciences.

### **GRADUATE STUDY IN PSYCHOLOGY (COURSE IX)**

The program of studies leading to the degree of Doctor of Philosophy is designed to prepare graduate students for careers in teaching and research. No student will be admitted who does not expect to become a candidate for the Ph.D. degree. The program permits concentration in any one of the three areas already described: physiological psychology, general experimental psychology, and social-developmental psychology. Regardless of his area of concentration, each student is required to take, during his first year in residence, the **PROSEMINAR IN PSYCHOLOGY (9.001)** as well as four graduate seminars; two of these will be in the student's area of concentration and one in each of the other two fields within the Departmental Program. Throughout his graduate career, a student will be involved in research projects occupying at least one-half of his time, and aptitude will be assessed as much in the light of his demonstrated research abilities as in his performance in seminars or tutorials.

Ordinarily, incoming graduate students will have majored in psychology or related fields; however, promising candidates with other backgrounds are eligible. In place of the general requirements for admission given in Section 3 of this Catalogue, a student is expected to have the equivalent of one year of college-level work in three of the following four areas: physics, chemistry, biology, and mathematics. Minor deficiencies in this undergraduate preparation can be removed, with the permission of the Department, by taking the appropriate subjects at the Institute.

### **DOCTOR OF PHILOSOPHY**

No stated number of graduate subjects in the Department of Psychology are required for the doctorate, but ordinarily the candidate will need

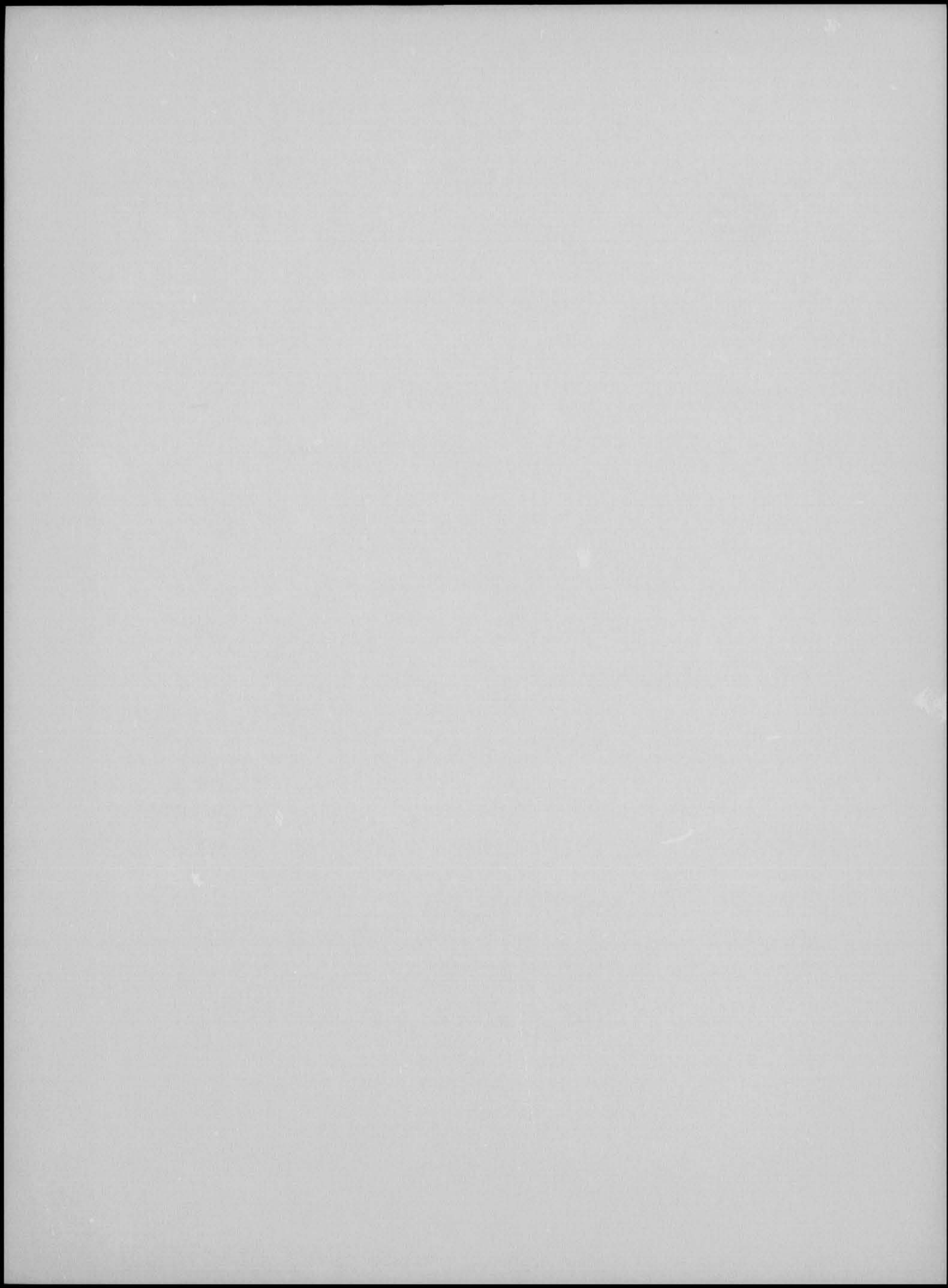
# Humanities

DEPARTMENT OF PSYCHOLOGY

two full academic years of work to prepare himself adequately for his general examinations and to meet other pre-thesis requirements.

The doctoral thesis must be written in residence. As a rule it represents one year's research.

Candidates are required to fulfill the departmental language requirement. The language or languages will ordinarily be chosen from German, French, or Russian; however, substitutions may be made when they have sufficient professional significance for the individual candidate.





*The Dean of M.I.T.'s Alfred P. Sloan School of Management describes its origins and present objectives.*

The Alfred P. Sloan School of Management, founded at M.I.T. in 1952 as the School of Industrial Management, is the outgrowth of a pioneering curriculum combining management and engineering education which was first organized at the Institute in 1914. From that time, Course xv became the regular vehicle for providing this unique pattern of education to M.I.T.'s undergraduates. During this period many of M.I.T.'s most distinguished sons made their reputations as managers and business leaders. The gift of Alfred P. Sloan, Jr., in 1952, however, was the landmark in establishing a new level and a new scope in management education at M.I.T., and much of the story of management education at the Institute has been written since then. The Sloan School now offers an undergraduate Course leading to the degree of Bachelor of Science in Management; a two-year Master's Program leading to the degree of Master of Science in Management; a Doctoral Program leading to the degree of Doctor of Philosophy; a one-year Alfred P. Sloan Program in executive development; and a Program for Senior Executives, a nine-week executive development program for senior members of management.

In all its efforts, this School is committed to educating enterprise managers — men who have the will to manage and

to risk, who can deal with complex systems, who have insight into themselves as well as others, who understand the total environment in which they live, and who continue to learn.

We seek to provide these men with a solid grounding in the academic disciplines relevant to management — economics, mathematics, and the behavioral sciences — and to develop their awareness of the multiple facets which characterize important management problems, from technical data to human factors. We want them to be able to reach decisions. At his best, our young graduate has the ability to move decisively and responsibly in an increasingly complex world. The opportunities for such men in a society full of challenge, both social and technical, are substantial and growing in fields which include industrial management, the management of health services, the management of education and the management of public and urban affairs.

The education of men for management is our first purpose. But we are equally committed to the conduct of research to produce new understanding and better solutions to management problems, and we are engaged in communicating these results to an increasingly broader audience. Together, our research and education goals are mutually reinforcing, and we are confident of their continued impact on the fields of management and management education.

WILLIAM F. POUNDS

## *Alfred P. Sloan School of Management*

### THE UNDERGRADUATE CURRICULA

#### *Management (Course XV)*

The Alfred P. Sloan School of Management offers five undergraduate programs that provide bases for widely varying alternative management-related careers. The five curricula range from an opportunity for student initiative in the design of special management programs, to those providing skills in the understanding and managerial use of behavioral science and management science, to one that develops the broad outlook needed for general management practice. In most of the programs it is possible for a student who is admitted to graduate work to schedule his electives to permit receipt of the Bachelor of Science in Management degree at the end of four years of study and the Master of Science in Management degree at the conclusion of the fifth year.

Common to all of the curricula is the principle that each of the School's undergraduate students should gain an education in depth in an area of relevance and importance to the future manager. This education includes exposure to the underlying disciplines of management and to the general environment in which management operates. A sequence of four core subjects enables a common foundation to be built around an understanding of the organizational problems of the manager in coping with situations arising inside and outside of the firm, and develops a knowledge of the psychological and economic fundamentals of management. Beyond this management core each student has a number of alternative paths by which he is encouraged to learn something about management reasonably well, in contrast with being exposed to a large number of things but only superficially.

In addition to the flexibility inherent in the five curricula, and especially in the option for student initiative in Program 1, each program provides the further freedom of a number of unrestricted elective subjects. By different approaches to elective choice a variety of educational objectives might be served. Selection of subjects treating the functional areas of management should permit completion of both the Bachelor and Master of Science degrees in five

years, as mentioned above. In-depth exposure to an area of physical science or engineering, in addition to an education in management, can be achieved by a technically oriented elective program. Appropriate selection of electives should permit a student to meet admission requirements of medical, law, or other graduate schools.

Each student arranges his program of studies with the advice and consent of a Faculty Counselor. To assist freshmen and sophomores further in choosing among the several alternative career paths, a senior faculty member of the Sloan School, designated the Undergraduate Planning Counselor, is available for discussions. Further information on any of the programs may also be obtained at the office of the Undergraduate Programs in Management, Room E52-472.

The curricula requirements are given below.

#### THE SPECIAL PROGRAM IN MANAGEMENT (PROGRAM 1)

The Special Program in Management has been designed to encourage student initiative in management education. Specific requirements are limited to General Institute Requirements and the four management core subjects. Beyond these any student (or group of students) may propose a coordinated program that he regards as meaningful to his own management-related career objectives. Each student-initiated professional program needs the approval of three faculty members (including at least two from the Sloan School of Management).

A proposed program should contain a specified series of subjects, planned and designated in advance of proposal submission, totaling between 54 and 82 Institute credit units. No more than one-third of these credits may be in Special Studies subjects. Not all of the individual subjects need be offered by the Sloan School of Management, but the program as a whole will be judged for its relevance and importance to management.

Programs 2, 3, 4 and 5 have been planned to meet the anticipated needs of most undergraduates interested in management. Program 1 is intended to cope with unanticipated student interests as well as with the special requirements

of the highly motivated student. A senior faculty member of the Sloan School of Management has been designated Undergraduate Planning Counselor. He is available to freshmen and sophomores to discuss the appropriateness of Programs 2, 3, 4 and 5 to each student's career plans, and/or to assist students in designing new professional programs within the over-all framework of Program 1.

**BEHAVIORAL SCIENCE IN MANAGEMENT PROGRAM (PROGRAM 2)**

This program is designed to provide its graduate with the proper tools for the utilization of behavioral science theory and research knowledge in the managerial context.

The curriculum will pursue a spiral course exposing the student to the same basic behavioral science principles at several levels of complexity, and each time, from a somewhat different vantage. In following such a course, the student will develop the structure necessary for the accomplishment of a major learning experience, the research practicum, in his senior year. In other words, following an introductory survey in the MANAGERIAL PSYCHOLOGY "core" subject (15.06), each student will go through a second cycle of the spiral process as he studies behavioral science concepts and their interrelations in depth in two subjects, SOCIAL PSYCHOLOGY (15.32) and COMPLEX ORGANIZATIONS (15.33). In his senior year the student encounters the third cycle, that of an actual experience in searching for new knowledge and interpreting his findings.

This combination of theory, research and practical experience in behavioral science will enable an individual to pursue any one of a number of endeavors upon completion of the program.

**MANAGEMENT SCIENCE PROGRAM (PROGRAM 3)**

The Management Science Program caters to the mathematically and scientifically oriented undergraduate who would like to participate in solving some of the technical problems central to the successful management of a complex society. The program is difficult and challenges even the superior student.

In recent years the rise of the computer, along with the development of mathematical models of systems and the collection of large quantities of data, has stimulated the growth of a technology of management. This is the domain of operations research and management science, two names commonly used to describe the field.

The knowledge and methods being developed are applicable to problem solving in business, government, and other public and private organizations. The elements of the technology are the interrelated techniques of systems analysis, mathematical models, statistics, and computer science. In systems analysis, problem solving is approached by identifying the system, establishing its objectives, and setting down measures of its performance. Then the variables or actions under managerial control are determined and a model is constructed to relate the controllable variables to the measures of system performance. Thereafter the variables can be set to optimize performance.

The Management Science Program develops an underlying competence in mathematical models, optimization techniques, statistics, and computers. This provides wide flexibility in career choice. It prepares the student for immediate participation in systems analysis or operations research activities in industry or government. Alternatively, it provides a basic groundwork for pursuing graduate work in several directions, either more broadly toward management and social science or more technically toward a research career in operations research, computer science, or applied mathematics.

**GENERAL MANAGEMENT PROGRAM (PROGRAM 4)**

Program 4 is designed to meet the educational needs of the undergraduate who wants a broader background in the decision making, policy formulation and operating problems of the manager. The program builds upon the four required management core subjects with specified subjects that integrate psychological, economic, and environmental considerations in management. Further depth in any of these areas may be attained through appropriate elective choice.

The General Management Program will prepare the student for line management responsibilities in the generalist tradition. Administrative positions in the functional and staff fields would be the normal beginnings of career development through this program with the special advantage of a wide choice of areas. For the graduate of this program, the typical company will provide effective orientation activities as a valuable complement to his educational experience. Research administration, engineering and office management, and varied executive responsibilities in production, marketing and finance are examples of employment possibilities.

# Management

SLOAN SCHOOL OF MANAGEMENT

## DYNAMICS OF MANAGEMENT SYSTEMS PROGRAM (PROGRAM 5)

The Dynamics of Management Systems Program focuses on the feedback structure of organizations. The unifying concepts of feedback processes are stressed to show how the same principles are encountered in management, economics, engineering, life processes, and the humanities.

The systems of interest to the manager are multi-loop, contain both positive and negative feedback, and are of high order and non-linear. To understand such systems they must be seen from as many perspectives as possible — as organized according to principles of structure; as laboratory observation using physical feedback processes; as descriptive subjects dealing with the structure and dynamics of social systems; as a mathematical interpretation relating structure and policy to growth and stability; as computer simulation of system models; and as field projects relating theory to practice.

This program uses feedback structure and dynamics to unify and interrelate the functional areas of management. The program is suitable for either the line manager or the systems analyst. It should serve as a foundation for graduate study or practice in a wide variety of fields.

### 1. SPECIAL PROGRAM IN MANAGEMENT CURRICULUM

<b>GENERAL INSTITUTE REQUIREMENTS</b> (see page 47)	<i>Total units</i>
Specific science and humanities and social science subjects. <sup>2</sup>	<b>132<sup>1</sup></b>
Science Distribution Requirements <sup>3</sup> (see page 50).	<b>36</b>
Laboratory Requirement <sup>3</sup> (see page 51).	<b>12</b>

#### DEPARTMENTAL PROGRAM

<b>Required Subjects</b>	
15.05 INTRODUCTION TO MANAGEMENT	4 0 8
15.06 MANAGERIAL PSYCHOLOGY	3 0 6
15.07 MANAGERIAL ECONOMICS	4 0 8
15.08 MANAGERIAL ENVIRONMENT	4 0 8
	<hr style="width: 100px; margin-left: 0;"/>
	<b>45</b>

#### **Restricted Electives<sup>1</sup>**

A coordinated program of professional electives relevant to management should be developed by the student, subject to faculty approval.

**54 to 82**

#### **Unrestricted Electives<sup>1</sup>**

**81 to 53**

Total units required for the S.B. degree **360**

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> The upperclass program in the humanities and social sciences is to be chosen in consultation with the student's Faculty Counselor.

<sup>3</sup> One or two science distribution or laboratory subjects may be required as part of an approved professional program. See, for example, the specified curricula of the Behavioral Science, Management Science, General Management, and Dynamics of Management Programs.

<sup>4</sup> The student has the option of designing his own professional program of electives (subject to faculty approval) or of selecting one of the previously designated professional programs in Course xv. For examples of the latter option see the curricula of the Behavioral Science Program, the Management Science Program, the General Management Program, and the Dynamics of Management Program.

## 2. BEHAVIORAL SCIENCE IN MANAGEMENT PROGRAM CURRICULUM

<b>GENERAL INSTITUTE REQUIREMENTS</b> (see page 47)	<i>Total units</i>
Specific science and humanities and social science subjects. <sup>2</sup>	<b>132<sup>1</sup></b>
The Science Distribution Requirement will be satisfied by 1.00 and 18.10, which are required in the Departmental Program, plus appropriate subjects (see page 50) totaling	<b>12</b>
The subject 15.36T, which is required in the Departmental Program, appears on the list of Laboratory Subjects (see page 51) and can be used to satisfy the Laboratory Requirement.	

#### DEPARTMENTAL PROGRAM

<b>Required Subjects</b>	
15.05 INTRODUCTION TO MANAGEMENT	4 0 8
15.06 MANAGERIAL PSYCHOLOGY	3 0 6
15.07 MANAGERIAL ECONOMICS	4 0 8
15.08 MANAGERIAL ENVIRONMENT	4 0 8
15.31 STATISTICS FOR BEHAVIORAL SCIENCE	3 0 6
15.32 SOCIAL PSYCHOLOGY	3 0 6
15.33 COMPLEX ORGANIZATIONS	3 0 6
15.34 INTERPERSONAL DYNAMICS LABORATORY	0 3 3
15.35 BEHAVIORAL SCIENCE RESEARCH METHODS	3 0 9
15.36T BEHAVIORAL SCIENCE RESEARCH PRACTICUM	2 8 8
1.00 INFORMATION SYSTEMS	3 3 6
18.10 APPLICATIONS OF PROBABILITY AND RANDOM VARIABLES	3 0 9
	<hr style="width: 100px; margin-left: 0;"/>
	<b>132</b>

#### **Restricted Electives**

A minimum of 27 units of additional engineering or science electives

**27**

#### **Unrestricted Electives<sup>3</sup>**

**57**

Total units required for the S.B. degree **360**

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> The upperclass program in the humanities and social sciences is to be chosen in consultation with the student's Faculty Counselor.

<sup>3</sup> Schedules of students in Course xv, Program 2, may always be arranged to leave available 12 units of unrestricted elective in the second year.

## 3. MANAGEMENT SCIENCE PROGRAM CURRICULUM

<b>GENERAL INSTITUTE REQUIREMENTS</b> (see page 47)	<i>Total units</i>
Specific science and humanities and social science subjects. <sup>2</sup>	<b>132<sup>1</sup></b>
The Science Distribution Requirement will be satisfied by 18.034, which is required in the Departmental Program, plus appropriate subjects <sup>3</sup> (see page 50) totaling	<b>24</b>
Laboratory Requirement (see page 51).	<b>12</b>

#### DEPARTMENTAL PROGRAM

<b>Required Subjects</b>	
15.05 INTRODUCTION TO MANAGEMENT	4 0 8
15.06 MANAGERIAL PSYCHOLOGY	3 0 6

15.07	MANAGERIAL ECONOMICS	4	0	8
15.08	MANAGERIAL ENVIRONMENT	4	0	8
6.28	PROBABILISTIC SYSTEMS ANALYSIS	4	0	8
15.10	QUANTITATIVE METHODS IN MANAGEMENT	3	0	6
15.54	<sup>4</sup> MANAGEMENT INFORMATION TECHNOLOGY	3	0	6
14.371	STATISTICAL THEORY	3	0	6
15.56	MANAGEMENT SCIENCE FIELD STUDY	4	0	8
15.094	STATISTICAL DECISION THEORY I	3	0	6
18.034	DIFFERENTIAL EQUATIONS	3	0	9
				117

**Restricted Electives**

A minimum of 18 units are to be selected from the following list of electives:

6.251	DIGITAL COMPUTER PROGRAMMING SYSTEMS	3	2	7
6.253	THEORETICAL MODELS FOR COMPUTATION	3	0	9
6.536	PROBABILISTIC MODELS IN SYSTEMS ENGINEERING AND OPERATIONS RESEARCH	3	0	9
6.544J	HEURISTIC PROGRAMMING AND ARTIFICIAL INTELLIGENCE	3	0	9
14.372	STATISTICAL THEORY	3	0	6
15.58	INDUSTRIAL DYNAMICS	3	0	6
15.591	MATHEMATICAL PROGRAMMING I	3	0	6
15.592	MATHEMATICAL PROGRAMMING II	3	0	6
15.593	STOCHASTIC SYSTEMS	3	0	6
				18

**Unrestricted Electives**

Total units required for the S.B. degree **360**

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> The upperclass program in the humanities and social sciences is to be chosen in consultation with the student's Faculty Counselor.

<sup>3</sup> 8.03 and 6.01, or 2.02 and another choice are suggested.

<sup>4</sup> 1.00 is an acceptable substitute for 15.54.

**4. GENERAL MANAGEMENT PROGRAM CURRICULUM**

GENERAL INSTITUTE REQUIREMENTS (see page 47) *Total units*

Specific science and humanities and social science subjects.<sup>2</sup> **132<sup>1</sup>**

The Science Distribution Requirement will be satisfied by <sup>1</sup> 00 and 18.10, which are required in the Departmental Program, plus appropriate subjects (see page 50) totaling **12** Laboratory Requirement (see page 51). **12**

**DEPARTMENTAL PROGRAM**

**Required Subjects**

15.05	INTRODUCTION TO MANAGEMENT	4	0	8
15.06	MANAGERIAL PSYCHOLOGY	3	0	6
15.07	MANAGERIAL ECONOMICS	4	0	8
15.08	MANAGERIAL ENVIRONMENT	4	0	8
15.10	QUANTITATIVE METHODS IN MANAGEMENT	3	0	6
15.34	INTERPERSONAL DYNAMICS LABORATORY	0	3	3
15.38	ADMINISTRATIVE THEORY AND PRACTICE	3	0	6
15.70T	INFORMATION AND DECISION SYSTEMS I	4	0	8
15.71T	INFORMATION AND DECISION SYSTEMS II	4	0	8
15.73	MANAGEMENT LABORATORY	3	3	3
1.00	INFORMATION SYSTEMS	3	3	6
18.10	APPLICATIONS OF PROBABILITY AND RANDOM VARIABLES	3	0	9
				126

**Restricted Electives**

A minimum of 27 units of additional engineering or science electives. **27**

**Unrestricted Electives**

Total units required for the S.B. degree **360**

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> The upperclass program in the humanities and social sciences is to be chosen in consultation with the student's Faculty Counselor.

**5. DYNAMICS OF MANAGEMENT SYSTEMS CURRICULUM**

GENERAL INSTITUTE REQUIREMENTS (see page 47) *Total units*

Specific science and humanities and social science subjects.<sup>2</sup> **132<sup>1</sup>**

The Science Distribution Requirement will be satisfied by 18.034, which is required in the Departmental Program, and 2.02 or 6.01, which appear on the list of restricted electives, plus appropriate subjects (see page 50) totaling **12**

The subject 15.571, which is required in the Departmental Program, appears on the list of Laboratory Subjects (see page 51) and can be used to satisfy the Laboratory Requirement.

**DEPARTMENTAL PROGRAM**

**Required Subjects**

15.05	INTRODUCTION TO MANAGEMENT	4	0	8
15.06	MANAGERIAL PSYCHOLOGY	3	0	6
15.07	MANAGERIAL ECONOMICS	4	0	8
15.08	MANAGERIAL ENVIRONMENT	4	0	8
18.034	DIFFERENTIAL EQUATIONS	3	0	9
15.571 <sup>3,4</sup>	FEEDBACK DYNAMICS LABORATORY	2	6	4
15.572	PRINCIPLES OF SYSTEMS	3	0	6
15.574	<sup>4</sup> SYSTEM MATHEMATICS	3	0	6
15.576	INDUSTRIAL DYNAMICS I	3	0	6
15.577	INDUSTRIAL DYNAMICS II	3	0	6
15.578	RESEARCH SEMINAR IN DYNAMICS OF MANAGEMENT SYSTEMS I	3	0	6
15.579	RESEARCH SEMINAR IN DYNAMICS OF MANAGEMENT SYSTEMS II	3	0	6
15.586	PROFESSIONAL WRITING TUTORIAL	3	0	6
				132

**Restricted Electives**

2.02	INTRODUCTION TO SYSTEM DYNAMICS	3	1	8
<i>or</i>				
6.01	INTRODUCTORY NETWORK THEORY	4	0	8
				12

A coordinated study in one area of social systems as institutional and descriptive foundation for the Research Seminar, subject to approval of the Faculty Advisor. **18**

**Unrestricted Electives<sup>5</sup>**

Total units required for the S.B. degree **360**

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> The upperclass program in the humanities and social sciences is to be chosen in consultation with the student's Faculty Counselor.

<sup>3</sup> If the student has already met the Institute undergraduate Laboratory Requirement, 15.571 can be replaced with an arranged 6-unit laboratory in feedback systems with registration under 15.95 or by an approved laboratory in another department.

# Management

SLOAN SCHOOL OF MANAGEMENT

<sup>4</sup> 6.213 or 2.14 can be substituted for 15.571 and 15.574. In this case another 12-unit laboratory subject (see page 51) must be taken in place of 15.571.

<sup>5</sup> Schedules of students in Course xv, Program 5, may always be arranged to leave available 12 units of unrestricted elective in the second year.

## GRADUATE STUDY IN MANAGEMENT

The Alfred P. Sloan School of Management offers graduate study leading to the degrees of Master of Science in Management and Doctor of Philosophy.

### MASTER OF SCIENCE

The basic disciplines underlying sound management are the central theme of the Master's program, a two-year graduate program for young men who seek executive careers. This program gives students a grasp of fundamentals and techniques in management coupled with a breadth of view which prepares them for general management responsibility. The emphasis of the School is on searching for and organizing an analytical framework on which later experience can build.

Applications are welcomed from college graduates in all fields of concentration in which rigorous preparation is required. Graduates in the physical sciences, engineering, the liberal arts, and the social sciences are encouraged to apply if they meet the general entrance requirements specified below.

The typical Master's degree program in management requires two years of study at M.I.T. Credit for subjects completed elsewhere may permit some students to meet the requirements for the degree in three terms or in one year. The following subjects, or equivalents thereof, are required of all students:

#### Fall Term

- 15.012 ECONOMICS FOR MANAGEMENT I
- 15.091 MATHEMATICS FOR MANAGEMENT I
- 15.201 THE MANAGEMENT ENVIRONMENT
- 15.331 HUMAN FACTORS IN MANAGEMENT I
- 15.501 INFORMATION AND DECISION SYSTEMS I

#### Spring Term

- 15.014 ECONOMICS FOR MANAGEMENT II
- 15.312 HUMAN FACTORS IN MANAGEMENT II
- 15.502 INFORMATION AND DECISION SYSTEMS II

The core requirement, since it is limited to eight term-subjects, leaves at least ten additional subjects plus a Master's thesis for student election. To satisfy the concentration requirement, the student is expected (a) to take three or more subjects in at least one of the several concentration areas and (b) to do thesis research relevant to his chosen area (or areas) of subject concentration.

The ten electives available in a "normal" program obviously make possible as many as three such concentrations without overload. However, while not required, it is strongly recommended: (a) that concentrations be limited to a maximum of two, (b) that the primary concentration consist of more than three subjects and (c) that some electives be employed deliberately to broaden the individual's range of interests.

Features of the graduate program include special seminars with visiting lecturers from industry, group field work, participation in faculty research, and individual field and laboratory investigation. The extensive facilities of the Institute's Information Processing Center, as well as the School's own computation facilities, are available for use in thesis and research work. The Master's thesis usually involves intensive study of a problem in industrial management or of problems in the management of other complex organizations. Such projects might include the management of education, health technologies, or public affairs.

Concentrations for Master's candidates are available in the following areas. Subjects listed under each of these are illustrative of the range of subject matter covered. The number of subjects needed to fulfill each concentration option is generally three or four; specific combinations are arranged between the student and faculty in that field.

Any student who wishes to do so may offer for consideration a "package" of logically interrelated subjects differing from any described below.

#### Finance

- 15.412 FINANCIAL MANAGEMENT
- 15.432 CAPITAL MARKETS AND FINANCIAL INSTITUTIONS
- 15.452 TAXATION AND BUSINESS MANAGEMENT
- 15.422 INVESTMENTS
- 15.46 FINANCIAL ADMINISTRATION OF INDUSTRY
- 15.423 THE MANAGEMENT OF FINANCIAL INTERMEDIARIES

#### Industrial Dynamics

- 15.573 PRINCIPLES OF SYSTEMS
- 15.581 INDUSTRIAL DYNAMICS I
- 15.582 INDUSTRIAL DYNAMICS II

#### Industrial Relations

- 15.671J LABOR ECONOMICS
- 15.672J PUBLIC POLICY ON LABOR RELATIONS
- 14.41 DISTRIBUTION OF INCOME AND EMPLOYMENT OPPORTUNITY
- 15.674J COMPARATIVE SYSTEMS OF INDUSTRIAL RELATIONS AND HUMAN RESOURCE DEVELOPMENT
- 15.322T MANAGEMENT OF HUMAN RESOURCES

#### International Management

- 15.221 INTERNATIONAL BUSINESS MANAGEMENT I (required)

- 15.222 INTERNATIONAL BUSINESS MANAGEMENT II
- 15.371 COMPARATIVE ANALYSIS OF ORGANIZATIONS
- 15.674J COMPARATIVE SYSTEMS OF INDUSTRIAL RELATIONS AND HUMAN RESOURCE DEVELOPMENT

*Managerial Economics*

- 15.019 SEMINAR IN ECONOMICS FOR MANAGEMENT
- 15.442 BUSINESS FORECASTING

*Managerial Information and Control*

- 15.511 MANAGERIAL INFORMATION AND CONTROL
- 15.512 ADVANCED CONCEPTS IN MANAGERIAL INFORMATION FOR PLANNING AND CONTROL
- 15.531 CONTROL PROCESSES AND SYSTEMS
- 15.542 MANAGEMENT INFORMATION SYSTEMS
- 15.46 FINANCIAL ADMINISTRATION OF INDUSTRY

*Management Information Systems*

- 15.541 MANAGEMENT INFORMATION TECHNOLOGY
- 15.542 MANAGEMENT INFORMATION SYSTEMS
- 15.555 ADVANCED COMPUTER SYSTEMS
- 15.544 SYSTEMS SIMULATION
- 15.512 ADVANCED CONCEPTS IN MANAGERIAL INFORMATION FOR PLANNING AND CONTROL

*Marketing*

- 15.812 MARKETING
- 15.842 INFLUENCE PROCESSES AND MASS COMMUNICATIONS
- 15.821 BUSINESS GAME
- 15.832 MANAGEMENT MEASUREMENT AND INFORMATION
- 15.852 MARKETING MODELS

*Operations Management*

- 15.712 OPERATIONS MANAGEMENT
- 15.781 STUDIES IN MANUFACTURING ANALYSIS
- 15.791 OPERATIONS PLANNING AND CONTROL SYSTEMS
- 15.792 MANUFACTURING DECISIONS SEMINAR

*Organization Studies*

- 15.334 PRACTICUM IN ORGANIZATION DEVELOPMENT
- 15.373 SEMINAR IN ORGANIZATION CHANGE
- 15.374 ORGANIZATION
- 15.384 RESEARCH MANAGEMENT
- 15.371 COMPARATIVE ANALYSIS OF ORGANIZATIONS
- 15.381 ADMINISTRATIVE THEORY AND PRACTICE

*Operations Research/Mathematical Models*

- 15.092 MATHEMATICS FOR MANAGEMENT II
- 15.093 STATISTICS FOR MODEL BUILDING
- 15.377 MATHEMATICAL BEHAVIORAL SCIENCE
- 15.712 OPERATIONS MANAGEMENT
- 15.812 MARKETING
- 15.095 STATISTICAL DECISION THEORY
- 15.591 MATHEMATICAL PROGRAMMING I
- 15.592 MATHEMATICAL PROGRAMMING II

**DOCTOR OF PHILOSOPHY**

The doctoral program in management is designed for students interested in teaching, consulting and other professional management careers. The goals of the program are to prepare intellectual leaders in management training with a mastery over a wide range of management research techniques, and to furnish the background required for adding to knowledge in some branch of management. The ultimate goal is that the successful Ph.D. will add to the research in his specialty both at M.I.T. and later during his professional career. For the candidate entering with a Bachelor's degree, it is possible to complete the program in three years. For students entering with advanced degrees, it

will be possible to finish in less time, depending upon the candidate's background. For descriptive purposes, the program can be divided into three parts.

**Part I**

The first part of the Ph.D. program is devoted to work in the basic disciplines of management and preliminary work in a major field. The entering candidate is required to write qualifying examinations in three disciplines, mathematics, economics, and psychology, and is offered three year-long subjects in these disciplines in preparation for these examinations. The subjects, however, are not required in order to take the qualifying examinations and students entering with advanced degrees may take these examinations at the beginning of their program. In addition to preparing for the qualifying examinations, the student should take two year-long subjects in the major field of his choice. During the first year, the student also works as a research assistant with his advisor, an apprenticeship which is expected to occupy the time of a one-term length subject.

**Part II**

The second year is devoted primarily to the candidate's applied area, during which time he masters the Course materials in the functional field designated as his "major field"; gains mastery over the materials in his "minor field," which should be one of a half dozen disciplines; and demonstrates the ability to formulate, conduct, and present a research study. A major field is defined by the candidate in conjunction with his advisor (examples of such fields are marketing, finance, or information systems). A Course schedule worked out with the advisor should prepare the candidate for General Examinations in this major field; such examinations differ in form (written, oral, research paper) from area to area and will be approved by the faculty members involved. It is recommended that second-year minor field work be done in applied mathematics, statistics, applied economics, behavioral science, computer science, or other broadly defined "disciplines." The minor field work should occupy the equivalent of three term-length subjects. General Examinations at the end of the second year will establish the student's competence in this minor field. In addition, each student in his role as a research assistant during the second year is required to write a paper of article length and quality in

# Management

SLOAN SCHOOL OF MANAGEMENT

conjunction with a faculty member. The work in the major field, the minor field, and the student's performance on the research paper will be used to evaluate his position at the end of the second year.

### *Part III*

This part of the Ph.D. program centers on the doctoral dissertation, which normally requires between one and two years of work in residence. Close working relationships with senior faculty are to be established early in Part III, so that the thesis is defined as a manageable project before the first year is complete. Each student is expected to complete his dissertation within two years after completing the requirements in Part II of the program. Since the Ph.D. candidate is likely to be involved in some form of teaching, whether in industry or a university, each doctoral student will also be promoted to instructor and will teach three hours each week upon entering Part III. This teaching will be done in cooperation with a faculty member and may take many forms: as a listener, discussion leader, or lecturer.

### *Entrance Requirements for Graduate Study*

The general admission requirements are those set forth in Section 3 of this Catalogue, with the following additions and exceptions.

Undergraduate preparation for this program should include: mathematics through college algebra and differential calculus; at least one year of an experimental science at the college level; and a subject in principles of economics. An undergraduate subject in elementary psychology is desirable. The Graduate Committee is willing to consider the particular needs of any applicant who is strongly motivated to study in the School and who has demonstrated high intellectual capacity.

### *Admission Test for Graduate Study in Business*

All candidates for admission to graduate study in the Alfred P. Sloan School of Management, other than applicants for the Executive Development Programs (see below), are required to take the Admission Test for Graduate Study in Business. This test is administered by the Educational Testing Service, Princeton, New Jersey; information about dates and locations at which the test will be administered may be obtained from that agency.

### **EXECUTIVE DEVELOPMENT PROGRAMS IN MANAGEMENT**

The Alfred P. Sloan School of Management pro-

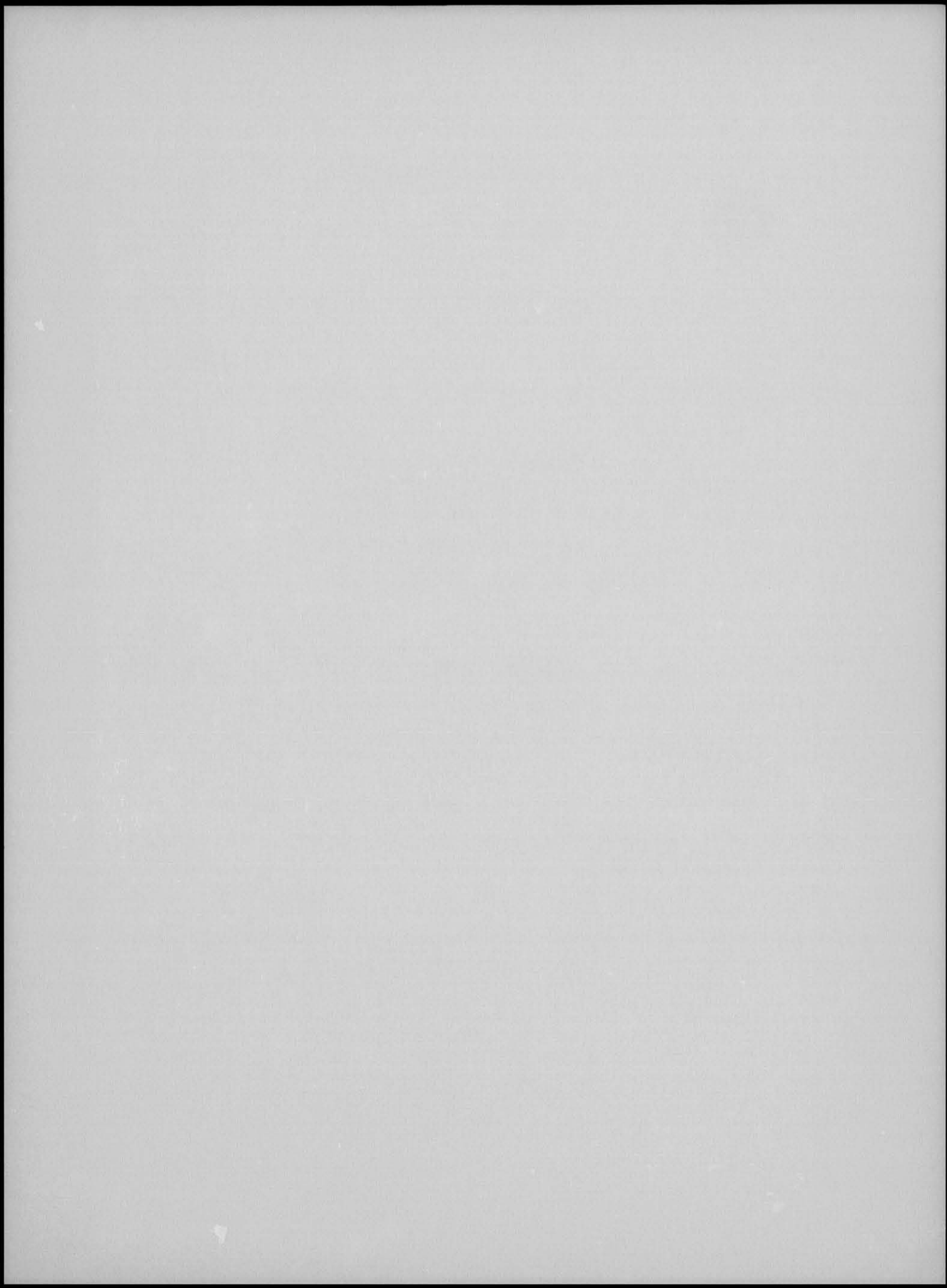
vides two programs for business executives who wish to extend their knowledge of the fundamentals underlying effective management. Applicants for these programs are nominated by their companies and selected by M.I.T.

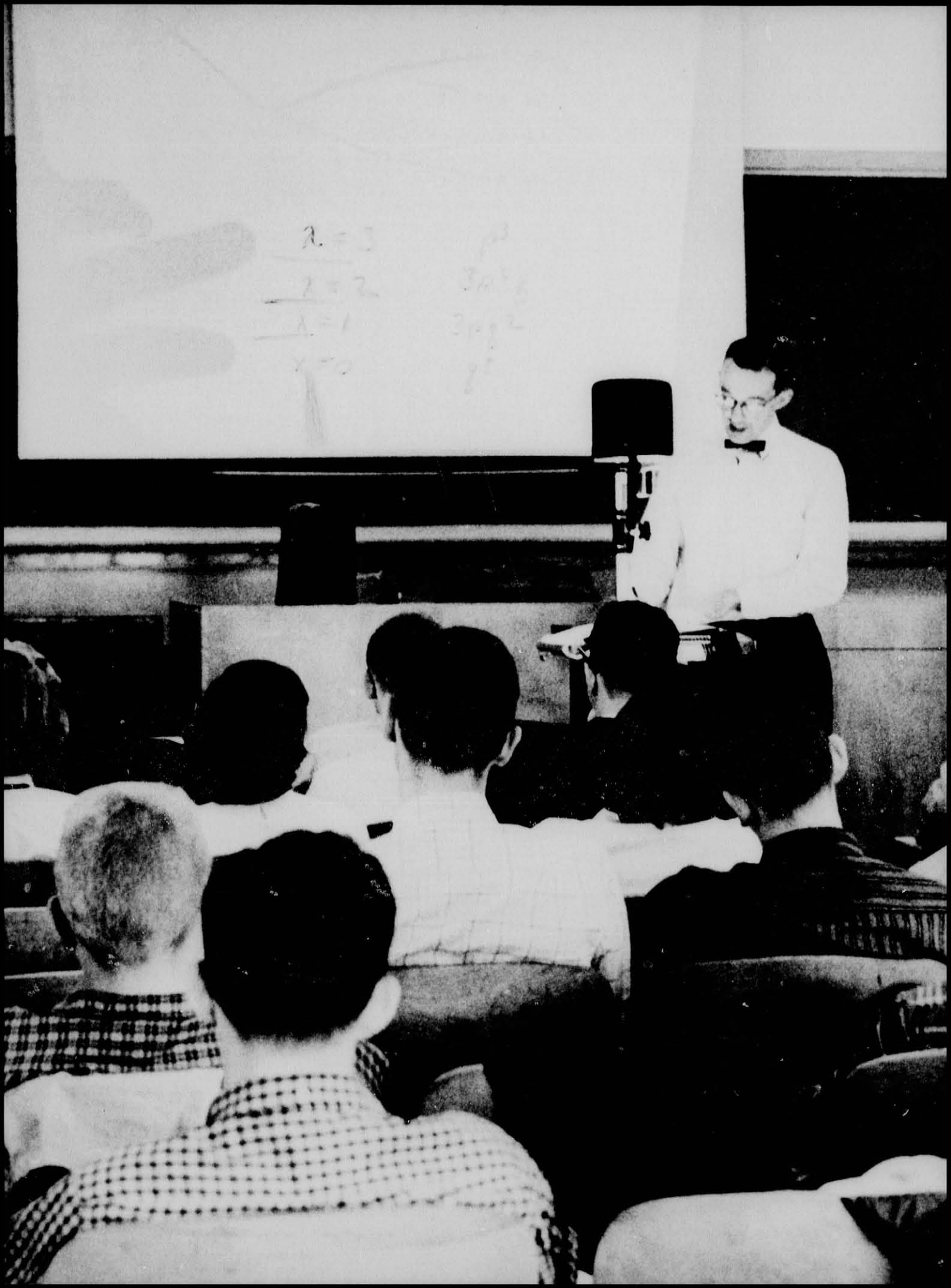
The *Alfred P. Sloan Program* enrolls exceptionally able young executives (32 to 38 years of age) who have demonstrated potential for filling positions of senior responsibility in the future. These young executives are sponsored by industry, government, and other organizations (or they may apply independently); a limited number of men are selected from abroad. The 12-month Program provides for regular classroom work plus intimate contact with business and government leaders here and abroad. It is taken in conjunction with the regular graduate program and may lead to the degree of Master of Science in Management. Approximately 45 men are admitted each year, and they are divided into two or three groups for most of their Course work.

The *Program for Senior Executives* is an intensive nine-week course of study designed for the mature executive already in or preparing for a position of major managerial responsibility. Enrollment is limited to 25 qualified executives in each of the two nine-week sessions held in the spring and fall each year.

Participants reside at Endicott House in Dedham, where they enjoy the quiet and graceful environment of a private estate furnished tastefully and comfortably. The regular classroom work is conducted at the Sloan Building, 50 Memorial Drive.

Information about these programs may be obtained by writing to the Associate Dean for Executive Programs.





$$\begin{aligned} \lambda &= 3 \\ \lambda &= 2 \\ \lambda &= 1 \\ \lambda &= 0 \end{aligned}$$

$$\begin{aligned} p^2 \\ 3R^2 \\ 2p^2 \\ p^2 \end{aligned}$$

*The role of science at M.I.T. is described by the Dean of the School.*

Science is concerned with the understanding of the physical world, and the range of this search for understanding extends from the innermost events in the atomic nucleus to the farthest detectable reaches of the universe. Modern science has proved useful in many important ways, but the search for understanding is also carried out because man is curious about the world around him. Scientific research has become increasingly exciting because of the breadth and depth of understanding which is being achieved and the increasing integration of knowledge from different fields.

Science has of course contributed in the most fundamental way to the advancement of technology, and technology has contributed importantly to the advancement of science. At M.I.T. the relationships between science and technology are especially close and mutually reinforcing.

Training in science provides the basis for many types of careers. People with scientific training are needed for teaching and research, but scientific training provides an opportunity to enter other professions as well. Industry and government have increasing needs for scientists to carry out research as individuals or as members of a larger team attacking a problem requiring a multidisciplinary approach. People with scientific training are also needed for managerial positions in industry and

government. Approximately 40 per cent of the professional employees of the Federal government are scientists and engineers.

The sciences may be broadly classified as earth and planetary sciences, life sciences, mathematics, and physical sciences. At M.I.T. instruction is provided in all of these fields at the undergraduate and graduate levels. Research is carried out in all of these fields by staff, graduate students, postdoctoral students, and also undergraduates.

The earth and planetary sciences are represented by oceanography, meteorology, geophysics and planetary physics, and geology-geochemistry. Instruction and research in these areas emphasize the application of the principles and techniques of fundamental scientific disciplines to understand our environment, and this tends to bring these fields together and emphasize their interdependence. In the study of oceanography there is active cooperation in research and teaching with the Woods Hole Oceanographic Institution.

The life sciences are in a period of rapid growth as a result of recent discoveries and the applications of techniques and ideas from chemistry and physics. At M.I.T. the areas of biology which receive special emphasis are cell biology and physiology, biochemistry, biophysics, microbiology, and nutrition and food science. Instruction and research in the life sciences cover the whole range from the properties of molecules of biological importance in-

cluding proteins, nucleic acids, enzymes and polysaccharides, the study of systems of biochemical reactions, the study of single cells, the study of the brain and nervous system, and finally the nutrition of man.

Mathematics is a field that is independent of the sciences but in its history it has received stimulation from the sciences and has greatly benefited them by providing a common language and powerful techniques. Instruction and research are provided in analysis, algebra, geometry, topology and many areas of applied mathematics. The latter field has involved collaborative work with many other disciplines at M.I.T.

The physical sciences are represented by chemistry and physics. Instruction and research in the Department of Chemistry include physical chemistry and chemical physics, organic chemistry, inorganic and nuclear chemistry, and analytical chemistry. In addition there are opportunities to cooperate with other departments in the application of chemistry to problems of biology, planetary and space science, material sciences and chemical engineering, for example. The field of chemistry has recently undergone major changes because of the introduction of more instrumental methods and theoretical techniques.

Physics has seen a remarkable development in this century as the result of the development of quantum mechanics and the theory of relativity. The identification of so many new particles in the last ten years has shown that much

remains to be done before an understanding of the fundamental building blocks of the universe will be achieved. Research in the Department of Physics involves too great a variety of fields to mention them all, but some fields are particle and nuclear physics, quantum theory, spectroscopy, astrophysics, space physics, solid-state physics, masers, atomic beams, nuclear magnetic resonance, cosmic rays, plasma, low temperatures, magnetism, and accelerator physics.

The science programs at M.I.T. profit from the availability of laboratories of an interdepartmental nature which facilitate work in fields which cross the lines of traditional disciplines. Some of these facilities include the Cambridge Electron Accelerator (operated jointly by Harvard and M.I.T.), Center for Materials Science and Engineering, Center for Space Research, Information Processing Center, Laboratory for Nuclear Science, Lincoln Laboratory, Bitter National Magnet Laboratory, and Research Laboratory of Electronics. Through these laboratories and through personal contacts by members of the science departments within the Institute and outside, the sciences are brought to bear on problems of importance to the surrounding academic community, industry, and government. The School of Science provides the possibility of study and research in the most basic scientific and mathematical areas and also for the use of these ideas in a wide variety of applications.

ROBERT A. ALBERTY

### THE UNDERGRADUATE CURRICULA IN THE SCHOOL OF SCIENCE

The S.B. curricula in the School of Science consist of a common program of general education emphasizing science, mathematics, and the humanities and social sciences (the General Institute Requirements) and groupings of subjects appropriate to specialization in particular fields of science (the Departmental Programs). The General Institute Requirements are given on page 47. The Departmental Programs are given by each department on the following pages.

In addition to the programs leading to the degree of Bachelor of Science in a designated field, as indicated under the appropriate departments, the School of Science also offers a program in the Physical Sciences (Course XII-B) leading to the degree of Bachelor of Science without designation of field.

This program is explained in detail under the Department of Earth and Planetary Sciences. See page 193 for further details.

Each student arranges his program of studies with a Faculty Counselor. Typical Course schedules are issued each term by the Registrar with the Class Schedules. R.O.T.C. subjects may be used according to the specifications in Section 2.

## *Department of Biology*

The field of biology has undergone an impressive development during the last 25 years. From the conventional fields of classical botany and zoology has evolved a new field of scientific endeavor. Today biology is an exact science, utilizing physics and chemistry and surpassing both these fields in its scope and its immediate importance to man's life and health. New scientific concepts have emerged from this development; the experimental means of the classical biologist are supplemented by modern research methods. The research laboratory of today's biologist comprises electronic and optical systems of all kinds, electron microscopes, and mass spectrographs, as well as many of the methods of electrical and nuclear instrumentation.

This new approach to the biological sciences is especially at home in the M.I.T. environment, where there are important activities and facilities in all the physical sciences. The Department of Biology thus offers unusual opportunities to undergraduate, graduate, and postdoctoral students.

### **NUTRITION AND FOOD SCIENCE**

The undergraduate curricula in Life Sciences also prepare students for careers in nutrition and food science and for graduate study in these fields. Students choosing specialization in this area should elect Program 3 and consult with the Department of Nutrition and Food Science before registration.

### **THE UNDERGRADUATE CURRICULUM**

#### *Life Sciences (Course VII)*

The undergraduate curriculum in the Life Sciences is designed to prepare students for teaching and research careers in biology, nutrition, and food science; for graduate study, and for work in industries which are concerned with biological materials and fermentation processes. The Life Sciences curriculum also prepares students for graduate study in physiological psychology. Special emphasis is placed on preparing students for medical school, and this program is strengthened by the presence of 20 or more medical doctors who have come to the Department for special postdoctoral

studies and research. Students find that the program is an excellent preparation for medical school and medical research.

The Life Sciences curricula stress a physical and chemical approach which includes the application of quantitative, analytical methods to various aspects of the life sciences; hence particular emphasis is given to those fields which, in the present stage of development, are susceptible of such treatment. As modern medicine becomes less empirical and more scientific, it is increasingly important that those who wish to prepare for medical research become acquainted with the quantitative approach of the physical sciences to biological phenomena. In Life Sciences Program 1 the student ordinarily takes general biology and organic chemistry in his second year; biochemistry, microbiology, physical chemistry, and genetics in his third year; and developmental biology and physiology in the fourth year.

A Life Sciences program with a greater degree of specialization in biophysics is also offered as Program 2. This program substitutes certain subjects in the physical sciences for some of the advanced subjects in the life sciences.

A Life Sciences program with specialization in nutrition and food science is offered as Program 3. Subjects in nutrition and food science are substituted for some advanced subjects in biology.

### ***Undergraduate Specialization***

The curricula in Life Sciences provide ample time for electives. Most students taking one of these curricula are preparing to go on to graduate work, and different electives are recommended depending upon the ultimate field of graduate specialization. Students interested in one of the following fields should consult the Department of Biology prior to registration: cell biology, physiology, biochemistry, biophysics, medicine, and microbiology.

All programs of the Course lead to the degree of Bachelor of Science in Life Sciences.

<b>PROGRAM 1. LIFE SCIENCES CURRICULUM</b>	<i>Total</i>
<b>GENERAL INSTITUTE REQUIREMENTS (see page 47)</b>	<i>units</i>
Specific science and humanities and social science subjects.	<b>132<sup>1</sup></b>

The subjects 5.41T, 7.01, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 50) and can be used to satisfy the Science Distribution Requirement.

The subject 5.31, which is required in the Departmental Program, appears on the list of Laboratory Subjects (see page 51) and can be used to satisfy the Laboratory Requirement.

**DEPARTMENTAL PROGRAM**

<i>Required Subjects</i>	
5.31	INTRODUCTION TO CHEMICAL EXPERIMENTATION 2 8 2
5.41T	INTRODUCTION TO STRUCTURE, BONDING AND MECHANISM 4 0 8
5.60	CHEMICAL EQUILIBRIUM 4 0 8
7.01	GENERAL BIOLOGY 4 0 8
7.011	INTRODUCTION TO EXPERIMENTAL BIOLOGY 1 8 3
7.03	GENETICS 3 0 9
7.04T	DEVELOPMENTAL BIOLOGY 3 0 6
7.05T	GENERAL BIOCHEMISTRY 4 0 8
7.06	GENERAL AND CELL PHYSIOLOGY 3 0 9
7.21T	GENERAL MICROBIOLOGY 3 0 9
18.034	DIFFERENTIAL EQUATIONS 3 0 9

**129***Restricted Electives**One of the following subjects:*

1.00	INFORMATION SYSTEMS 3 3 6
6.01	INTRODUCTORY NETWORK THEORY 4 0 8
8.03	PHYSICS III 5 0 7

*One of the following subjects:*

7.031	EXPERIMENTAL GENETICS AND MICROBIOLOGY 2 16 6
7.041T	EXPERIMENTAL CELL BIOLOGY 2 16 6
7.051T	EXPERIMENTAL BIOCHEMISTRY 2 16 6
7.061T	EXPERIMENTAL PHYSIOLOGY 2 16 6

**36***Unrestricted Electives<sup>2</sup>***63**Total units required for the S.B. degree **360**

<sup>1</sup>The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup>Schedules of students in Course VII, Program 1, may always be arranged to leave available 24 units of unrestricted elective in the second year. A thesis is recommended but not required. The Department strongly recommends that students elect 24 units of 5.62 or 5.63, 8.06, and 18.05.

**PROGRAM 2. SPECIALIZED BIOPHYSICS CURRICULUM**GENERAL INSTITUTE REQUIREMENTS (see page 47) *Total units*Specific science and humanities and social science subjects **132<sup>1</sup>**

The subjects 5.41T, 7.01, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 50) and can be used to satisfy the Science Distribution Requirement.

The subject 5.31, which is required in the Departmental Program, appears on the list of Laboratory Subjects (see page 51) and can be used to satisfy the Laboratory Requirement.

**DEPARTMENTAL PROGRAM***Required Subjects*

5.31	INTRODUCTION TO CHEMICAL EXPERIMENTATION 2 8 2
5.41T	INTRODUCTION TO STRUCTURE, BONDING AND MECHANISM 4 0 8
5.60	CHEMICAL EQUILIBRIUM 4 0 8
7.01	GENERAL BIOLOGY 4 0 8
7.011	INTRODUCTION TO EXPERIMENTAL BIOLOGY 1 8 3
7.05T	GENERAL BIOCHEMISTRY 4 0 8
8.03	PHYSICS III 5 0 7
8.04	PRINCIPLES OF QUANTUM PHYSICS 5 0 7
8.05	PHYSICS OF ATOMS AND MOLECULES 4 0 8
18.034	DIFFERENTIAL EQUATIONS 3 0 9

**120***Restricted Electives**Any two of the following subjects:*

7.03	GENETICS 3 0 9
7.04T	DEVELOPMENTAL BIOLOGY 3 0 6
7.06	GENERAL AND CELL PHYSIOLOGY 3 0 9
7.21T	GENERAL MICROBIOLOGY 3 0 9

*One of the following subjects:*

7.031	EXPERIMENTAL GENETICS AND MICROBIOLOGY 2 16 6
7.041T	EXPERIMENTAL CELL BIOLOGY 2 16 6
7.051T	EXPERIMENTAL BIOCHEMISTRY 2 16 6
7.061T	EXPERIMENTAL PHYSIOLOGY 2 16 6

**45 or 48***Unrestricted Electives<sup>2</sup>***63 or 60**Total units required for the S.B. degree **360**

<sup>1</sup>The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup>Schedules of students in Course VII, Program 2, may always be arranged to leave available 24 units of unrestricted elective in the second year. A thesis is recommended, but not required. The Department strongly recommends that students elect 24 units of 5.62 or 5.63, 8.06, and 18.05.

**PROGRAM 3. NUTRITION AND FOOD SCIENCE**

CURRICULUM (See DEPARTMENT OF NUTRITION AND FOOD SCIENCE, page 218.)

**GRADUATE STUDY IN BIOLOGY**

The Department of Biology offers graduate work leading to the degrees of Master of Science in Biology, Biochemistry, or Biophysics, and Doctor of Philosophy or Doctor of Science. Study may be pursued in the following fields of specialization; cell biology, physiology, microbiology, biochemistry, and biophysics.

The Master's degree is not a prerequisite for a program of study leading to the doctorate. Master's candidates may, by permission, change to a doctoral program without loss of credit.

The Department has exceptional facilities for graduate education, not only in basic analytical biology but also in many specialized fields. Students may prepare for careers in teaching, in pure and applied biological research, in medical research, and in many fields of industry and

industrial research, such as biophysical, biochemical, pharmaceutical, leather, oil, fermentation, and other industries. The educational program is based upon a number of general and specialized subjects and upon each student's active participation in research work.

Research facilities are available for a wide variety of fields in analytical biology, biochemistry, biophysics, and microbiology.

#### **CELL BIOLOGY AND PHYSIOLOGY**

The laboratories of biology apply chemical and physical methods to modern problems of biology. Major areas of research include molecular biology; analytical cytology; physiological genetics; cellular, sensory, and neuro-physiology; and growth and differentiation. Specific current research projects include the chemistry and structure of nerve tissue, connective tissue and chromosomes, electrical properties of nerve and muscle, and the study of tissues in culture.

#### **BIOCHEMISTRY**

The laboratories of biochemistry are equipped with the most modern tools for teaching and research. Special equipment for the isolation and characterization of enzymes, a radioactivity center, and a mass spectrograph are in current use in these laboratories for the solution of problems in enzymology, biosynthesis of proteins, nucleic acids and co-enzymes, intermediary metabolism, and microbiology.

#### **BIOPHYSICS**

The physical aspects of biological problems are approached in the biophysical laboratories through the use of techniques such as X-ray diffractions, electron microscopy, ultracentrifugation, electrophoresis, and spectroscopy, as well as through the development of new instruments. Current research problems lie in the area of the structures of proteins, polysaccharides, and nucleic acids; the physical chemistry of proteins and their interactions; molecular genetics; communications biophysics; and instrumentation for use in biology and medicine.

The cooperative arrangement with Harvard University is described in Section 3 of this Catalogue.

#### **MICROBIOLOGY**

The general properties of microorganisms are stressed, with special emphasis on microbial genetics and metabolism. Bacterial and mammalian viruses are considered, with special emphasis on problems of reproduction. Microorganisms are compared with mammalian cells in tissue culture.

#### **Entrance Requirements for Graduate Study**

The Department modifies the general Institute requirements for graduate study (see Section 3) as follows:

*Mathematics.* CALCULUS (18.01, 18.02).

*Physics.* One year of college physics.

*Chemistry.* INTRODUCTION TO STRUCTURE, BONDING AND MECHANISM (5.41T).

*Professional Subjects.* GENERAL BIOCHEMISTRY AND PHYSIOLOGY OF MICROBIOLOGY.

Deficiencies in the subjects listed above may be removed, if not too extensive, while pursuing a graduate program.

#### **Requirements for Advanced Degrees**

There are no specified programs for degree work, since the subjects required vary with the field of specialization. Each student selects his own program, according to certain broad principles, after consultation with the Graduate Committee of the Department.

In addition to the general requirements for advanced degrees (see Section 3), the Department requires all students to take BIOLOGY SEMINAR (7.31, 7.32).

#### **Assistantships and Fellowships**

A number of qualified students are appointed each year as teaching or research assistants. A research assistant may be permitted to use the results of his assigned research work in a graduate thesis, with possible acceleration of his program. In addition, a number of predoctoral and postdoctoral fellowships are available in cell biology, microbiology, physiology, biochemistry, and biophysics. Information is available from the Head of the Department.

## Department of Chemistry

The Department of Chemistry offers an undergraduate program sufficiently flexible in its electives to provide excellent preparation for careers in many different areas of chemistry. The Department offers graduate programs leading to the degrees of Master of Science, Doctor of Philosophy, and Doctor of Science. There is a wide variety of opportunities for study and research in analytical, biophysical, geological, inorganic, nuclear, organic, and physical chemistry and in chemical physics.

### THE UNDERGRADUATE CURRICULUM

#### Chemistry (Course V)

The Course is designed to provide a general education based on science, both for those who seek the Bachelor's degree and a career in some field in which a sound knowledge of chemistry is important and for those who wish to go on to graduate study and a professional career in chemistry. Students receive thorough instruction in the principles of chemistry, supplemented by instruction in mathematics and physics and in the humanities and other non-professional subjects.

Elective time allows each student to extend his knowledge in areas of special interest. Students intending to take graduate work may elect subjects which may give them more detailed knowledge in the areas in which they will pursue their graduate training. Students intending to enter industry may take subjects which offer the fundamentals in a selected field of science or engineering. Elective time may also be used for additional subjects in the humanities and other non-professional areas.

The Course aims to stimulate and develop the research attitude, and the curriculum may include a thesis in the fourth year, or earlier, to give the student an opportunity to demonstrate his aptitude for creative effort.

The curriculum is carefully planned with a minimum amount of required basic material in chemistry and related fields, and there is ample opportunity for students to make a choice of electives from a large number of advanced chemistry and related subjects. Thus each student is given a general background in chem-

istry with opportunity for detailed study in specific areas. The Course leads to the degree of Bachelor of Science in Chemistry. The curriculum requirements for the degree are given below.

**GENERAL INSTITUTE REQUIREMENTS** (see page 47) *Total units*  
Specific science and humanities and social science subjects. **132<sup>1</sup>**

The Science Distribution Requirement will be satisfied by 5.41T or 5.60, which are required in the Departmental Program, plus appropriate subjects (see page 50) totaling **24**

The subject 5.31, which is required in the Departmental Program, appears on the list of Laboratory Subjects (see page 51) and can be used to satisfy the Laboratory Requirement.

#### DEPARTMENTAL PROGRAM

##### Required Subjects

5.41T	INTRODUCTION TO STRUCTURE, BONDING AND MECHANISM	4	0	8
5.31	INTRODUCTION TO CHEMICAL EXPERIMENTATION	2	8	2
5.42	ORGANIC CHEMISTRY	4	0	8
5.32	INTERMEDIATE CHEMICAL EXPERIMENTATION	2	8	2
5.60	CHEMICAL EQUILIBRIUM	4	0	8
5.33	ADVANCED CHEMICAL EXPERIMENTATION	2	12	4
5.62	PHYSICAL CHEMISTRY	4	0	8
5.63	PHYSICAL CHEMISTRY	4	0	8
5.03	PRINCIPLES OF INORGANIC CHEMISTRY I	3	0	9
				<b>114</b>

##### Unrestricted Electives<sup>2</sup>

Total units required for the S.B. degree **90**  
**360**

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> The student's Faculty Counselor can offer suggestions for elective subjects, which are offered by this Department and by other departments, that will be of value in preparation for specialization in the various broad areas of chemistry. The proper choice of electives is particularly important for students planning to continue their education in a graduate school.

Students planning to take 5.89, particularly if they expect to prepare an undergraduate thesis during their fourth year, should indicate this intent to their Faculty Counselor as early as possible and not later than the beginning of their third year in order to arrange their subjects properly so as to have an adequate background in their area of specialization.

#### GRADUATE STUDY IN CHEMISTRY

The subjects offered in the graduate program aim to develop a sound knowledge of funda-

mentals and a familiarity with current progress in the most active and important areas of chemistry. In addition to studying formal subjects, each student undertakes a research problem which forms the core of his graduate work. Through the experience of conducting an investigation leading to a doctoral or Master's thesis, the student learns general research attitudes and methods of approach, and acquires training in some of the specialized techniques of research.

Attainment of the Master's degree is not prerequisite to a program of study leading to a doctorate. Indeed, new graduate students should register as doctoral candidates from the beginning of their graduate work. Applications for admission as a S.M. candidate are not accepted unless there is some special reason to seek a Master's degree as a terminal degree.

All graduate students are encouraged to select a research supervisor during the first term of residence. The research supervisor will serve as the student's advisor during the balance of his graduate career. In particular, the final program of graduate subjects will be established by the student and his research supervisor. In planning this program and in establishing a thesis problem, careful consideration will be given to the candidate's previous academic record and professional experience as well as his long-range aims and objectives.

The areas of research in the Department are organic, inorganic, physical, analytical, nuclear, geological, and biophysical chemistry, and chemical physics. A student's thesis research frequently will involve more than one of these fields.

Some of the research activities of the Department are carried out in association with the work of various interdisciplinary laboratories, such as the Center for Materials Science and Engineering, the Research Laboratory of Electronics, the Laboratory for Nuclear Science, and the Spectroscopy Laboratory. These interdepartmental research laboratories provide a stimulating interaction among the research programs of several M.I.T. departments and give students the opportunity to become familiar with research work in disciplines other than chemistry. There is also an opportunity for research in cooperation with other departments, such as Biology, Earth and Planetary Sciences, and Physics.

Detailed information on the research activi-

ties of the faculty can be found in the *Directory of Graduate Research* published by the American Chemical Society.

### **Entrance Requirements for Graduate Study**

The general requirements for admission to the Graduate School are set forth in Section 3 of this Catalogue. In particular, a student intending to pursue graduate work in chemistry should have as a background the equivalent of a good undergraduate program in chemistry. The Department is flexible in its attitude toward the specific mathematics and physics preparation mentioned in Section 3; the essential requirement is demonstration of ability to progress with advanced study and research in some area of special interest. Mathematics and physics at least equivalent to the content of those subjects listed in Section 3 are important prerequisites for graduate work in physical chemistry or chemical physics. On the other hand, less preparation in mathematics and physics would be required for work in organic chemistry.

*Graduate Record Examinations.* Applicants for graduate admission to this Department are not required to submit G.R.E. scores. However, it is requested that scores be submitted by those persons who are taking the Graduate Record Examination.

### **The Graduate Degrees**

The general requirements for graduate degrees are set forth in Section 3 of this Catalogue. Additional details relevant to Chemistry are given below.

#### **MASTER OF SCIENCE IN CHEMISTRY**

Candidates for the S.M. degree in Chemistry must demonstrate to the Department of Foreign Literatures and Linguistics an ability to read scientific literature in German, French, or Russian.

#### **DOCTOR OF PHILOSOPHY AND DOCTOR OF SCIENCE**

The Department does not have any formal subject requirements for the doctoral degree. Each student, with the advice of his research supervisor, will pursue an individual program of study which is pertinent to his long-range research interests. For some students this will include the acquisition of proficiency in reading scientific German.

*Major examinations.* Written major examinations are cumulative, and a series of examinations is given each term. Separate examinations in physical, organic and inorganic chemistry are offered each time, and additional examinations in nuclear, analytical, biophysical chemistry or other specialized areas are also offered several times during the year. The level of these examinations will correspond to introductory graduate subjects, but they are not based specifically on such subjects. Considerable emphasis is placed on seminars and current literature. Six of these cumulative examinations must be passed to complete the written major examination. No fixed time limit is set for completion of this requirement, but progress will be reviewed periodically.

No other general written examinations are required. In particular, no qualifying (or "entrance") examinations are given. An assessment of each new student's background and a decision on the proper level of first-term graduate work is made on the basis of individual interviews.

A comprehensive oral examination in the candidate's major field of advanced study is held near the end of the third term of residence. Progress in research is examined at that time.

A final oral presentation of the subject of the doctoral research is scheduled after the thesis has been submitted and tentatively evaluated by a committee of examiners.

#### ***Assistantships***

The Department appoints a number of degree candidates as teaching assistants who are usually assigned to laboratory subjects in the Department or to discussion sections of lecture subjects. It is customary to offer continued financial support to students who maintain a satisfactory record. Many students receive appointments to research assistantships after their first year, although departmental fellowships and reappointments to teaching assistantships are also available.

---

Inquiries about the graduate program or concerning appointments should be addressed to the Chairman of the Department Committee on Graduate Students, Chemistry Graduate Office, Room 18-391.

## Department of Earth and Planetary Sciences

Study of earth and planetary sciences at M.I.T. includes the broad field of the evolution of the main planetary features; the composition, structure, and state of the atmospheres, oceans, surfaces, and interiors of planets; and the nature of the interplanetary medium. These problems are attacked by *in situ* physical measurements where possible, by laboratory studies on samples or models, and by theoretical-numerical studies influenced by the available data. No single department can fully cover all aspects of this broad subject. Chosen for special emphasis at M.I.T. are the fields of mineralogy-crystallography, experimental petrology, rock mechanics, regional geology and geophysics, geochemistry, seismology, planetary magnetism and electricity, heat flow, high pressure geophysics, geophysical fluid dynamics, particles in planetary fields, physical and chemical oceanography, and marine geology and geophysics. Experimental facilities are available for training and research in these fields in the Department, in M.I.T. laboratories such as the Center for Space Research and Lincoln Laboratory, and in cooperating institutions such as the Woods Hole Oceanographic Institution. To summarize in more conventional terms, the Department is concerned with a program of education and research in modern aspects of geology and geochemistry, solid earth geophysics, space physics, and oceanography. The latter two fields are also covered by other M.I.T. departments, and joint programs not only are possible but are encouraged.

Graduates in the earth sciences typically pursue careers in universities, government agencies, and industrial firms where they are concerned with teaching, research, or management.

Students who wish to transfer into Course XII will, in general, be able to get full credit for subjects they have taken. Hence it should not be difficult for science and engineering students to transfer into the Department.

### THE UNDERGRADUATE CURRICULA

#### *Earth and Planetary Sciences (Course XII)*

The undergraduate programs in Course XII provide students with an opportunity to acquire competence in some aspect of the earth and planetary sciences as described above. They are

designed to prepare the student for work in the leading graduate departments in geology and geophysics in the country.

Two programs are offered. Program 1, for geologists and geochemists, is built around a core of prescribed professional subjects and basic subjects in physics and chemistry; electives allow for additional work in the basic and applied sciences and in the earth sciences. Program 2, which encompasses solid earth and planetary geophysics, emphasizes physics and mathematics in the required core; electives are used to meet the departmental requirement for the senior-year subjects in earth sciences and for further work in related fields. While both programs are normally begun in the sophomore year, in some cases students may enter at the beginning of the third year. Both programs lead to the degree of Bachelor of Science in Earth and Planetary Sciences.

### 1. GEOLOGY, GEOCHEMISTRY AND GEOLOGICAL OCEANOGRAPHY PROGRAM CURRICULUM

GENERAL INSTITUTE REQUIREMENTS (see page 47)	<i>Total units</i>
Specific science and humanities and social science subjects.	<b>132<sup>1</sup></b>

The subjects 8.03, 12.01T, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 50) and can be used to satisfy the Science Distribution Requirement.

Laboratory Requirement (see page 51).	<b>12</b>
---------------------------------------	-----------

### DEPARTMENTAL PROGRAM

<i>Required Subjects</i>		
5.60	CHEMICAL EQUILIBRIUM	4 0 8
8.03	PHYSICS III	5 0 7
18.034	DIFFERENTIAL EQUATIONS	3 0 9
12.01T	GEOLOGY I	3 4 5
12.02	GEOLOGY II	3 4 5
		<hr style="width: 100px; margin-left: auto; margin-right: 0;"/> 60

### *Restricted Electives*

An approved sequence of subjects concentrating in some field. Copies of recommended programs in the fields of geochemistry, hard-rock geology, soft-rock geology, and geological oceanography may be obtained from departmental headquarters. Students who wish to take some other program must submit it for approval to the departmental committee on undergraduates.

**108**

Students concentrating in geology are required, and those primarily interested in geochemistry are

strongly urged, to attend a summer field camp in geology. This requirement is ordinarily met by attendance at an eight-week field course in geology in Montana conducted by the Department of Geology of Indiana University. Students completing this course of study satisfactorily may receive academic credit of 24 units.

Unrestricted Electives<sup>2</sup> 48  
Total units required for the S.B. degree 360

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> Schedules of students in Course XII, Program 1, may always be arranged to leave available 12 units of unrestricted elective in the second year.

#### THE SOLID EARTH AND PLANETARY GEOPHYSICS PROGRAM

A physically oriented earth sciences student pursues a sequence of subjects similar to that of a student in Physics (Course VIII), making use of the astronomy and earth and planetary sciences electives at the sophomore, junior, and senior levels.

#### 2. SOLID EARTH, PLANETARY GEOPHYSICS AND GEOPHYSICAL OCEANOGRAPHY PROGRAM CURRICULUM

GENERAL INSTITUTE REQUIREMENTS (see page 47)	Total units
Specific science and humanities and social science subjects.	132 <sup>1</sup>
The Science Distribution Requirement will be satisfied by 8.03 and 18.034 which are required in the Departmental Program, plus appropriate subjects (see page 50) totaling	12
Laboratory Requirement (see page 51).	12

#### DEPARTMENTAL PROGRAM

<b>Required Subjects</b>	
8.03 PHYSICS III	5 0 7
18.034 DIFFERENTIAL EQUATIONS	3 0 9
	<u>24</u>
<b>Restricted Electives</b>	
<i>Four of the following subjects:</i> 48	
8.04 PRINCIPLES OF QUANTUM PHYSICS	5 0 7
8.05 PHYSICS OF ATOMS AND MOLECULES	4 0 8
8.06 THEORETICAL PHYSICS I	4 0 8
8.07 THEORETICAL PHYSICS II	4 0 8
8.08 THEORETICAL PHYSICS III	4 0 8
Electives chosen by the student in consultation with his advisor from among the following: physics, mathematics, astrophysics, earth and planetary science, and laboratory and/or field work.	48
	<u>96</u>
<b>Unrestricted Electives</b>	<u>84</u>
Total units required for the S.B. degree	<u>360</u>

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

#### Earth and Planetary Science (Five-Year Course) (Course XII-A)

The problems that geologists, geochemists, geophysicists, and other earth scientists now have to consider require more basic science and more geological training than ever before, and this situation will certainly be intensified in the future. For this reason, students no longer receive training adequate for certain kinds of professional careers in the earth sciences in the normal four-year program. The primary educational objective of Course XII-A is to train earth and planetary scientists; the five-year plan has been organized with this purpose in view. This plan gives the qualified student maximum opportunity for a broad and thorough training in the basic sciences and a comprehensive training in the different fields of earth science — geology, geochemistry, geophysics, and others. Upon completion of the program he should be able to work in widely diversified fields and on many different kinds of problems in the areas mentioned in the description of the four-year curriculum.

Inasmuch as all requirements, except number of hours of thesis and of unrestricted electives, are the same for both Course XII and Course XII-A, candidates for the five-year plan will generally apply for it by the end of the first term of the senior year; at that time their qualifications will be examined and their preparation for graduate work determined. Since Course XII-A leads to the Master's degree, acceptance of a student for the graduate year will depend partly on his scholastic record and partly on the professional promise he has demonstrated in the field, the laboratory, or professional summer work with some organization.

Course XII-A leads to the degrees of Bachelor of Science in Earth and Planetary Science and Master of Science in Earth and Planetary Science, awarded simultaneously at the end of the graduate year.

#### THE CURRICULUM

The undergraduate curriculum requirements are the same as for Course XII.

The graduate requirement is 66 units of graduate study and an acceptable thesis.

#### Physical Sciences (Course XII-B)

The School of Science offers a program in the physical sciences leading to the degree of Bachelor of Science without designation of field, on the recommendation of the Department of Earth and Planetary Sciences. The program

is directed by the Department of Earth and Planetary Sciences but this implies no commitment for the student to follow a program in the earth sciences. The program serves the following purposes.

1. To enable students to delve more deeply into a different range of subjects than would be possible under a standard physical science course.

2. To enable qualified science students who do not wish to follow a standard physical science degree program to develop a more comprehensive science orientation than would be possible in a social science curriculum but a less stringent approach than would be possible through concentration in one field.

3. To enable those science students who are initially less definite about their future careers but who want a strong physical science background to obtain a degree in the School of Science without specialization.

4. To provide non-scientists among the undergraduates with an opportunity to obtain a background in science more intensive than is possible under a social science curriculum but less intensive than that given to students concentrating in a specific field.

Faculty members from the Department of Earth and Planetary Sciences will serve as a team of advisors for the program. The curriculum will be individually arranged in consultations with an advisor to meet the specific needs of the student. In addition to the general Institute requirements, each curriculum will contain a coherent set of science and engineering subjects and will specifically not be restricted to a sampling of all introductory subjects. The program aims to provide a broad, interdisciplinary and coherent education in science. It is anticipated that students in this curriculum will be qualified for admission to graduate studies in one of the physical, environmental or applied sciences.

Admission to the program will be by the approval of the advisory team only, during an experimental period in which the program will be evaluated.

The curriculum requirements for this degree are given below.

	<i>Total units</i>
<b>GENERAL INSTITUTE REQUIREMENTS</b> (see page 47)	
Specific science and humanities and social science subjects.	<b>132<sup>1</sup></b>
Science Distribution Requirement (see page 50).	<b>36</b>
Laboratory Requirement (see page 51).	<b>12</b>

### *Restricted Electives*

Science, and in special cases, engineering subjects chosen with advisor's approval **84**

### *Unrestricted Electives*

Total units required for the S.B. degree **360**

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

## GRADUATE STUDY

### *Earth and Planetary Sciences*

The Department of Earth and Planetary Sciences offers a wide choice of graduate study and research for specialization in geology, geochemistry, and solid earth and planetary geophysics. In the borderland between geology, geophysics, geochemistry, and another science, the student may arrange a program of study and research under supervision of a special interdepartmental committee. Advanced work in the fields mentioned leads to one of the following degrees: Master of Science in Earth and Planetary Sciences, or Doctor of Philosophy or Doctor of Science with a thesis in the field of specialization.

The Department offers graduate students an unusual opportunity to pursue study and research in both theoretical and experimental aspects of the subjects. Modern laboratory facilities, electronic computers, research instruments, and extensive collections of specimens and materials are available to qualified graduate students. Field studies are included as an essential part of the graduate curriculum in geology, geophysics, and geochemistry, and special arrangements may be made for summer employment and field research on departmental projects and with industrial organizations and government agencies.

### *Oceanography*

M.I.T. and the Woods Hole Oceanographic Institution have established a joint program in oceanography which leads to jointly awarded degrees of Doctor of Philosophy or Doctor of Science. For details of this program, see the description on page 210.

### *Entrance Requirements for Graduate Study*

The general admission requirements are those given in Section 3 of this Catalogue.

In addition, the Department requires preparation essentially equivalent to the program of subjects leading to the degree of Bachelor of Science in Earth and Planetary Science at the Institute. If the student is not fully prepared in certain of the required subjects, he usually will

be asked to extend his preparation in these while he pursues his advanced work. The subjects to be taken for this purpose will be selected by the student after his preparation and proposed program of study have been considered by an advisory committee. The actual program of advanced subjects and research leading to a graduate degree is arranged by the student and his faculty advisors, to whom he is assigned at the time he first registers and who will generally direct the major part of his program.

#### ***The Graduate Degrees***

##### **MASTER OF SCIENCE IN EARTH AND PLANETARY SCIENCES OR MASTER OF SCIENCE IN OCEANOGRAPHY**

In addition to the general and departmental requirements stated in the preceding paragraphs, the candidate for the degree of Master of Science in Earth and Planetary Sciences or in Oceanography is required to pursue a program of advanced study and research in an area approved by his faculty advisors. Possible fields of specialization are specified above.

#### **THE DOCTORATES**

The general requirements for the degrees of Doctor of Philosophy or Doctor of Science are given in Section 3. Possible fields of specialization are indicated above. Departmental requirements for graduate work leading to these degrees are given in the following paragraphs.

The preparation and research ability of any candidate for the doctorate must be such as to satisfy the Department Committee on Graduate Students that he is qualified to undertake advanced study and research. The thesis is expected to be a publishable contribution in the field of the candidate's specialization.

Soon after the student registers in the Department as a doctoral candidate, he will be required to take a qualifying examination, which may be partly oral and partly written; this examination is intended to survey his training and attainments and to serve as a basis for certifying him for a Doctor's program.

The program of graduate work may, with the approval of an appropriate Departmental Committee on Graduate Students, include subjects in other departments for which the student has adequate preparation. Candidates for the doctorate in oceanography will work under the guidance of an interdepartmental committee.

A reading knowledge of one or more foreign languages is strongly recommended, but not required of doctoral candidates.

In general, students are required to take at least 24 units of approved study in another department.

#### ***Teaching and Research Assistants***

The Department regularly appoints 45 to 50 assistants who are candidates for a graduate degree. Teaching assistants conduct regularly scheduled laboratory sections and examinations, grade papers, and prepare teaching materials. Research assistants do assigned work on one of the Department's projects and may be able to use some of the work done toward a thesis. Information about these appointments may be obtained by writing to the Head of the Department.

## Department of Mathematics

This Department offers a variety of programs to those interested in mathematics primarily as a pure science or for the additional purpose of applying it to other sciences, to fields of engineering, or to business.

### THE UNDERGRADUATE CURRICULUM

#### Mathematics (Course XVIII)

Each undergraduate's program is arranged through continuous collaboration between the individual student and his Faculty Counselor, subject only to a minimum uniform set of Course requirements. In most cases, the undergraduate curriculum in mathematics is preparatory to further professional training at the graduate level. For this purpose each student is encouraged both to obtain a substantial grounding in each of the fundamental branches of mathematics and also to explore certain fields of application, in order to establish a basis for the selection of an appropriate field of graduate specialization.

Whatever the ultimate objective — preparation for teaching, participation in the research programs of an industrial or government-sponsored organization, or a position as consultant in a business or in a modern high-speed computation center — the immediate educational aims are to provide an understanding of a substantial part of the existing body of mathematical knowledge and an ability to impart this knowledge to others. But most important, the Department hopes to inspire a deep interest in the discovery or invention of new mathematics or in the application of mathematics to a new field.

Students wishing to work with a small group of fourth-year students under the supervision of a faculty member or to do individual work with a member of the Department may elect either to participate in a senior mathematics seminar or to write a thesis. These possibilities furnish excellent opportunities for students to develop initiative. The experience gained from active participation in a seminar conducted by a research mathematician may be particularly valuable for a student planning to pursue graduate work in any branch of mathematics.

The undergraduate Course leads to the degree of Bachelor of Science in Mathematics. The curriculum requirements for the degree are given below.

### CURRICULUM OF MATHEMATICS PROGRAM 1 *Total units*

<b>GENERAL INSTITUTE REQUIREMENTS</b> (see page 47)	<i>132<sup>1</sup></i>
Specific science and humanities and social science subjects.	
The Science Distribution Requirement will be satisfied by 18.034, which is required in the Departmental Program, plus appropriate subjects (see page 50) totaling	<b>24</b>
Laboratory Requirement (see page 51).	<b>12</b>

### DEPARTMENTAL PROGRAM

<i>Required Subjects</i>	
18.034 <sup>3</sup> DIFFERENTIAL EQUATIONS	3 0 9
18.21 ANALYSIS	3 0 9
<sup>2</sup> LANGUAGE	4 0 8
	<b>36</b>

### *Restricted Electives* at least **96**

An integrated program of mathematics and advanced professional subjects in the Schools of Science and Engineering consisting of 96 units, of which at least 72 must be in the field of mathematics. In fulfilling this program, the following four requirements must be satisfied

1. <i>Either</i>	
18.20 LINEAR ALGEBRA	3 0 9
<i>or the following combination:</i>	
18.25 MODERN ALGEBRA and	3 0 9
18.26 MODERN ALGEBRA	3 0 9
2. <i>Either</i>	
18.22 ANALYSIS	3 0 9
<i>or</i>	
18.31 THEORY OF FUNCTIONS	3 0 9
<i>or</i>	
18.49 HARMONIC ANALYSIS AND POTENTIAL THEORY	3 0 9
3. <i>Either</i>	
18.24 ELEMENTARY DIFFERENTIAL GEOMETRY	3 0 9
<i>or the following combination:</i>	
18.241 INTRODUCTION TO TOPOLOGY	3 0 9
<i>and</i>	
18.242 RIEMANNIAN GEOMETRY	3 0 9
4. <i>Either</i>	
18.23 SEMINAR IN MATHEMATICS	3 0 9
<i>or</i>	
THESIS	12
<i>or</i>	
Advanced mathematics subject at the undergraduate or graduate level	3 0 9

### *Unrestricted Electives<sup>1</sup>* up to **60**

Total units required for the S.B. degree **360**

<sup>1</sup>The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup>The language must be French, German, or Russian. Any student who has taken two or more years of French, German, or Russian before coming to M.I.T. or who demonstrates to his Faculty Counselor his ability to read fluently mathematical literature in one of these languages may substitute 12 units of unspecified elective subjects for the language requirement.

<sup>3</sup>The sequence 18.031 and 18.032 may be substituted for 18.034. Note that 18.031 appears on the list of Science Distribution subjects.

<sup>4</sup>The Unrestricted Electives must be at least 36 units.

**CURRICULUM OF MATHEMATICS PROGRAM 2** *Total units*  
**GENERAL INSTITUTE REQUIREMENTS** (see page 47) *units*

Specific science and humanities and social science subjects. **132<sup>1</sup>**

The Science Distribution Requirement will be satisfied by 8.03 and 18.034, which are required in the Departmental Program, plus appropriate subjects (see page 50) totaling **12**

Laboratory Requirement (see page 51). **12**

**DEPARTMENTAL PROGRAM**

*Required Subjects*

8.03	PHYSICS III	5 0 7	
18.034	<sup>3</sup> DIFFERENTIAL EQUATIONS	3 0 9	
18.21	ANALYSIS	3 0 9	
18.651	INTRODUCTION TO APPLIED MATHEMATICS	3 0 9	
	<sup>2</sup> LANGUAGE	4 0 8	
		60	<b>60</b>

*Restricted Electives* at least **84**

An integrated program of mathematics and advanced professional subjects in the Schools of Science and Engineering consisting of 84 units, of which at least 60 must be in the field of mathematics. In fulfilling this program, the following four requirements must be satisfied:

1. <i>Either</i>			
18.20	LINEAR ALGEBRA	3 0 9	
<i>or the following combination:</i>			
18.25	MODERN ALGEBRA and	3 0 9	
18.26	MODERN ALGEBRA	3 0 9	
2. <i>Either</i>			
18.22	ANALYSIS <i>or</i>	3 0 9	
18.652	INTRODUCTION TO APPLIED MATHEMATICS	3 0 9	
3. <i>Either</i>			
18.60	INTRODUCTION TO FLUID MECHANICS <i>or</i>	3 0 9	
18.66	INTRODUCTION TO ELASTICITY	3 0 9	
4. <i>Either</i>			
18.23	SEMINAR IN MATHEMATICS	3 0 9	
<i>or</i>			
	THESIS	12	
<i>or</i>			
	Advanced mathematics subject at the undergraduate or graduate level	3 0 9	

*Unrestricted Electives*<sup>4</sup> up to **60**

Total units required for the S.B. degree **360**

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> The language must be French, German, or Russian. Any student who has taken two or more years of French,

German, or Russian before coming to M.I.T. or who demonstrates to his Faculty Counselor his ability to read fluently mathematical literature in one of these languages may substitute 12 units of unspecified elective subjects for the language requirement.

<sup>3</sup> The sequence 18.031 and 18.032 may be substituted for 18.034. Note that 18.031 appears on the list of Science Distribution subjects.

<sup>4</sup> The Unrestricted Electives must be at least 36 units.

Transfer from one program to the other may be made at any time. In either program the minimum algebra requirement is the one-term subject LINEAR ALGEBRA (18.20), but students wishing more work in algebra as undergraduates should take the two-term subject sequence in MODERN ALGEBRA (18.25, 18.26). For students following Program 1, the minimum requirement in geometry is the one-term subject ELEMENTARY DIFFERENTIAL GEOMETRY (18.24), but students wishing more work in geometry should take instead the two one-term subjects INTRODUCTION TO TOPOLOGY (18.241) and RIEMANNIAN GEOMETRY (18.242). Students interested in applied mathematics normally would follow Program 2, with INTRODUCTION TO APPLIED MATHEMATICS (18.652) recommended. It is strongly recommended that the requirements in algebra, analysis, and introduction to applied mathematics be completed by the end of the third year, and that Physics 8.03 be included at an early stage in Program 2. The language requirement should be completed as early as possible.

It is also recommended that undergraduate students planning to pursue graduate work in elasticity, fluid mechanics, and related fields include the following elective subjects:

- INTRODUCTION TO FUNCTIONS OF A COMPLEX VARIABLE (18.27, 18.28)
- THEORETICAL PHYSICS I (8.06)

**GRADUATE STUDY IN MATHEMATICS**

On the graduate level, the Department offers programs leading to the degrees of Master of Science, Doctor of Philosophy, or Doctor of Science.

Students may select their programs from a broad range of subjects, descriptions of which appear elsewhere in this Catalogue. Numerous informal seminars supplement the basic program. There are also a weekly Mathematics Colloquium sponsored by M.I.T., Brandeis, and Harvard and a weekly Colloquium on Applied Mathematics, each of which brings guest lecturers from other institutions.

# Science

DEPARTMENT OF MATHEMATICS

Candidates whose primary interest is in the field of pure mathematics will ordinarily take most of their subjects in the Department of Mathematics. In addition to their advanced specialization, they will be encouraged to acquire breadth by taking basic subjects in analysis, algebra, geometry, and topology.

Candidates whose primary interest is in the field of applied mathematics will be encouraged to study important aspects of one or more engineering or scientific fields closely related to research in applied mathematics, in addition to their studies in mathematics.

Candidates primarily interested in pure mathematics which is basically motivated by applications and developments in theoretical physics or other disciplines will take special programs involving substantial breadth in both pure mathematics and the relevant cognate discipline.

Assistance or even collaboration in problems in pure or applied mathematics which are being investigated by members of the staff may constitute part of a graduate student's program.

## *Entrance Requirements for Graduate Study*

The admission requirements are those set forth in Section 3 of this Catalogue, with the following additions and exceptions:

*Science.* Students are expected to have one year of college-level natural science.

*Mathematics.* Students will normally be expected to present an undergraduate mathematics program approximating that required of undergraduate mathematics majors at M.I.T. Students may enter the applied mathematics program from any undergraduate field of concentration and special consideration will be given to students with a strong scientific background.

## *The Graduate Degrees*

### **MASTER OF SCIENCE IN MATHEMATICS**

For the Master's degree, a student must take not less than 72 units including at least four 12-unit graduate ("A") subjects offered by the Department as well as submitting an acceptable thesis. With the approval of the registration officer two subjects may be taken from among the advanced undergraduate subjects offered by the Department. Where deemed appropriate, subjects from other Departments may be allowed.

### **DOCTOR OF PHILOSOPHY AND DOCTOR OF SCIENCE**

The general requirements for the Doctor of Philosophy and Doctor of Science degrees are those set forth in Section 3. As soon as possible after beginning graduate work, each student who plans to take a doctorate should elect one of the following two plans of study:

*Plan A.* Under Plan A, there is a three-hour written qualifying examination on basic undergraduate mathematics, which is required of those who do not present satisfactory evidence of having learned the material. The examination will be waived for students presenting to the Departmental Graduate Committee satisfactory evidence of having learned the material; for example, by having achieved sufficiently high standing in classes in these subjects at M.I.T. or elsewhere.

A general oral examination is required of each candidate. The plan of this examination is made in consultation with three faculty members and is reviewed by the Graduate Committee.

*Plan B.* All students electing Applied Mathematics as their field of study should normally follow this program. Its basic objective is a proper balance of specialization and diversity. To secure maximum flexibility, each student's program is considered individually. The degree candidate, in consultation with a faculty advisor, submits a "Plan of Study" in his second term for approval by the Applied Mathematics Committee. In addition to a listing of subjects related to the major field, the plan must include a distinct minor, or its equivalent, to assure familiarity with the basic concepts of Applied Mathematics, i.e., propagation, equilibrium, stability, optimization, cybernetics and random processes. This plan forms the basis for the oral general examination which is arranged by the prospective thesis advisor and takes place in the second year of full-time graduate work. (The oral examination proposal is submitted to the Graduate Committee of the Department.) The student may officially begin his thesis research after passing this examination.

Students in both Plan A and Plan B will take additional subjects, chosen in consultation with an advisor. Unless otherwise specified by the advisor, 132 hours of graduate (A) credits with grade A or B are required. Where deemed advisable, subjects from other departments may be allowed.

In special circumstances a student may receive permission to work under another plan (Plan N), in which regular Course requirements and written examinations in mathematics subjects are omitted. Students admitted to this program are given oral examinations on their general mathematical progress.

Doctoral candidates are required to demonstrate to the Department of Mathematics a mathematical reading knowledge in at least one foreign language. French, German, and Russian are acceptable languages.

Thesis work is done under the supervision of an advisor. The thesis is expected to represent original research and to meet the standards ordinarily required for publication in one of the standard journals devoted to research in mathematics or in a closely allied field. The thesis examination committee consists of three members, including the advisor.

***Fellowships and Assistantships***

Fellowships and teaching and research assistantships are available to graduate students in mathematics. Detailed information about these opportunities may be obtained from the Department.

## *Department of Meteorology*

Meteorology is the science of the atmosphere. It is one of the earth sciences, all of which deal with the physical properties of the earth. Many of man's unsolved problems depend for their solution on increased knowledge of our physical environment. The Department's educational aim is to provide its students with a broad background in meteorology and related sciences, one which will prepare them to cope with these challenging problems of the atmosphere and the physical environment.

### **UNDERGRADUATE PREPARATION FOR METEOROLOGY**

The first requisite for this educational objective is a sound preparation in physics and the concomitant mathematics. Students should also acquire a broad background in the earth sciences by taking selected subjects in geology and oceanography as well as in meteorology. The stage is then set for professional specialization in meteorology.

Undergraduate students who wish to prepare for graduate work in meteorology are advised to register in Earth and Planetary Sciences (Course XII), which is designed to provide the necessary background for graduate work in any of the earth sciences. Adequate preparation is also provided by other M.I.T. undergraduate curricula, particularly in the Departments of Physics and Mathematics. Students who are taking their undergraduate work at other institutions are advised to include in their programs the equivalent of the mathematics and physics contained in the M.I.T. curricula referred to above. Some undergraduate preparation in meteorology or oceanography is helpful but is not required.

### **GRADUATE STUDY (Course XIX)**

Emphasis in graduate training is placed on the theoretical and quantitative approach, supplemented by empirical and experimental methods. This approach is based on the conviction that the progress of meteorology depends on the quantitative application of the laws of physics to the atmosphere. However, the Department recognizes that there is equal demand for individuals who are more concerned with applications and experimental studies. Such students

need to understand the implications of the theoretical developments, while the theory-oriented students need an appreciation of the observational material.

### **METEOROLOGY**

Formal subjects of instruction are offered in all of the principal areas of meteorology. Subjects commonly taken by graduate students include:

19.15	LONG-RANGE FORECASTING
19.22	AIR AND SEA INSTRUMENTS
19.24	FLUID DYNAMICS LABORATORY
19.35	STATISTICAL PROBLEMS IN METEOROLOGY
19.45	SYNOPTIC METEOROLOGY II
19.46	NUMERICAL WEATHER PREDICTION
19.53	SYNOPTIC LABORATORY
19.64	DYNAMIC METEOROLOGY II
19.65	TURBULENCE AND RANDOM PHENOMENA IN FLUID MECHANICS
19.67	PLANETARY FLUID DYNAMICS
19.71	ATMOSPHERIC PRECIPITATION PROCESSES
19.72	PHYSICAL METEOROLOGY
19.74	PHYSICS OF THE UPPER ATMOSPHERE

As this list suggests, facilities for instruction and research are available in all of the principal areas of meteorology. There are several radar systems and associated equipment together with a large and comprehensive file of radar data. Current weather data covering North America, Western Europe, and the adjacent oceans are available on teletypewriter circuits and by facsimile. Extensive files of weather data are available for most areas of the world; much of this is already in form for use on modern computing machines, and students have access to desk computers, IBM card equipment, and the high-speed computing facilities of the Information Processing Center.

The Meteorological Instrumentation Laboratory contains standard and specialized instrumentation and special test equipment. Laboratory facilities are available for research in physical meteorology, especially in the fields of cloud and precipitation physics. The Fluid Dynamics Laboratory contains apparatus that models atmospheric and oceanic circulations.

The Department conducts an extensive program of sponsored research. Graduate students are often able to participate in this program as research assistants. Such active participation is considered a valuable supplement to the

formal academic program and also provides some financial assistance.

The area surrounding Cambridge contains a number of institutions engaged in research in meteorology and related fields, such as the Air Force Cambridge Research Laboratories, the Woods Hole Oceanographic Institution, Harvard University, and the Boston offices of the United States Weather Bureau. Close contact with the scientific personnel of these institutions is maintained through joint seminars and symposia as well as by more informal means.

#### OCEANOGRAPHY

The Department of Meteorology is an active participant in the joint M.I.T.-Woods Hole Oceanographic Institution graduate program in oceanography which is described in this section of the Catalogue on page 210. It is urged that candidates for the doctorate enter this joint program because of its many advantages. However, in special circumstances, a student may pursue a doctorate entirely under the auspices of the Department. The degree of Master of Science in Oceanography is offered by the Department but not in the joint program. The Master of Science degree is not a prerequisite to the doctorate but many students find it desirable to earn a Master of Science on the way to the doctorate. The Department is active in physical oceanography including theoretical studies of the oceanic circulation, observational studies at sea, laboratory models and field and laboratory investigations of the interactions between the atmosphere and the ocean. The programs of graduate students in oceanography also include subjects in oceanography and related areas offered by the Department of Earth and Planetary Sciences, several other M.I.T. departments and the Woods Hole Oceanographic Institution.

#### *Entrance Requirements for Graduate Study*

Although an undergraduate program of the type described above is considered the best preparation for graduate study, it is not required; graduates of recognized institutions who present evidence of sound preparation in physics and mathematics and who meet the general requirements for admission to the Graduate School (see Section 3 of this Catalogue) may be admitted. However, training substantially equivalent to that provided by SYNOPTIC METEOROLOGY I (19.43T) and INTRODUCTION TO DYNAMICAL METEOROLOGY (19.601) will make it possible for students to pursue a more advanced program of

studies immediately after admission. Applicants with no previous training in meteorology will generally be required to take these subjects during their graduate study and therefore must expect to be in residence for a somewhat longer period.

The advanced subjects offered by the Department lead to the degrees of Master of Science in Meteorology, Master of Science in Oceanography, Doctor of Philosophy and Doctor of Science.

#### *The Graduate Degrees*

##### MASTER OF SCIENCE IN METEOROLOGY OR IN OCEANOGRAPHY

The graduate ("A") subjects required for the Master of Science degree may be selected from those offered in meteorology or in oceanography and those in related fields offered by other departments. Undue specialization in one branch of the field is discouraged. There are no foreign language requirements for the degree.

##### DOCTOR OF PHILOSOPHY AND DOCTOR OF SCIENCE

The general requirements for the degrees of Doctor of Philosophy and Doctor of Science are given in Section 3. The Department does not require candidates for the doctorate to present evidence of competence in a foreign language or languages. Because of the importance of communication with foreign scientists, it is strongly urged that candidates for the doctorate acquire intermediate competence in one or more foreign languages. It is preferable that this competence in foreign languages be acquired prior to enrollment as a graduate student, but the study of language may be undertaken while in residence at M.I.T. Russian and German are recommended, but French and Spanish are also appropriate.

#### *Assistantships and Fellowships*

The Department offers a limited number of research and teaching assistantships each year. Research assistants are assigned to work on one of the many research projects in the Department. Teaching assistants may be assigned to assist in laboratory instruction or in the preparation of teaching materials and the grading of papers. Information concerning these appointments may be obtained from the Head of the Department. The Department offers a few predoctoral fellowships in the atmospheric sciences and oceanography. Announcements and application forms are available around the first of the year and may be obtained from the Head of the Department.

## *Department of Nutrition and Food Science*

The biological sciences have in recent years undergone a dramatic expansion and development. Nutrition and food science have also fallen under the influence of this change. In the past, nutrition was traditionally concerned with requirements for specific nutrients, and food science with practical means for food preservation. Concomitant with the recent dramatic developments in life sciences, physical sciences and engineering, these disciplines have acquired a broader context, requiring the application of modern, quantitative principles and techniques to many aspects of the relationship of man to his environment. The Department of Nutrition and Food Science, by virtue of the diverse interests and backgrounds of its faculty, integrates knowledge from chemistry, physics, microbiology, medicine and engineering in research and teaching programs dealing with fundamental problems in nutritional biochemistry and metabolism, food science and technology, and biochemical engineering.

Problems associated with the increasing world population and with the rapid application of scientific and technological discoveries by both medicine and the food industry present an unprecedented challenge for nutrition and food scientists. The prevalence of malnutrition in technically underdeveloped countries and of degenerative diseases in the technically advanced countries; the need for improved understanding of the origin and nature of human disease and disability; the variety of new compounds being added intentionally or finding their way unintentionally into man's food; the need for new and improved methods of food processing and for prolonged storage and widespread distribution of foodstuffs — these are among the problems that have increased the need for fundamental scientific information about human nutrition and metabolism and human food supply and for ways of applying such information for the welfare of mankind. In response to the challenge of these problems, a broad and integrated Department of Nutrition and Food Science has been developed at M.I.T. The staff of the Department includes scientists trained in medicine and public health, animal nutrition and pathology, physiology and physiological chemistry, food

toxicology and microbiology, food and flavor chemistry, and food processing and engineering. The Department thus offers interdisciplinary training to students planning careers in these fields.

The Department is cooperating with the Pan American Health Organization and has established joint research and training programs with the Institute of Nutrition of Central America and Panama (INCAP) in order to contribute more directly to the solution of the nutritional problems of technically underdeveloped areas and to provide a better opportunity for the training of students who plan to participate in this work.

Among the variety of careers open to students with training in nutrition, food science and technology are: university teaching and research, research in government, private and industrial laboratories; product and process development in the food and related industries; work with international agencies.

### **UNDERGRADUATE SPECIALIZATION IN NUTRITION AND FOOD SCIENCE**

This Department offers an undergraduate curriculum as part of the Life Sciences Curriculum Program 3. This curriculum (described below) emphasizes fundamental subjects in the physical and biological sciences. These, together with the subjects prescribed under the General Institute Requirements (page 47), provide the undergraduate student with the broad background in basic sciences which is necessary either for an understanding of food science or of the adaptive responses of mammals to nutritional and other environmental factors. Either of two fields of specialization may be elected. For those interested in nutrition, introductory subjects are taken in nutrition, biochemistry, mammalian physiology; and a series of planned electives may be chosen from areas which include physiological chemistry, human nutrition, endocrinology, neuroendocrinology, and psychology. For those interested in specializing in food science and technology, a series of planned electives may be selected from subjects such as food engineering, analytical chemistry, physiology, microbiology, and food

toxicology. Although most of the specialized training in food science and technology and nutritional biochemistry and metabolism must be obtained at the graduate level, the undergraduate student may sample these fields while acquiring knowledge which will serve him well in a broad range of careers in the life sciences.

### Life Sciences (Course VII)

#### PROGRAM 3. NUTRITION AND FOOD SCIENCE CURRICULUM

##### GENERAL INSTITUTE REQUIREMENTS (see page 47)

Specific science and humanities and social science subjects. **132<sup>1</sup>**

The subjects 5.41T, 7.01, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 50) and can be used to satisfy the Science Distribution Requirement.

The subject 5.31, which is required in the Departmental Program, appears on the list of Laboratory Subjects (see page 51) and can be used to satisfy the Laboratory Requirement.

#### DEPARTMENTAL PROGRAM

##### Required Subjects

5.31	INTRODUCTION TO CHEMICAL EXPERIMENTATION	2	8	2
5.41T	INTRODUCTION TO STRUCTURE, BONDING AND MECHANISM	4	0	8
5.60	CHEMICAL EQUILIBRIUM	4	0	8
7.01	GENERAL BIOLOGY	4	0	8
7.011	INTRODUCTION TO EXPERIMENTAL BIOLOGY	1	8	3
7.05T	GENERAL BIOCHEMISTRY	4	0	8
7.21T	GENERAL MICROBIOLOGY	3	0	9
18.034	DIFFERENTIAL EQUATIONS	3	0	9
20.02	NUTRITION AND FOOD SCIENCE PROJECTS LABORATORY	1	8	3
20.30	NUTRITIONAL BIOCHEMISTRY AND METABOLISM	4	0	8
				<b>120</b>

##### Restricted Electives

One of the following subjects:

8.03	PHYSICS III	5	0	7
1.00	INFORMATION SYSTEMS	3	3	6
6.01	INTRODUCTORY NETWORK THEORY	4	0	8

One of the following subjects:

5.62	PHYSICAL CHEMISTRY	4	0	8
5.63	PHYSICAL CHEMISTRY	4	0	8

One of the following:

(a) Food Science				
20.11	FOOD SCIENCE AND TECHNOLOGY	3	0	5
20.41	MICROBIOLOGY LABORATORY or	2	4	3
(b) Nutrition				
20.38	FACTORS DETERMINING FOOD VALUE and	3	0	6
20.63	SYSTEMIC PHYSIOLOGY	3	0	6

##### Unrestricted Electives<sup>2</sup>

Total units required for S.B. degree **41 or 42**  
**67 or 66**  
**360**

<sup>1</sup>The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup>Schedules of students in Course VII, Program 3, may always be arranged to leave available 24 units of unrestricted elective in the second year. A thesis is recommended but not required.

### GRADUATE STUDY (COURSE XX)

The Department of Nutrition and Food Science offers advanced programs in Nutritional Biochemistry and Metabolism, in Food Science and Technology, and in Biochemical Engineering leading to the degrees of Master of Science, Doctor of Philosophy, and Doctor of Science.

The Department offers a wide choice of graduate study and research with opportunities for specialization in clinical and public health nutrition, animal nutrition, physiological chemistry, food toxicology, food chemistry, flavor chemistry, food microbiology, food processing, food engineering, and biochemical engineering. It also offers special programs for veterinarians wishing to undertake advanced training in animal pathology and physiological chemistry or in food science. Physicians and dentists wishing to undertake advanced training in nutrition and related sciences may also become degree candidates.

The Department has excellent facilities for research which include a clinical research center for metabolic studies on human subjects; well-equipped laboratories for physical, chemical, biochemical and microbiological research; modern animal laboratories; and processing laboratories for research on the effects on foods of heat, refrigeration, freezing, dehydration, radiation, and fermentation.

#### NUTRITIONAL BIOCHEMISTRY AND METABOLISM

Research in nutritional biochemistry and metabolism is concerned with nutritional, genetic, environmental and endocrine variations in the metabolic processes of man and various laboratory animals and their alterations in disease states. Current research projects include: biochemical, morphological and physiological effects of malnutrition; the biochemical defects underlying inherited disorders of the endocrine system; endocrine control mechanisms; effects of infection and physical and mental stress on nutrient requirements and nutritional status; dietary and hormonal factors influencing protein synthesis; effects of amino acid imbalances; environmental factors influencing endocrine rhythms; protein digestion and biological availability of amino acids in foods; enzyme synthesis

and turnover in tissues; utilization in metabolism of synthetic compounds as energy sources; functions of vitamin A in the metabolism of amino acids and related compounds; electron transport and energy availability in endocrine organs; protein and nucleic acid synthesis and turnover in endocrine tissues and their control; the role of diet in the development of dental caries; biological activities of fatty acids; effects of nutritional and endocrine variations on the activities of tissue enzymes; congenital defects due to vitamin deficiencies; and nutrient requirements and food for space exploration.

A program of training in nutritional biochemistry is offered to those graduate students who want to acquire knowledge and research experience in physiological chemistry and biochemistry as it applies to nutritional problems. To this end, several advanced subjects in nutritional biochemistry have been instituted. The staff of the Department also carry out research into the regulation of protein synthesis in mammals by nutritional and hormonal factors, into vitamin and amino acid metabolism and function, into the metabolism of sulfur amino acids and into the nutrition of newborn mammals. There is a close relationship to modern biological studies, the knowledge gained being in the area of the effect of the environment, and especially the nutritional environment, on the functioning of the whole organism.

#### FOOD SCIENCE

Research in food toxicology, food chemistry, and flavor chemistry is concerned with the occurrence of toxic substances in foods, composition of foods, changes in food composition due to chemical reactions, and with components contributing to the organoleptic properties (flavor) of foods. Current research projects include isolation, identification, and biosynthesis of fat soluble toxic compounds, and toxic compounds produced by molds; biochemical and physiological effects of other potential toxic substances found in foods; isolation and identification of the components contributing to food flavor; mechanism and kinetics of chemical reactions occurring in foods, and factors affecting food acceptability.

Food microbiology, food processing and food engineering deal with the establishment of scientific principles and engineering practices for the processing, storage, distribution and use of foods and with procedures for maintaining or improving their acceptability and nutritive value.

Current research projects include effects of ionizing radiation on foods and micro-organisms; engineering properties of food materials and their effect on process design; heat and mass transfer factors in food processing and storage; colloidal and surface phenomena in food processing; ecological factors in the growth of pathogenic micro-organisms; factors causing deterioration of processed foods; and viability and mutation of micro-organisms under various environmental conditions, including those of outer space.

#### BIOCHEMICAL ENGINEERING

A program in biochemical engineering is offered leading to the Master of Science and doctoral degrees. In this program integration of studies in biological sciences with engineering is emphasized. Particular attention is directed toward industrial microbiology and fermentation processes. Research projects in biochemical engineering include: continuous culture of micro-organisms; dynamics of microbial growth; microbiology of mixed cultures and multiple substrate utilization; recovery of metabolites from fermentation broths; ultrafiltration and reverse osmosis for recovery of biological substances; mass transfer in fermentation vessels; microbiology and fermentation technology in single-cell protein production; and biosynthesis of secondary metabolites.

#### SPECIAL PROGRAMS

##### *Food Toxicology*

A program of training in food toxicology is offered for degree candidates in either nutritional biochemistry and metabolism or in food science and technology. This research area is concerned with the origin, occurrence and potential health hazards of toxic substances in foods. Of major interest are contaminants entering the food chain accidentally, such as microbial toxins, residues of materials (pesticides, preservatives, etc.) used in food production or toxic components of foodstuffs not previously used for human consumption. Research areas include isolation and chemical characterization of toxic compounds; biochemical effects of toxic substances in animal tissues; effects of chemical carcinogens on nucleic acid metabolism; chemical carcinogenesis; and development of new methods for toxicologic investigations.

##### *Clinical Nutrition and Metabolism*

Persons who hold the M.D. or equivalent degree from an acceptable medical school and who have completed at least one year of internship

or equivalent postdoctoral training may apply for admission to the Graduate School as candidates for the degree of Master of Science in Nutritional Biochemistry and Metabolism or Doctor of Philosophy. Such individuals will be required to present credentials indicating a basic science background equivalent to those described for holders of baccalaureate degrees. Provision may be made for making up minor academic deficiencies after admittance.

The Department administers a clinical research center for metabolic studies on both hospitalized patients and ambulatory subjects.

#### *Oral Science*

Research in disorders of the teeth and soft tissues of the mouth requires a thorough knowledge of the basic sciences, including the use of special techniques and instruments. The program in oral science in the Department, supported by a grant from the National Institute of Dental Research, is designed to prepare graduate students, postdoctoral dental investigators, and others for research careers in oral science. It is expected that at the end of the training program such students will have completed requirements for the Ph.D. or Sc.D.

#### *Veterinary Pathology and Nutritional Biochemistry and Metabolism*

A program is offered for veterinary graduates wishing to obtain a doctorate based on the study of animal pathology and nutritional biochemistry and metabolism. This program satisfies a part of the requirements for the Board examinations of the American College of Veterinary Pathology. Special fellowships are available.

#### *Experimental Medicine*

The Unit of Experimental Medicine is concerned in teaching and research related to human disease, especially endocrinology and metabolism. Investigations in progress involve studies in hormone action at the cellular level and the nature of metabolic disturbances which are found in, or result in human disease. The members of the Unit participate in the activities of the Clinical Research Center where patients with endocrine and metabolic disease are received for intensive investigation. Postdoctoral Fellows are received for intensive training in the application of scientific disciplines to disease problems. Members of the Unit also receive graduate students for training in scientific disciplines related to medical science and for disease oriented research.

#### *Food Science for Veterinarians*

Veterinarians have long been concerned with maintenance of food safety for both civilian and military purposes. Recognizing the need for training veterinarians in food science and technology for the armed forces and for civilian work throughout the world, the Department has established a program of study leading to the degree of Master of Science in Food Science and Technology.

#### **COOPERATIVE PROGRAM WITH THE INSTITUTE OF NUTRITION OF CENTRAL AMERICA AND PANAMA**

Under a cooperative program with the Institute of Nutrition of Central America and Panama, provision is made for a limited number of qualified students to do their thesis research while in residence in Guatemala. This program offers students a unique opportunity to study the serious nutritional and food problems characteristic of many technically underdeveloped areas of the world.

Physicians and dentists who are candidates for a degree ordinarily will be required to take the subject CLINICAL AND PUBLIC HEALTH NUTRITION, which is given in Guatemala during the summer term.

#### *Entrance Requirements for Graduate Study*

The general requirements for admission to the Graduate School are given in Section 3 of this Catalogue. The Department modifies the Institute requirements for graduate study to one year each of calculus and physics.

To qualify for graduate study in the Department of Nutrition and Food Science, a student should have a Bachelor's degree with a major in nutrition, food science, food technology, chemistry, biology, or chemical engineering or in one of the medical, agricultural or other physical sciences with a strong background in chemistry; or an M.D., D.D.S., D.M.D., or D.V.M. degree. He should have a superior record in his undergraduate work. Basic subjects in calculus and physics and in analytical, organic, and physical chemistry are required for qualification. Students with minor deficiencies may be admitted with the understanding that such deficiencies will be made up during the first year of graduate study.

#### *The Graduate Degrees*

#### **MASTER OF SCIENCE IN NUTRITIONAL BIOCHEMISTRY AND METABOLISM; MASTER OF SCIENCE IN FOOD SCIENCE AND TECHNOLOGY**

Students who have a Bachelor of Science degree

in Life Sciences at M.I.T. or equivalent training may attain a Master of Science degree in Nutritional Biochemistry and Metabolism or in Food Science and Technology in one year. The general requirements for the Master of Science degree are set forth in Section 3. A thesis based on original research directed by a faculty member is required of all candidates for this degree.

For the degree of Master of Science in Nutritional Biochemistry and Metabolism, the following graduate subjects are strongly recommended:

TECHNIQUES IN FOOD AND NUTRITION RESEARCH (20.32)  
HUMAN NUTRITION (20.36)  
SEMINAR IN NUTRITION AND FOOD SCIENCE (20.61, 20.62).

For the degree of Master of Science in Food Science and Technology, the following graduate subjects are strongly recommended:

TECHNIQUES IN FOOD AND NUTRITION RESEARCH (20.32)  
FOOD MICROBIOLOGY (20.46)  
or  
ADVANCED FOOD SCIENCE (20.51)  
SEMINAR IN NUTRITION AND FOOD SCIENCE (20.61, 20.62)

Subjects in chemistry, biochemistry, physics, mathematics, or chemical engineering are recommended according to each individual case.

#### MASTER OF SCIENCE IN BIOCHEMICAL ENGINEERING

For the Master of Science in Biochemical Engineering, greater emphasis is placed on electives in biochemistry, microbiology, chemistry of micro-organisms, chemical engineering, or industrial management, again depending on the individual student's interests.

#### DOCTOR OF PHILOSOPHY OR DOCTOR OF SCIENCE DOCTORAL PROGRAMS IN NUTRITIONAL BIOCHEMISTRY AND METABOLISM OR FOOD SCIENCE AND TECHNOLOGY

The choice of subjects in these programs depends on each student's background, his aptitudes, and his future plans. Opportunities are provided for advanced study and research in the various fields of specialization described above. The Department Committee on Graduate Students assists with the planning of programs.

Although the language requirement is no longer an Institute requirement, students should consult the departmental Graduate Registration Officer concerning the departmental ruling.

Students are expected to prepare themselves for comprehensive written and oral examinations within three years. The examination is designed to test the student's knowledge of the fundamentals of his field of specialization and

his ability to utilize his knowledge of the basic sciences in solving modern problems in nutrition, food science, and food technology.

A thesis based on original research is required of all candidates for the Doctor of Philosophy and Doctor of Science degrees.

The time required for the Doctor of Philosophy or Doctor of Science degree will vary with the individual. A superior candidate with undergraduate training equivalent to that given at M.I.T. can complete the Doctor of Philosophy or Doctor of Science degree in three and one-half years of full-time work.

#### DOCTORAL PROGRAMS IN BIOCHEMICAL ENGINEERING

No rigid sequence of graduate subjects is specified in this program. Advanced studies are recommended in the fields of biochemistry, microbiology, enzymology, and chemical engineering, coordinated with studies of problems in the modern fermentation industry. Programs must be approved by an interdepartmental committee which includes representatives from the Departments of Nutrition and Food Science; Biology; and Chemical Engineering. Doctoral examinations, which are prepared and conducted by this committee, follow the pattern described above for nutrition, food science and technology and include a general written and an oral examination.

#### Fellowships and Assistantships

Students who are considering graduate study in the Department of Nutrition and Food Science are encouraged to apply for assistantships. Funds are available to support qualified graduate students as research assistants throughout their graduate careers. Many of the available research assistantships are supported by research grants obtained by members of the faculty for work on specific projects of interest to them.

A number of fellowships are available for postdoctoral study in either nutrition or food science. Fellowships are also available for American citizens through the Public Health Service Training Grants Program in the fields of nutrition, nutritional pathology, food toxicology, food science and technology, and biochemical engineering.

Applicants wishing to be considered for assistantships or fellowships should so indicate in a letter to the Head of the Department which may be included with the completed application. The letter should indicate clearly the applicant's objectives in undertaking graduate study.

## *Department of Physics*

The progress of physics during the first half of the twentieth century has been unprecedented in the history of science. The great advances of quantum theory and the theory of relativity have enabled physics to move far beyond the conventional areas of mechanics, sound, heat, light, electricity, and magnetism; these advances have led to a remarkably complete understanding of the structure of atoms, molecules, and matter in bulk, of electronics and gas discharges, and of atomic and molecular spectra and the nature of light. The discovery of radioactivity, of cosmic rays and "strange" particles, and of nuclear fission and fusion has led to an increased understanding of the atomic nucleus and its structure. The rapidly expanding field of high-energy physics provides all the excitement and challenge of the unknown and partially understood which have characterized the periods of great discoveries of physics in the past. As a result of recent work, the fundamental laws governing the nature of matter and energy are partly understood, and great progress in these matters is bound to be made in the foreseeable future.

Along with this remarkable advance in basic knowledge has come, with unprecedented speed, a widespread application of new principles and methods to practical problems in a variety of fields. New methods of electronics have revolutionized communications and instrumentation and have led to new high-speed digital computers, which find ever widening realms of applicability. Relatively old fields such as fluid dynamics have become revitalized. Physical tools acquired from researches in X-ray, electron, and neutron diffraction, electron microscopy, and modern optical spectroscopy have opened entirely new experimental approaches to problems in chemistry, metallurgy, and biology, as well as in technology as a whole. Applied nuclear physics, with its use of artificial radioactive tracers, plays a similar role in a multitude of scientific and technological disciplines. The day has passed when physics, or any branch of it, can be considered as merely of academic interest. The broad knowledge of physical principles and methods prepares a man uniquely

and powerfully to tackle new problems of industry and modern technology.

The Department of Physics is aware of the vital importance of maintaining an active research program of the highest quality in the pursuit of fundamental knowledge. Excellent research facilities are available, additional facilities are being developed, and extensive research programs are carried on in practically every field of active interest. The facilities of these research programs are available to students in the Department of Physics.

In the fields of nuclear and elementary particle physics, there are available electro-nuclear machines capable of producing high-energy particles. These include a cyclotron, electrostatic generators and a linear accelerator. A major facility, the Cambridge Electron Accelerator, is operated under the joint auspices of Harvard and M.I.T. In addition to the research centered around these machines, there is active research in nuclear physics using, among others, the techniques of atomic beams and nuclear magnetic resonance, and there is an active program in applied radioactivity.

While M.I.T. has no astrophysics or astronomy departments as such, active research in these fields is being carried out in the Departments of Physics, Mathematics, Earth and Planetary Sciences, and Electrical Engineering. Facilities and staff in one or more of these departments are available for research in theoretical astrophysics, radio astronomy, and theoretical and experimental studies of the interplanetary and interstellar medium. Several of these investigations have made use of earth satellites and deep space probes. Cosmic rays are studied both for their astrophysical implications and as a source of very high-energy particles. In addition to the facilities in Cambridge, M.I.T. now has apparatus operating in Bolivia and New Mexico.

A large and active program in atomic, molecular, plasma, and solid-state physics provides a student with unique opportunities for studies in these fields. Equipment is available for spectroscopic studies at radio, microwave, infrared and optical frequencies. Currently available are

# Science

DEPARTMENT OF PHYSICS

facilities for the production of low temperatures, high pressures, and magnetic fields up to 100,000 gauss. A magnet capable of producing a steady magnetic field of 250,000 gauss is available as one of the facilities of the Francis Bitter National Magnet Laboratory. Facilities for the study of matter using X-ray and neutron diffraction techniques are at hand. The 5,000 kw M.I.T. Reactor is used for neutron diffraction studies.

The extensive facilities of the Information Processing Center and of the Multiple Access Computer (Project MAC) are available for research that involves the use of high-speed computation.

Closely integrated with the experimental work, using the equipment mentioned, there are active groups studying nuclear, elementary particle, field, atomic, molecular, and solid-state theory.

Much of the research described above is carried out as part of the work of various interdepartmental laboratories, including the Laboratory for Nuclear Science, Research Laboratory of Electronics, Spectroscopy Laboratory, Center for Materials Science and Engineering, Center for Space Research, the Center for Theoretical Physics, and the Education Research Center. These facilities provide close relationships among the research activities of a number of M.I.T. departments and give students the opportunity for contact with research carried out in disciplines other than physics.

## THE UNDERGRADUATE CURRICULUM

### *Physics (Course VIII)*

The undergraduate curriculum in physics offers students the opportunity of acquiring basic competence in the fundamentals of both experimental and theoretical physics. The offerings are of sufficient depth and breadth so that the Course VIII graduate is well equipped either to build a career in the field of applied physics in industry or to enter a graduate program in preparation for more advanced professional work. The central core of requirements for the Bachelor's degree, as listed in the subsequent tabulation of departmentally prescribed subjects and elective subjects, is designed not only to accomplish the foregoing objective but also to allow each student to select a considerable variety of subjects and to proceed at the pace best suited to his individual desires and capabilities.

The curriculum for the first year is described on pages 47-50.

In the second year it is suggested that the student take **INTRODUCTORY NETWORK THEORY (6.01)** or **INTRODUCTION TO ELECTRONICS (6.14T)** in the second term in order to acquire a familiarity with and a knowledge of some topics in electrical engineering. Adequate elective time is made available in the second year and students may wish to take a mathematics subject beyond 18.034 at this time.

The departmentally prescribed subjects 8.05, 8.13, and 8.14 are normally taken in the third year and this is an appropriate time to take some of the restricted elective subjects. It is usual to start the theoretical physics sequence with 8.06 in the second term of the third year. Each student is urged to explore with his Faculty Counselor various possibilities of electing those subjects which are best suited to his individual needs at this stage of his studies.

In the fourth year the theoretical sequence is then continued with 8.07 and completed with 8.08. A relatively large amount of elective time thus becomes available in this year and can be used effectively in a wide variety of ways. **EXPERIMENTAL PHYSICS (8.15)** is designed to enable the student to come face to face with the challenge of exploring a problem in experimental physics in the same spirit in which research is done by the professional physicist.

In the specific choice of a curriculum for Course VIII, each student should keep in mind the following essential pattern of subjects falling into two major categories:

1. An orderly sequence of laboratory subjects culminating in 8.15 to enable him to obtain the competence in experimental work which he needs to embark successfully on his future professional career.
2. A corresponding sequence of lecture (and recitation) subjects. In this sequence the theoretical subjects 8.06, 8.07 and 8.08 are designed to recapitulate and organize the essentials of theoretical physics and also to provide a solid springboard for much of the student's future education in physics.

The Course leads to the degree of Bachelor of Science in Physics. The curriculum requirements for the degree are given below.

<b>GENERAL INSTITUTE REQUIREMENTS</b> (see page 47)	<i>Total units</i>
Specific science and humanities and social science subjects.	<b>132<sup>1</sup></b>

The Science Distribution Requirement will be satisfied by 8.03 and 18.034, which are required in the Departmental Program, plus appropriate subjects<sup>2</sup> (see page 50) totaling

12

The subject 8.13, which is required in the Departmental Program, appears on the list of Laboratory Subjects (see page 51) and can be used to satisfy the Laboratory Requirement.

**DEPARTMENTAL PROGRAM****Required Subjects**

18.034	DIFFERENTIAL EQUATIONS	3	0	9
8.03	PHYSICS III	5	0	7
8.04	PRINCIPLES OF QUANTUM PHYSICS	5	0	7
8.05	PHYSICS OF ATOMS AND MOLECULES	4	0	8
8.13	EXPERIMENTAL ATOMIC PHYSICS I	0	6	6
8.14	EXPERIMENTAL ATOMIC PHYSICS II	0	6	6
8.15	EXPERIMENTAL PHYSICS	2	0	2
	<sup>3</sup> THESIS			12

88

**Restricted Electives**

Two subjects given by the Department of Mathematics beyond 18.034 24

Two subjects given by the Department of Physics in addition to those listed above<sup>4</sup> 24

48

**Unrestricted Electives<sup>5</sup>**

80

Total units required for the S.B. degree 360

<sup>1</sup> The requirement for Classes '70, '71, and '72 is 128 units, the Unrestricted Elective units being increased by 4.

<sup>2</sup> Students may find it advantageous to elect 6.01 INTRODUCTORY NETWORK THEORY (4-0-8) or 6.14T INTRODUCTION TO ELECTRONICS (4-2-6) in the second term of the second year. This would complete the Science Distribution Requirement.

<sup>3</sup> A thesis of 12 units is required. Not more than 30 units of thesis credit may be included in the minimum of 360 units required for the S.B. degree.

<sup>4</sup> Students planning to do graduate work in physics would normally take the theoretical sequence 8.06, 8.07 and 8.08.

<sup>5</sup> Schedules of students in Course VIII may always be arranged to leave available 12 units of unrestricted elective in the second year.

**GRADUATE STUDY IN PHYSICS**

The Department of Physics offers graduate work leading to the degrees of Master of Science in Physics, Doctor of Philosophy, and Doctor of Science. No stated curriculum of subjects of instruction is required for any of these degrees; instead, individual curricula are chosen in consultation with the Registration Officer, in accordance with certain broad principles.

Subjects of study include work in almost all of the experimental fields described in the paragraphs above, and in the various branches of theoretical physics as well. Graduate students are expected to gain real familiarity with several of the branches of physics, not merely with one

specialty. They will be well prepared for either academic work or industrial research, since the training includes a broad and thorough understanding of both the fundamentals of physics and its advanced applications.

A number of assistantships are available each year for graduate students. The duties of these assistants involve both the teaching and research activities of the Department. Application forms and further information may be obtained from the Graduate Registration Officer, Department of Physics.

**Entrance Requirements for Graduate Study**

The general requirements are those given in Section 3 of this Catalogue. Specifically, a student intending to pursue graduate work in physics should have as a background the equivalent of the S.B. requirements for Course VIII, but some deficiencies may be removed while the student is engaged in graduate work.

**The Graduate Degrees**

The general requirements for graduate degrees are set forth in Section 3.

**MASTER OF SCIENCE IN PHYSICS**

For the Master of Science degree in Physics the requirements are the General Institute Requirements for this degree as listed on page 47 of this Catalogue. The Department of Physics has no language requirement for this degree.

**DOCTOR OF PHILOSOPHY AND DOCTOR OF SCIENCE**

A student for the degree of Doctor of Philosophy or of Doctor of Science is expected to take graduate subjects to prepare himself for the General Examination, but there are no stated required subjects. A reading knowledge of French, German, or Russian, or such other language as the Department may approve, must be demonstrated.

## ***Joint Doctoral Program in Oceanography with the Woods Hole Oceanographic Institution***

The Woods Hole Oceanographic Institution and the Departments of Earth and Planetary Sciences and of Meteorology offer a joint program of education and research in oceanography that leads to the degree of Doctor of Philosophy or Doctor of Science, awarded jointly by the two institutions. The program is administered by a committee drawn from the faculty and staff of the two institutions. The general requirements for the degrees are the same as those for the M.I.T. doctorates, given in Section 3. Students in this program may choose to specialize in marine geophysics, marine geology, marine chemistry or physical oceanography. A student will normally spend his first graduate year at M.I.T., his second year of course work at either or both institutions and do his thesis research at either institution depending on his research interests and the location of the appropriate facilities. The Woods Hole Oceanographic Institution operates a fleet of research ships and aircraft, has extensive laboratory facilities and a research staff active in all areas of oceanography. Extensive resources for advanced study and research in oceanography are available at M.I.T. A modest marine facility is maintained on Boston Harbor consisting of dock space, a staging area and a small research boat. These facilities are a useful supplement to the more complete resources at Woods Hole; they provide ready access to local ocean areas for students at M.I.T.

### ***Entrance Requirements for the Joint Program***

Oceanography is not a separate scientific discipline but is a field in which the basic sciences and the methods of other earth sciences are used to explore the scientific problems of the waters and the floors of the ocean basins. All applicants must have a sound preparation in physics and the concomitant mathematics. Students specializing in marine geology or marine chemistry must have undergraduate preparation in geology and chemistry. Some undergraduate preparation in fluid mechanics or dynamic meteorology will prove advantageous to students interested in water motions. Such students are advised to take mathematics through advanced calculus. No previous academic work in oceanography is required.

### **THE GRADUATE PROGRAM**

Subjects in oceanography are offered by the Departments of Meteorology and of Earth and Planetary Sciences and by the Woods Hole Oceanographic Institution. These subjects are described in the Description of Subjects section of this Catalogue under Course XII, Earth and Planetary Sciences, and Course XIX, Meteorology. In addition several other M.I.T. departments offer subjects in the marine sciences or in areas basic to oceanography. Each student in the program will have an advisor or advisors who will help him to plan an academic program that is adapted to his interests. The program of academic subjects occupies the first two years of graduate study and serves to prepare the student for the General Examination. As a part of the General Examination, each student is required to submit and defend a thesis proposal.

### ***The Graduate Degrees***

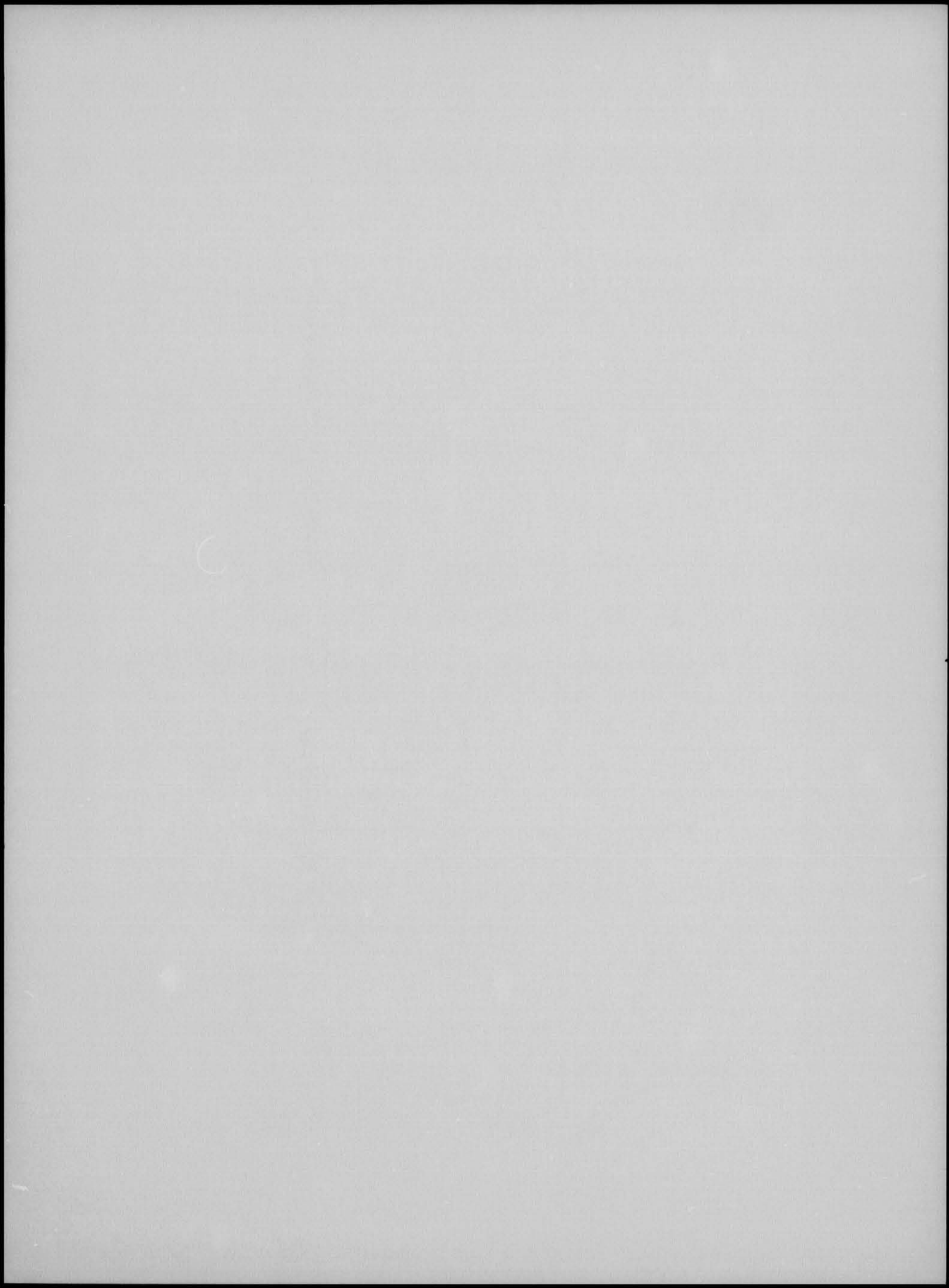
The joint program leads to the degree of Doctor of Philosophy or Doctor of Science. The degree of Master of Science in Oceanography is offered by the Department of Earth and Planetary Sciences and by the Department of Meteorology. Further information on this degree will be found on the pages devoted to these departments.

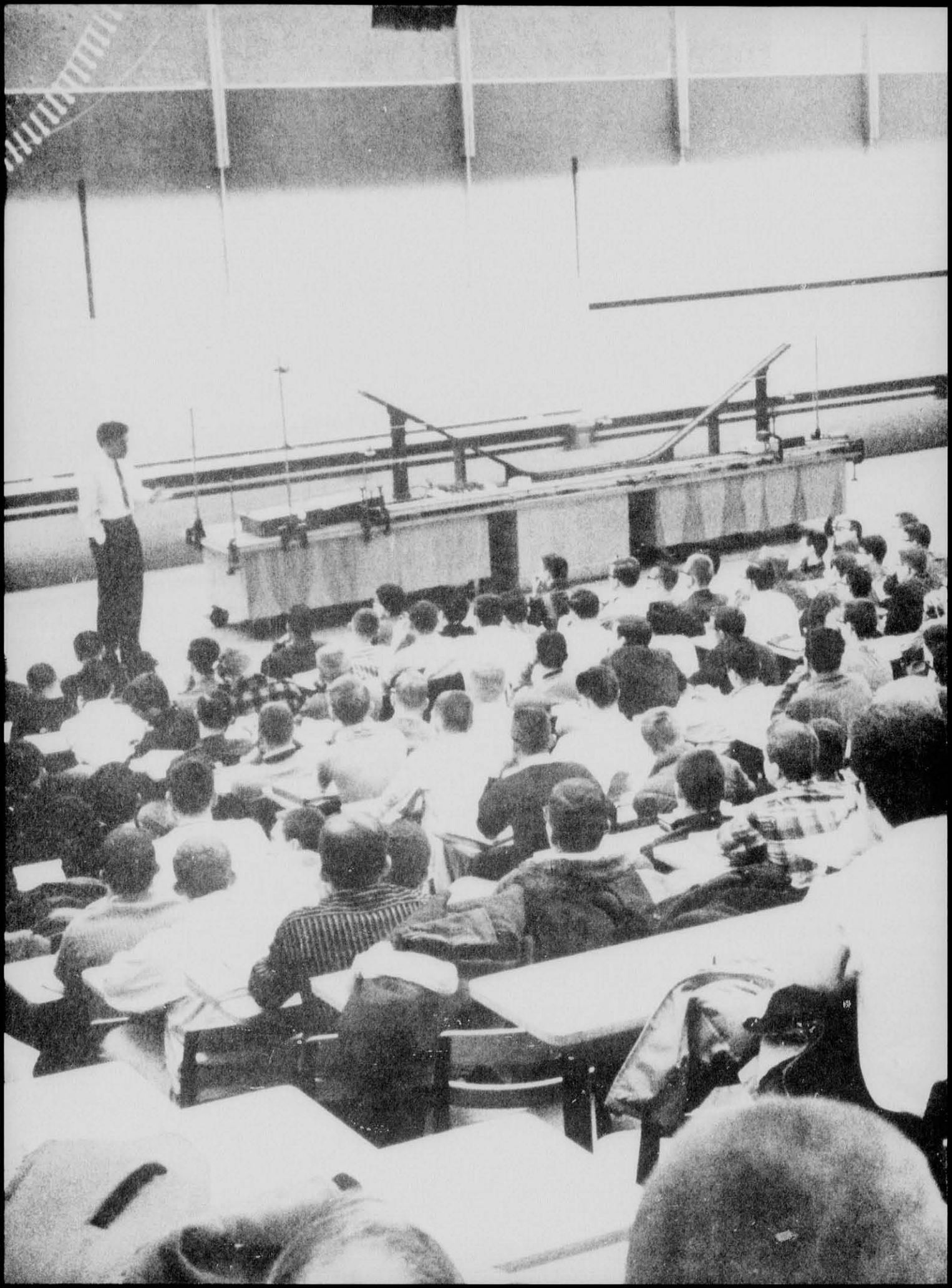
### ***Assistantships and Fellowships***

A limited number of fellowships and graduate assistantships is available on a competitive basis. Further information and applications may be obtained from the Heads of the Departments of Meteorology and of Earth and Planetary Sciences and from the Dean of Graduate Studies of the Woods Hole Oceanographic Institution.

### ***Application Procedures***

Application for admission to the joint program should be made on the M.I.T. Graduate Application form, copies of which may be obtained from the Director of Admissions at M.I.T. or from the Woods Hole Oceanographic Institution. Requests for further information on the joint program may be addressed to the Head of the Department of Earth and Planetary Sciences, the Head of the Department of Meteorology or the Dean of Graduate Studies of the Woods Hole Oceanographic Institution.





## DESCRIPTIONS OF SUBJECTS

The subjects and descriptions given in this Section are subject to change. The final list of subjects to be given in 1969-70 will be published with the class schedules prior to the beginning of each term.

"T" at the end of a subject number indicates that (1) a change has been made in the content or units of the subject or (2) the number was previously assigned to a different subject.

"J" at the end of a subject number indicates that the subject is a joint offering of more than one department.

"(A)" following the name of a subject indicates that it is an approved subject for a graduate degree.

"(R)" following the name of a subject indicates that it is restricted to special groups because of content; all subjects open only to special groups are so noted at the end of the description of the subject.

The information given below the number and name of the subject is as follows:

1. The number(s) of prerequisite subjects, if any. Numbers in italics indicate subjects which may be taken simultaneously with the subject described. Prerequisites may be waived by the instructor in charge, for particularly well qualified students.
2. The year classification (and term in which the subject is normally scheduled). "U" is an undergraduate subject; "G" is a subject given primarily for graduate students.
3. The time distribution of the subject, showing in sequence the units allotted to: recitation and lecture; laboratory, design, or field work; and preparation. Each unit represents 15 hours of work. The total unit credit for a subject is obtained by adding together all the units shown. One unit of recitation or lecture credit, and two units of laboratory or design credit, are each equivalent to one semester hour.

"Arr." indicates that time units are specially arranged.

4. The name of the instructor(s) in charge, when known at press time.

# Descriptions

CIVIL ENGINEERING

## 1.

### Civil Engineering

#### 1.00 Information Systems

Prereq.: —  
Year: U (1, 2)

3-3-6

Introduction to computer-based systems for the acquisition, processing, storage, retrieval, display, and transmission of engineering information. Basic principles of programming systems and languages. Man-machine communications, input/output design, organization of computer systems. Introduction to the design and applications of problem-oriented languages and integrated systems. Real-time systems, computer-aided design, graphical data processing, and the role of information systems in engineering organizations. Extensive laboratory experience in computer programming. (Limited enrollment.)

Roos

#### 1.01 Engineering Mechanics

Prereq.: 8.01, 18.02  
Year: U (1)

4-0-8

Static behavior of rigid and deformable bodies with primary emphasis on deformable systems. Equilibrium conditions for a rigid body. Statical determinacy and indeterminacy. Force analysis of statically determinant systems. Introduction to the analysis of deformable bodies. Application to systems involving only uniaxial deformation. Analysis of stress and strain at a point. Discussion of stress-strain relations. Stresses and deflections of beams due to bending. Analysis of statically indeterminate beams. Introduction to elastic stability.

Connor

#### 1.02 Engineering Materials

Prereq.: 8.01  
Year: U (1, 2)

3-3-6

Principles underlying the structure-properties interaction in materials important to civil engineers. Topics including atomic arrangements in crystalline and non-crystalline phases; thermodynamics of phase relationships and structural change; elasticity, microplasticity, viscoelasticity, and fracture; corrosion. Application of principles to structural metals, cementitious materials, structural ceramics, wood, asphalt, and polymers. Mechanical properties of composite materials, including Portland cement concrete, asphalt-aggregate mixtures, and reinforced plastics. Laboratory work on the common techniques used in the study of microstructure and in the determination of mechanical properties. (Fall term — recommended for Course IV students. Spring term — recommended for Course I students.)

Jones, Moavenzadeh

#### 1.03 Engineering Analysis

Prereq.: 1.01, 18.034

Year: U (1)

4-0-8

Mathematical formulation of engineering problems, solution and physical interpretation of results. Applications of ordinary differential equations in dynamics. Equations of motion for rigid bodies via vectors, Lagrange's equations, constraints and degrees of freedom. Free and forced vibrations, damping, superposition integral, unit impulse function, linear systems. Perturbation analysis of non-linear ordinary differential equations. Boundary value problems in structural theory with eigenfunctions introduced through vibration and buckling of beams and columns. Fourier series, Bessel functions, and an introduction to partial differential equations by separation of variables. Gelhar

#### 1.04 Structural Analysis and Design I

Prereq.: 1.01

Year: U (1)

3-3-6

The analysis of determinate and indeterminate structural systems and the design of structural elements. Particular emphasis on indeterminate systems and on the relation between the behavior of a member and the criteria pertinent to its rational design. Basic force-deformation relationships for member elements. Discussion of equilibrium, compatibility, and stress-strain equations. The force and displacement methods for solution, including superposition, slope deflection, and moment distribution. Formulation of the matrix equations for pin-connected trusses. Solution techniques using the stiffness method. Techniques for the approximate analysis of large framed structures. Contemporary design criteria and practice for the design of steel elements, trusses, and rigid frames. (See also 1.51)

Biggs

#### 1.05 Fluid Dynamics

Prereq.: 1.01, 1.03

Year: U (1)

3-3-6

The fundamental principles and methods of fluid dynamics for Newtonian compressible and incompressible fluids. Fluid continua and their properties; kinematics and rotating coordinate systems. Conservation equations for mass, momentum, and energy. Stress-strain relations, leading to the development of the Navier-Stokes equations for three-dimensional laminar fluid motions. Introduction to stream functions and velocity potentials. Dynamic similitude and basic concepts of creeping motions, flow in porous media, boundary layers, turbulence, and turbulent shear stresses. Flow and energy dissipation in uniform conduits. Design of pipe line systems. Lectures supplemented by laboratory experiments and projects.

Harleman

#### 1.06 Soil Mechanics

Prereq.: 1.01

Year: U (2)

3-3-6

The fundamental principles of soil behavior, with applications to retaining walls, foundations, and slope stability problems. Composition and structure of soils; phase relationships and unit weights; interactions between mineral particles and water; classification systems; transmission of forces between mineral particles. Influence of pore pressure on strength and compressibility; effective stress; effect of flowing water on stability. Drained and undrained strength. Theory of consolidation. Principles of limit analysis for soil masses. Methods for estimating soil deformations. Project-type laboratory exercises emphasizing applications of principles to practical problems.

Bromwell

#### 1.07 Analysis of Uncertainty

Prereq.: 18.034

Year: U (2)

3-1-5

Introduction to probabilistic methods in civil engineering. Formulation and analysis of stochastic models of

engineering systems and their environment, including estimation of the models' parameters and measures of the models' quality. Elementary notions of probability including events, random variables, expectation, and derived distributions. Common distributions as models of physical phenomena. Simple time-dependent processes. Statistical treatment of experimental data. Elementary theory of decision making under uncertainty, including classical hypothesis testing. Examples and problems drawn from practice and literature in structures, transportation, materials, water resources, and soils. *Cornell*

### 1.08 Geotechnology

Prereq.: —

Year: U (1)

3-3-6

Basic principles of physical geology, with emphasis on topics pertinent to civil engineering. Minerals. Igneous, metamorphic and sedimentary rocks. Alluvial, glacial, eolian, lacustrine, marine, and colluvial sediments. Weathering. Rock defects. Earthquakes. Airphotos and geologic maps. Field trips. *Hirschfeld*

### 1.09 Civil Engineering

Prereq.: 1.04, 1.05, 1.06, 1.07, 1.08

Year: U (2)

0-6-12

Fourth-year subject designed for permitting application of knowledge and methods from all undergraduate studies. Undertaking of a broadly based civil engineering project by students, typically working in two teams. Past projects: a parking garage, an offshore airport in outer Boston, a sports stadium for Boston. Lectures on organization of engineering firms and on the background for the pre-selected project during the early weeks of the term. Proposals for the specific terms of the project, followed by the teams' working with only general guidance from the faculty. Preparation of a written report and an oral presentation by each team. (Primarily for fourth-year undergraduates in Course 1; others by permission of instructor.) *Harleman*

### 1.10 Civil Engineering Laboratory

Prereq.: —

Year: U (1, 2)

0-6-6

A program designed to introduce the student to the experimental solution of problems in the major disciplines of civil engineering. Work by students on three experimental projects, each in a different laboratory of the Department. (Primarily for first- and second-year undergraduates or third-year undergraduates in Course 1; others by permission of instructor.) *Ippen*

### 1.131 Applications of Multivariate Statistical Analysis (A)

Prereq.: 1.07 or 6.28 or 13.60 or 14.371 or 18.10

Year: G (1)

3-0-6

Presentation of several statistical techniques useful in the analysis of engineering system performance. Emphasis on regression, analysis of variance, and the design of experiments. Approximate coverage: two-variable, least-squares regression; significance tests (review of chi-square, t, F, and correlation coefficient); normality tests on residuals; transformations of data; types of models; interactions; experimental designs and their analysis (e.g., factorial, fractional factorial, hierarchical, randomized block, and Latin square); parameter estimation and interpretation of results; multivariate regression and correlation. Brief discussion of discriminant analysis and principal components. Examples drawn from a wide range of engineering applications. *Godfrey, Nelson*

### 1.141 Linear Methods of Engineering Analysis

Prereq.: 18.034

Year: G (1)

3-0-6

Review of linear algebra. Vector space. Linear dependence. Matrix notation and operations. Solvability

of linear algebraic equations. Quadratic forms. Characteristic value problems. Computational techniques for linear algebraic equations. Computational techniques for discrete characteristic value problems. Linear inequalities and convex sets. Introduction to linear programming and the simplex method. Formulation of linear models in engineering. *Reinschmidt*

### 1.142 Numerical Methods of Engineering Analysis (A)

Prereq.: 18.034

Year: G (2)

3-0-6

Focus on formulation and numerical solution of problems arising in civil engineering, including topics from fluid mechanics, structural dynamics and soil mechanics. Interpolation, integration, finite difference solutions to initial and boundary value problems, and an introduction to variational approaches for finite element methods. Emphasis on methods suitable for machine calculation. Ability to program a computer desirable, but not necessary. *Christian*

### 1.143 Mathematical Optimization Techniques I (A)

Prereq.: 1.00, 1.141

Year: G (1, 2)

3-0-6

Systematic survey of theory and applications of mathematical optimization techniques to problems encountered in the analysis, synthesis, and operation of engineering systems. Solution techniques for classes of problems. Duality theory as a central approach to linear programming theory and algorithms. Primal and dual simplex, primal-dual, upper bounding techniques and post-optimality problems. Introduction to graph theory, network flow algorithms. Non-linear programming. Classical methods, quadratic programming, separable programming, direct search techniques. Computation emphasis on application and use of optimization techniques as the core of an integrated computer system for linear and non-linear programming. Experience in computer programming of optimization algorithms. *Hershendorfer*

### 1.144 Mathematical Optimization Techniques II (A)

Prereq.: 1.143

Year: G (2)

3-0-6

Continuation of 1.143. Formulation of discrete and non-linear programming models for engineering problems. Solution techniques for discrete problems: cutting plane methods, branch and bound, discrete duality theory. Solution techniques for non-linear programs: indirect and direct methods, geometric programming. Partitioning techniques for mathematical programming problems. Comprehensive study of stochastic programming problems and solution techniques (expected value problems, Dantzig's two-stage approach, chance-constrained approach, minimal variance). Dynamic programming. Computation emphasis on applications and use of an integrated computer system for discrete and non-linear programming. *Hershendorfer*

### 1.146 Elements of Systems Analysis (A)

Prereq.: 1.07, 1.141, 14.02T

Year: G (1)

3-0-6

Development of integrated procedures for the identification, definition and selection of optimal systems. Formulation of the design of complex systems as a multi-dimensional problem in resource allocation among a spectrum of technically acceptable alternatives. Classi-

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## CIVIL ENGINEERING

cal analysis techniques: production functions; marginal analysis; tradeoffs between system configurations. Special treatment of the impact of computers on the scope and techniques of engineering analysis. Mathematical programming for the identification of desirable design characteristics, the definition of least-cost mixes, and the optimization of systems with time-dependent benefits and costs. Application of risk strategies and statistical decision theory to planning under uncertainty. Modeling of system interactions through simulation and other techniques. Current use of benefit/cost and cost/effectiveness analysis in engineering practice. Detailed study of specific designs in the fields of transportation, water resources, structures, and others of interest to the students. (*Special sessions for Practicing Engineers in the Center for Advanced Engineering Study.*) de Neufville, Stafford

### 1.147 Engineering Systems Analysis (A)

Prereq.: 1.146

Year: G (2)

3-0-6

Methods for the design of large-scale systems with full recognition of the implications of the economic and social environment. Integration of the principles of systems analysis by intensive examination of proposed projects. Definition of policy objectives and their effect on engineering design and public works investment policies. Identification and measurement of benefits. Use of statistical inference for the prediction of the demand for facilities and of the differential impact of alternative designs. Analysis of demand-supply equilibrium to determine optimal tolls and to minimize costs by designing for market stability. Use of computer-aided design procedures in the search for and choice of optimal systems. (*Special sessions for Practicing Engineers in the Center for Advanced Engineering Study.*) de Neufville, Stafford

### 1.148 Decision Theories in Engineering and Planning (A)

Prereq.: —

Year: G (2)

3-0-6

Prescriptive decision theories and limitations in applying them to real engineering and planning problems. Primarily from the point of view of urban and regional planning and such engineering areas as transportation and water resource planning. Development of general concept of a problem solving process, including search, prediction, evaluation, choice and other component activities. Definitions of, and limitations on, rationality; subjective probabilities and Bayesian decision theory; relaxation of information requirements in applying Bayesian decision theory in practical situations; sequential decision models; economic analysis of systems; problems of generating alternatives; Alexander's methods for structuring the search process; hierarchical structure; economics of problem solving. Research seminar with extensive student contributions. (*Primarily for advanced students in psychology, political science, economics, planning, operations research, systems, civil engineering, or other selected areas.*) Mannheim

### 1.151 Computer Approaches to Engineering Problems

Prereq.: —

Year: G (1, 2)

3-2-4

Basic principles of man-machine communication, programming languages, and computer-based information systems. Particular emphasis on the planning and development of large-scale programs and systems for engineering and management applications. Basic internal and operating system concepts. Introduction to problem-oriented languages, integrated systems, computer organization, time sharing, computer-aided design, and the use of computers in an engineering organi-

zation. Extensive laboratory experience in computer programming and the application of information systems to engineering problems. Roessel

### 1.152 Engineering Computer Systems Design (A)

Prereq.: 1.00 or 1.151

Year: G (1)

3-2-4

Integration of engineering and computer considerations in the design of engineering computer systems. Engineering requirements on operating systems and programming languages; generation and processing of problem-oriented language; dynamic data and program structures; data management; memory management implications on application systems design; effective utilization of the Integrated Civil Engineering System (ICES). Laboratory experience with IBM System/360 assembler language and with planning and implementation of an engineering information system. (*Enrollment limited; undergraduates accepted only by permission of instructor.*) Logcher, Sussman

### 1.153 Engineering Computer System Management and Use (A)

Prereq.: 1.00 or 1.151

Year: G (2)

4-0-5

Computer system organization, multiprogramming, multiprocessing and time sharing. How to choose and configure computer equipment. Remote computer use and its impact on engineering organizations. Implications of the use of computers in engineering problem solving and the design process. Implementation and use of computers by engineering organizations — hardware, software, operational, economic and organizational considerations. Several seminars by qualified outside speakers. Roos

### 1.154 Simulation Methods (A)

Prereq.: 1.00 or 1.151 or 1.156;

1.07 or 6.28 or 6.579

Year: G (2)

3-0-6

Basic simulation methodology as applied to stochastic systems. Role of simulation in systems analysis. Comparison of various time-flow mechanisms. Use of several computer languages to program simulation models. Computer system requirements for simulation modeling. A survey of simulation applications including the study of several in depth. Random number generation and testing. Statistical aspects of simulation analysis including validation, variance reduction, experiment design, validity of results, run length considerations, model initialization, autocorrelated data. Sussman

### 1.156 Computer Systems

Prereq.: —

Year: G (1)

2-1-6

Basic components of a computer system. Computer programming, including programming languages, organization and planning of programs. Man-machine communication, time sharing remote processing. Design and use of problem-oriented languages. Role of graphical input-output. Operating systems. Dynamic memory allocation. Comparisons between computer systems. Impact of the computer on the practice of engineering and management. (*Restricted to Fellows in the Center for Advanced Engineering Study.*) Sussman

### 1.16J Special Studies in Systems Engineering (A)

(Same subject as 2.191J, 6.604J, 13.47J, 17.818J)

Prereq.: —

Year: G (2)

2-4-6

Introduction to basic techniques employed in planning and design of complex systems. Detailed design of subsystems by individual student groups with emphasis upon use of parametric design principles in arriving at suitable

tradeoffs between subsystems. Supplementing lectures covering general principles of the operational complex and subsystems by guest lecturers. The particular operational complex chosen for each term to be announced before start of the term. Students encouraged to discuss subject with staff prior to registration. (Previous projects: Group 1—An integrated urban transportation system; Group 2—A manned satellite inspection and retrieval system.) *Seifert, Baumann, Frankel, R. C. Wood*

### 1.18 Building Design Systems (A)

Prereq.: 1.152

Year: G (1)

3-2-4

Application of advanced computer systems concepts to the modeling of buildings for analysis and evaluation in building design. This field includes: Survey of existing techniques for design synthesis of building systems. Problems of maintaining a computer representation of the current state of the building design. Organization of building description according to component systems. Data structures for describing building geometry. Computational algorithms for building systems evaluation. Data transfer among evaluative routines. Development of a building design data library. Role of problem-oriented languages and interactive input-output devices. Team design via multiterminal systems. *Hershendorfer*

### 1.19 Urban Systems Analysis Techniques (A)

Prereq.: —

Year: G (2)

3-0-6

Investigation of the application of information processing and systems analysis to methods of dealing with urban problems. Emphasis on the translation of general criteria into specific programs, with applications via case studies. Structuring of problems to isolate quantifiable and judgmental components. Topics selected from the following: use of computers for urban data storage and retrieval and for the application of mathematical optimization, cost-effectiveness analysis, program budgeting, and other systems analysis techniques; design of information systems for specific urban planning and design applications; problems involved in the integration of independent information systems. (Primarily for advanced graduate students with background and interests in urban problems.) *Hershendorfer*

### 1.201 Transport Systems Analysis I (A)

Prereq.: —

Year: G (1)

3-0-6

Introduction to the transport systems problem: system components, functions of transportation, demand patterns, types of transportation problems. A framework for analysis: decision makers and their options, social and economic impacts of transportation, the prediction problem, the decision problem. Transportation technology: basic physics of transportation, major technologies, the spectrum of alternative technologies. Some basic transportation problems: urban, megalopolitan transportation; transportation and economic policy. (Primarily for incoming graduate students with diverse backgrounds.) *Manheim*

### 1.202 Transport Systems Analysis II (A)

Prereq.: 1.143, 1.146, 1.201

Year: G (2)

3-0-6

Techniques for the analysis of multimode transportation systems. Demand models for freight, passenger movements. Modeling line-haul and collection-distribution systems for various modes; general models of transportation technology. Supply functions. Predicting the equilibrium of supply and demand in transportation networks: traffic assignment, optimal flow, routing and scheduling and other techniques. Predicting the impacts of transportation on the social, economic, and political

environment. Evaluation of transportation alternatives: costing; evaluating indirect and intangible impacts.

*Manheim*

### 1.203 Transport Systems Analysis III (A)

Prereq.: 1.148, 1.151, 1.202

Year: G (1)

3-0-6

The transportation planning process. Options and objectives in transportation. Typical transportation study environments: urban, regional, developing country. Search techniques: network generation, land use plan design, optimal scheduling, etc.; tradeoff analysis; capital budgeting. Evaluation and choice: utility theory and scale construction, evaluation of non-economic impacts. Uncertainty: decision theory, flexibility, evolutionary planning techniques. Information acquisition: sampling, monitoring flows, data systems. Allocation of analysis resources: hierarchical structure, critical-path, etc. Organization of the planning process: theory, practice. Interaction of analysis with the political process. Case study. Student papers. *Staff*

### 1.212 Urban Transportation Systems (A)

Prereq.: 1.201

Year: G (2)

3-0-6

Techniques for planning and programming large-scale urban transportation systems. Estimation of traffic demand and its distribution to facilities utilizing mathematical models and computer programs. Analysis and design of system components and control systems. Measures of effectiveness of alternate schemes. New urban transportation technologies. Applications to specific projects. *Staff*

### 1.221J Flight Transportation (A)

(Same subject as 15.483J, 16.751J)

Prereq.: 1.201

Year: G (1)

3-0-6

Integrated discussion covering basic concepts and operational characteristics of flight transportation systems. Methods of predicting vehicle performance, anticipating future design trends, and determining direct operating costs; airport design and functional layout; guidance and control techniques, both in terminal area and en route; communication and radar system performance. *Bone, S. Myers, R. H. Miller*

### 1.222J Flight Transportation Seminar

(Same subject as 15.484J, 16.752J)

Prereq.: —

Year: G (1)

1-0-2

Economics of airline operation, problems of financing and of domestic and international route allocation. Subject developed around seminars presented by speakers from the regulatory agencies, national and international organizations, and industry on particular phases of flight transportation. Preparatory lecture preceding each seminar. Opportunity for students to conduct studies in their area of major specialization on a particular topic covered by the subject. *Bone, S. Myers, Browne*

### 1.23 Flight Transportation Facilities (A)

Prereq.: 1.201 or 1.221J

Year: G (2)

3-0-6

Basic requirements of an airport system, including air traffic control, airfield layout, terminal functional design, parking facilities, and ground transportation. Consideration of aircraft requirements, present and future; air traffic potentials; protection of runway approaches; and influence on aircraft operation of airport environs. Development of an airport master plan; runway, taxiway,

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## CIVIL ENGINEERING

and apron layouts; parking, drainage, and lighting systems. Site planning of terminal area, including access roads, parking lots, loading areas, and terminal building space requirements. Circulation systems for passengers and cargo, airline operations, and apron activities. *Bone*

### 1.251 *Theory of Traffic Flow (A)*

*Prereq.:* 1.07 or 6.28 or 13.60 or 18.10

*Year:* G (2)

3-0-6

Integrated presentation of traffic flow theory and its applications in traffic engineering and flow control; queuing theory; and operational models of transportation system elements. The dynamics of car following and the propagation of perturbations in single-lane flow. Velocity-flowrate relationships. Velocity distributions and density oscillations on multilane roads. Techniques of data collection and analysis. Queuing models for merging and other intersection phenomena. Optimal control of traffic signals; synchronization schemes and platoon diffusion. Area-wide models of road traffic flow based on the work of Smeed and Wardrop; network design. Routing and scheduling in public transport systems; optimal terminal location in urban areas. Queuing models of passenger and freight terminal operations. Safety and reliability considerations. *Godfrey*

### 1.258 *Case Studies in Transportation Engineering (A)*

*Prereq.:* 1.201

*Year:* G (2)

3-0-6

Techniques for the planning and design of components of transportation systems. Measures of effectiveness of alternate schemes. Applications to specific projects in fields of highway, traffic control, public transit or airport engineering. *Bone*

### 1.261T *Advanced Transportation Planning I (A)*

*Prereq.:* 1.203

*Year:* G (1)

Arr.

### 1.262T *Advanced Transportation Planning II (A)*

*Prereq.:* 1.261T

*Year:* G (2)

Arr.

Integration of technical tools in concerted attack on a specific major transportation problem, such as development of a transportation plan for a U. S. metropolitan area or for a major region in a developing country. Review of transportation planning techniques and related methodologies: economic analysis, socio-economic impacts of transportation, demand models, network models, vehicle performance prediction, analysis of uncertainty, etc. Discussion of substantive issues of transportation policy, in general and in the specific problem context: goals in transportation planning, tradeoffs among technologies, technological innovations, problems of consumer preferences. Student work individually and in groups to resolve specific policy questions through technical analyses. Emphasis on the critical analysis of present transportation planning methods, on the development of improved approaches, and on the ability to adapt approaches to data limitations, political considerations, and other substantive realities. (*Primarily for advanced students in transportation. Permission of instructor required.*) *Manheim*

### 1.27 *Special Studies in Transportation Engineering (A)*

*Prereq.:* 1.201

*Year:* G (1 or 2)

Arr.

Advanced study of a topic in transportation systems selected with the approval of the instructor. *Staff*

### 1.311 *Theoretical Soil Mechanics I (A)*

*Prereq.:* 1.06

*Year:* G (1)

3-0-6

Discussion of elementary theories important in soil mechanics. Theories of elastic halfspace and elastic layers. Applications of elastic theories, especially to settlement problems. Use of limit analyses for active and passive stresses, bearing capacity, and slope stability. Theory of consolidation for one-dimensional problems and introduction to three-dimensional consolidation. Mathematics, construction and interpretation of flow nets. Introduction to finite element methods and their use. *Christian*

### 1.312 *Theoretical Soil Mechanics II (A)*

*Prereq.:* 1.311

*Year:* G (2)

3-0-6

Content variable from year to year. Such topics as advanced problems in three-dimensional consolidation; Kotter's equation; modern earth pressure theories of Brinch Hansen and Sokolovski; theories of plasticity applied to soil systems. Finite element methods in soil mechanics. (*Alternate years.*) *Christian*

### 1.321 *Soil Behavior (A)*

*Prereq.:* 1.361

*Year:* G (2)

3-0-6

Detailed study of soil properties with emphasis on methods of measuring properties in the field and laboratory and interpretation of experimental data for use in practice. Topics include: consolidation behavior of clays; basic strength principles; stress-strain behavior of saturated clays, emphasizing the influence of sampling, different types of stress systems, and environment; strength and compression of granular soils; engineering properties of compacted clays; permeability and capillarity. *Ladd*

### 1.322 *Soil Technology (A)*

*Prereq.:* 1.06

*Year:* G (1)

3-0-6

Application of physicochemical principles to an understanding of the engineering behavior of soils. Structural chemistry, clay mineralogy, chemical weathering, colloid chemistry, properties of adsorbed water, soil fabric, mineral friction. Emphasis on the use of fundamental principles in the interpretation and prediction of engineering properties such as permeability, compressibility, and shear strength. (*Not offered 1969-70.*) *Bromwell*

### 1.331 *Soil Dynamics (A)*

*Prereq.:* 1.06

*Year:* G (1)

3-0-6

Design of foundations for machinery; effects of earthquakes upon structures and earth dams, and ground motions caused by explosions. Stress-strain behavior of soil during transient and repeated loadings; relation of soil properties to wave velocity. Theory of wave propagation and dynamics of lumped systems as applied to problems in soil dynamics. *D'Appolonia*

### 1.361 *Advanced Soil Mechanics (A)*

*Prereq.:* 1.06

*Year:* G (1)

3-0-6

Consideration of the following fundamentals of soil mechanics: the nature of soil, including a description of soil particles and stress transmission between particles, effective stress concept; fluid flow and its effect on soil behavior; stress-strain behavior of soil: lateral earth stresses and earth retaining structures; earth slopes; settlement and stability analyses of foundations and earth slopes. *Ladd*

**1.362 Earth Structures (A)**

Prereq.: 1.361

Year: G (2)

3-0-6

Design of earth dams and embankments including site exploration, stability, seepage, specifications, and construction control. Field measurements of settlement, horizontal deformations, pore pressures, and seepage. Case studies. *Hirschfeld*

**1.364 Foundations (A)**

Prereq.: 1.361

Year: G (2)

3-0-6

Foundations and earth retaining structures including considerations of shallow foundations, deep foundations, and braced excavations. Subject built around case studies involving exploration, laboratory and field tests, analyses, and the measurement of field performance. *Lambe*

**1.365 Improvement of Engineering Properties of Soils (A)**

Prereq.: 1.06 or 1.361

Year: G (2)

3-0-6

Presentation and evaluation of mechanical, physical, and chemical methods for altering engineering properties of soils. Discussion of construction specifications and control. Topics: compaction, mechanical stabilization, and chemical stabilization. (*Alternate years.*) *Wissa*

**1.37 Experimental Soil Mechanics (A)**

Prereq.: 1.06

Year: G (1)

2-4-3

Laboratory determination of soil properties emphasizing experimental techniques. Topics include: classification of soils; oedometer tests with measurements of pore pressure dissipation; undrained strength of clays from vane and unconfined tests; drained and undrained shear tests with pore-pressure measurements employing triaxial, simple shear, or plane strain equipment; strength-volume change-permeability characteristics of compacted clays; special topics of interest to students, such as frost heave, capillarity, stabilization, or thixotropy. *Wissa*

**1.38 Engineering Geology (A)**

Prereq.: 1.06, 1.08

Year: G (2)

3-0-6

Geologic aspects of subsurface exploration, dams, reservoirs, foundations, slopes, tunnels and transportation systems, with emphasis on case studies. (*Alternate years.*) *Hirschfeld*

**1.381 Rock Mechanics (A)**

Prereq.: 1.06, 1.08; or 12.01T, 12.04

Year: G (2)

3-0-6

Principles of rock mechanics applicable to civil engineering. Engineering classification of rock. Field exploration. Stress distribution. State of stress in the earth's crust. Permeability, deformability, and strength of intact rock and rock masses. Introduction to applied rock mechanics—excavation, underground openings, slopes, foundations of heavy structures, rock reinforcement, field instrumentation. (*Alternate years. Not offered 1969-70.*) *Hirschfeld*

**1.39 Special Studies in Soil Engineering (A)**

Prereq.: —

Year: G (1, 2)

Arr.

For graduate students desiring further study of special topics. *Staff*

**1.40 Introduction to Electron Microscopy**

Prereq.: —

Year: U (1)

1-3-2

Introduction to electron scattering and electron optics. Emphasis on student use of electron microscope for transmission and diffraction studies. Principles of operation.

Preparation of specimens. Thin-film and replica techniques. Analysis and interpretation of micrographs and diffraction patterns. Supplementary use of optical microscopy. Application to study of structure of solid materials: metals, ceramics, glasses, polymers. Introduction to X-ray diffraction. *R. C. Jones*

**1.41 Strength of Structural Materials (A)**

Prereq.: 1.02

Year: G (1)

3-0-6

Detailed examination of strength theories applicable to structural materials. Analysis of failure criteria and phenomena: creep, yield, plastic flow, crack initiation and propagation, fracture mechanics. Effects of combined stress, loading rate, temperature, environment, radiation exposure. Ferrous and non-ferrous metals, cementitious materials, composites, timber, expanded substances, ceramics. *McGarry*

**1.42 Structural Materials (A)**

Prereq.: 1.02

Year: G (2)

3-2-4

Mechanical behavior of important materials in civil engineering structures. Principles relating composition and structure to such behavior. Emphasis upon basic factors to facilitate understanding and use of new materials and combinations. Elastic, plastic, viscoelastic, and other time-dependent types of deformation. Influence of defects and imperfections. Consideration of creep and fracture phenomena, adhesion and corrosion, composites and multiphase systems. Reference to present and anticipated materials. Laboratory primarily concerned with structure-composition-mechanical property interactions. *R. C. Jones*

**1.43 Structural Properties of Metals (A)**

Prereq.: 1.02

Year: G (1)

3-0-6

Engineering properties of structural metals. Structure, alloying, and the production of metals. Strengthening mechanisms and heat treatment. Mechanical properties of structural steels, reinforcing steels, cast and wrought iron-carbon alloys, and aluminum alloys. Forming, fabrication, and joining by welding or high-strength bolting. Design, preparation and properties of composite metals. Effect of environment on the properties of metals. Field trips to production, fabrication and heat treating facilities. *R. C. Jones*

**1.44 Cementitious Materials**

Prereq.: 1.02

Year: G (1)

3-0-6

Detailed study of cementitious materials with particular emphasis on the physical aspects of Portland cement and other hydraulic cements. Synthesis of elementary physical phenomena such as interlocking, chemical or phase changes, dimensional changes into the over-all reactions associated with binding materials. The nature of surfaces, absorption and adhesion with emphasis on the dependence of mechanical properties of the resulting microstructure. Laboratory demonstrations of surface forces, adhesion and hydration of Portland cement. Experimental techniques of investigating cementitious materials including peel tests, X-ray diffraction and electron microscopy. *Staff*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## CIVIL ENGINEERING

### 1.45 Structural Design of Pavements (A)

Prereq.: 1.02, 1.06

Year: G (1)

3-0-6

Pavement types and wheel loads. Stresses in flexible and rigid pavements. Principles of engineering design of flexible and rigid pavements for highways and airfields. Detailed study of properties of highway materials. Discussions of environmental effects. Evaluation and strengthening of existing pavements. *Moavenzadeh*

### 1.46 Portland Cement Concrete (A)

Prereq.: 1.02

Year: G (2)

3-2-4

Advanced study of Portland cement concrete. Emphasis on mechanical behavior and durability as related to composition of binders, type and quantity of aggregates, nature of hardening. Creep, fracture mechanisms, and fatigue. *Moavenzadeh*

### 1.47 Mechanics of Materials (A)

Prereq.: 1.02

Year: G (1)

3-0-6

Mechanical equation of state for engineering materials. Concepts of stress and strain. Isotropy, rate dependence, temperature effects. Elasticity, viscosity, plasticity, viscoelasticity. Applications to engineering analysis and design. *Moavenzadeh*

### 1.471 Mechanical Behavior of Plastics (A)

Prereq.: 1.02

Year: G (1)

3-2-4

Relation between chemical composition, physical structure, and mechanical behavior of plastics or synthetic high polymers. Study of types of polymers; fundamentals of viscoelastic phenomena such as creep, stress relaxation, stress rupture, mechanical damping, impact; effects of chemical composition and structure on viscoelastic and strength properties; methods of mechanical property evaluation. Influences of plastics fabrication methods. Emphasis on recent research techniques and results. Laboratory on individual project basis investigating problems related to current research. *McGarry*

### 1.472 Composite Materials (A)

Prereq.: 1.42

Year: G (2)

3-2-4

Concepts underlying formation, characteristics and behavior of plastics-based composites such as fiberglass laminates, structural sandwiches, plywood, and load-bearing adhesive joints. Typical components such as metals, glass, synthetic and natural adhesives, plastics foams, wood, paper, fabrics, and rubber. Correlation between adhesion principles and physical behavior. Methods of design, analysis, fabrication, and testing. Discussion of failure mechanisms of chemical, electrical, and mechanical types. Laboratory on individual project basis investigating problems related to current research. *McGarry*

### 1.473 Viscoelasticity (A)

Prereq.: 1.02

Year: G (2)

3-0-6

Methods of analysis of viscoelastic phenomena. Discrete element models, continuous distribution spectra. Constitutive equations for representation of viscoelastic behavior. Creep, relaxation, dynamic analyses. Principles of correspondence, interconversion, superposition. Treatment of non-linear systems. Applications to structural elements composed of metals, concrete, asphalt, soils. (*Alternate years.*) *Moavenzadeh*

### 1.48 Special Studies in Materials (A)

Prereq.: 1.42

Year: G (1, 2)

Arr.

Advanced study, research, and laboratory investigations in the field of materials engineering. Arrangement of

individual and group study of topics by the instructor in charge. Special reading assignments, consultation, and original investigations in the Materials Research Laboratory. *Staff*

### 1.51 Structural Analysis and Design

Prereq.: 1.04, 18.034

Year: U (2)

3-2-5

Matrix displacement method for member systems. Analysis of curved beams and also variable depth members. Small deflection theory of plates. Elastic and inelastic stability of columns. Dynamic behavior of simple structural systems. Design of reinforced concrete beams, columns, slabs, and framing systems. Introduction to design of prestressed concrete. *Pahl*

### 1.521 Model Laboratory for Structural Design (A)

Prereq.: 1.04

Year: G (1)

2-3-4

Lectures, assigned reading, and laboratory covering the theory and practice of model analysis to facilitate the analysis and design of structures and structural elements. Dimensional analysis, materials, fabrication, loading, instrumentation, and interpretation of results are considered. Illustration, by comprehensive laboratory problems, of the use of qualitative and quantitative models to study unusual structural behavior. *Little*

### 1.531 Special Problems in Structural Engineering (A)

Prereq.: —

Year: G (1 or 2)

Arr.

Individual study of advanced subjects under staff supervision. Arrangement of each program to suit the particular requirements of the student and interested members of the staff, subject to the approval of the instructor in charge. *Staff*

### 1.541 Behavior of Concrete Structures (A)

Prereq.: 1.51

Year: G (1)

3-0-6

Consideration of the mechanics of reinforced and prestressed concrete structural elements with emphasis on ultimate strength and time-dependent behavior. Systematic procedures for member checking and member design, with emphasis on design criteria. Detailing, formwork design, and construction procedures for *in situ* and precast reinforced and prestressed concrete. *Pahl*

### 1.542 Behavior of Metal Structures (A)

Prereq.: 1.51

Year: G (2)

3-0-6

Consideration of properties of structural metals and the behavior of metal structures, including elasto-plastic behavior, buckling, fatigue and brittle fracture phenomena. Problems of fireproofing and fabrication and erection procedures. *Little*

### 1.551 Planning of Structural Systems (A)

Prereq.: 1.51

Year: G (1)

3-0-6

Planning of a total structural system to meet given functions. The nature and range of functional requirements for structures. The nature of loadings, the relationship of deterministically vs. statistically based codes. The nature of constraints on structural arrangements brought about by fabrication and erection procedures, and the characteristics and installation procedures for other subsystems involved in the total structure. Emphasis on the conception and initial selection procedure of the structural system by case studies — both those drawn from practice, and problems contrived for student solution, over a range of structural problems including low- and high-rise buildings, long span structures, bridges, and special structures. *Little*

**1.552 The Practice of Structural Engineering (A)**

Prereq.: 1.541, 1.542, 1.551

Year: G (2)

2-3-4

Consideration of the preliminary design including structural concepts, selection of a system to engineer, and the proportioning of members and connections. Several case studies, given with lectures from practicing professionals and faculty members of the division, but presented for solution by students in groups.

R. J. Hansen

**1.561 Advanced Structural Mechanics (A)**

Prereq.: 1.51

Year: G (1)

3-0-6

Introduction to continuum mechanics: analysis of strain, small and large deformations, compatibility equations; analysis of stress, equilibrium equations; principle of virtual displacements, principle of virtual stresses. Stress-strain-temperature relations for elastic and non-elastic materials. Principles of stationary potential energy and of stationary complementary potential energy. Plane stress and plane strain. Flexure and torsion of prismatic bars, shear center of thin walled beams, effect of restraint against warping. Technical theory of beams and plates. Small and large deflection theories. Applications of energy principles.

Connor

**1.571 Advanced Structural Analysis (A)**

Prereq.: 1.51

Year: G (1)

3-0-6

Review of matrix algebra. Matrix formulation for an ideal truss including physical and geometrical non-linearities. Discussion of the force and displacement methods of solution. Solution techniques for non-linear trusses. Formulation of the engineering theory for a member element. Application to prismatic, planar, and space members. Matrix analysis of member systems by the displacement and force methods. Development of the finite element displacement method and application to plate and shell structures. Derivation of element matrices for plane stress, plate bending, and combined stretching and bending.

Connor

**1.582 Structural Reliability (A)**

Prereq.: 1.07, 1.51

Year: G (2)

2-0-4

Analysis and specification of structural performance and safety through probability. The description of uncertain live, wind, and earthquake loadings. The treatment of material properties' variability. Analysis of the reliability of the performance of structural systems. Optimum design accounting for uncertainty and failure consequences. New and developing code specifications with a probabilistic basis.

Cornell

**1.584 Analysis and Design of Shell Structures (A)**

Prereq.: 1.561

Year: G (2)

3-0-6

Formulation of the governing equations of thin shells in orthogonal curvilinear coordinates: analysis of stress; analysis of strain, small and large deformations, compatibility equations. Principle of virtual displacements, principle of virtual stresses. Stress-strain relations for elastic and non-elastic materials. Energy principles. Membrane theory, inextensional bending, conditions for realization of membrane behavior, application to ellipsoids, hyperboloids, paraboloids, cones and cylinders of revolution. Axisymmetric bending of shells of revolution. Shells with edge beams, design considerations, desirability of prestress, variable thickness. Application to various geometries. General theory of cylindrical

shells. Design of cylindrical shell roofs. General theory of spherical shells, applications. Shell theory in Cartesian coordinates, shallow shell theory, application to the design of elliptic and hyperbolic paraboloid shell roofs. Applications of energy principles. Elements of stability analysis.

Pahl

**1.586 Structural Dynamics (A)**

Prereq.: 1.51

Year: G (1)

3-0-6

Analysis and design of structures subjected to dynamic loads. Modal analysis of multidegree systems. Numerical methods. Inelastic response. Continuous systems. Practical design methods. Applications to earthquake design, blast-resistant structures, machine supports, bridge vibration, etc.

Roesset

**1.588 Structural Stability (A)**

Prereq.: 1.561

Year: G (2)

3-0-6

Detailed consideration of elastic and plastic buckling behavior of individual column and flexural elements. Buckling of plates considered and applied to local buckling of structural members. Buckling of shells, frames, trusses and arches also discussed.

Roesset

**1.592 Structural Information Systems (A)**

Prereq.: 1.00 or 1.151; 1.551

Year: G (2)

3-0-6

Identification of objectives, decision variables, processes and information flow in structural design. Interrelationships with participating disciplines in building and bridge design. Current building information systems and their technological problems. Current languages and computer systems for structural design, ICES: STRUDL, BRIDGE, TABLE, and BUILD, information identification, hierarchical data structures. Sensitivity analysis, substructure analysis, man-machine interaction. (Alternate years. Not offered 1969-70.)

Logcher

**1.594 Optimization of Structures (A)**

Prereq.: 1.143

Year: G (2)

3-0-6

Mathematical and computer techniques for the optimization of structural designs. Connections with traditional methods of design. Member-level sub-optimization. Linear programming in plastic design. Methods for non-linear design problems: gradient search, cutting plane, geometric programming. Formulation of constraints and objective functions for structural design problems. Integer variables. Choice of design parameters. Approximations and simplifications for formulation and solution of problems. Variation of structural topology and geometry. Optimization under uncertainty. Non-convex design spaces and transformations to convex problems. Use of statistical decision methods for searching local optima. The role of optimization techniques in the structural design process.

Reinschmidt

**1.60T Introduction to Water Resources**

Prereq.: —

Year: U (2)

3-0-6

Selected aspects of water resource development and use. Global, continental, and regional resource inventories. Nature of water use and its magnitude as affected by population growth, industrialization, urbanization, etc. The water quality issue and its relation to water use. Structural, operational, administrative and legal opportunities for water resource development. Emphasis on formulating goals and objectives for water planning. Special attention given to role of the U.S. Congress and the Federal agencies in U.S. water management.

Schaake

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## CIVIL ENGINEERING

### 1.612 Fluid Mechanics

Prereq.: 1.01, 18.034  
Year: G (1)

3-0-6

Introduction to theoretical fluid mechanics. Development of general equations of motion, their significance in dimensionless form, and their application to the solution of problems involving pressure, gravitational, and viscous forces. Emphasis on dynamic similarity, laminar and turbulent flows, surface and form resistance, lift, propulsion, cavitation, and the use of turbomachinery in hydraulic systems. *Eagleson*

### 1.631 Advanced Hydromechanics I (A)

Prereq.: 1.05 or 1.612; 18.05; 18.06  
Year: G (1)

3-0-6

The kinematics and dynamics of ideal-fluid motions and their mathematical expression. Formulation of boundary conditions. Complex potential and conformal mapping. Virtual mass, airfoil theory, Schwarz-Christoffel transformations and free streamline motions, cavity flows, vortex motions, water waves, and other topics from ideal-fluid theory. *Gelhar, Mei*

### 1.632 Advanced Hydromechanics II (A)

Prereq.: 1.631  
Year: G (2)

3-0-6

Kinematics and dynamics of real-fluid motions and their mathematical formulation. Navier-Stokes equations. Laminar motion and lubrication theory. Stability of laminar motion, origin and generation of turbulence, structure of turbulence and its description. Laminar and turbulent boundary layers. Boundary layers in pressure gradients, separation, stall, secondary flows, boundary layer control. Jets, wakes, and other free turbulent flows. Turbulent mixing, diffusion, and mass transport. *Gelhar, Mei*

### 1.65 Free Surface Flow (A)

Prereq.: 1.05

Year: G (1)

3-0-6

Steady and unsteady flow in open channels, boundary resistance and boundary layer problems, surface curves, channel transitions and controls, standing waves, hydraulic jump, surges and waves. Secondary flow, stratification, internal currents due to density variation, turbulent diffusion phenomena. *Ippen*

### 1.66 Special Problems in Hydromechanics (A)

Prereq.: —  
Year: G (1, 2)

Arr.

Advanced topics selected by students for individual study with staff approval. Choice of subjects from theoretical, experimental, and practical phases of hydromechanics, hydraulic engineering, and water resources. *Staff*

### 1.681 Experimental Hydromechanics (A)

Prereq.: 1.05

Year: G (1)

2-0-4

The role of experimental studies in research and design. Theories of dynamic similarity and dimensional analysis with particular emphasis on their relation to fundamental hydromechanics, interpretation of experimental data and modeling. Criteria for modeling with geometric distortion and other conditions of incomplete dynamic similarity. Fundamentals of measurement and instrumentation. Analysis of the operating principles and performance characteristics of instruments for the measurement of physical quantities such as temperature, pressure and flow. *Perkins*

### 1.683 Experimental Hydromechanics (A)

Prereq.: 1.631 or 1.681

Year: G (2)

0-6-0

Experimental studies of fundamental flow phenomena such as turbulence, diffusion, boundary layers, fluid vibrations, surface and form resistance, cavitation, wave

motion, sediment movement, and density currents. Experimental verification of theory of dynamic similarity and of potential flow analysis. Small group project experiments selected in accordance with particular interests. *Perkins*

### 1.69 Waves and Coastal Processes (A)

Prereq.: 1.65 or 1.681

Year: G (2)

3-0-6

Hydrodynamics of waves for deep and shallow water, wave generation refraction, energy transmission and dissipation; coastal phenomena, harbor and breakwater problems. Analysis of tides and tidal currents; saltwater-freshwater interaction and diffusion in estuaries; erosion and shoaling in tidal waters. *Ippen, Cross*

### 1.70 Mechanics of Sediment Transport (A)

Prereq.: 1.65

Year: G (2)

2-0-4

Measurement and description of sediment characteristics. Mechanics of entrainment, movement, and deposition of sedimentary materials by moving fluids. Analysis of roughness and sediment transport rate of alluvial channels. Design of earth canals. Morphology of rivers. *Mei*

### 1.711T Dynamic Hydrology (A)

Prereq.: 1.05

Year: G (1)

3-0-6

Dynamics of the principal physical processes of interest to the engineering hydrologist. Transport processes in the atmosphere and oceans, energy balance of the earth, atmospheric and oceanic circulations. Emphasis upon the mechanics of evaporation and transpiration, precipitation and snowmelt, infiltration and groundwater flow, surface runoff. Structure of the drainage network. Synthesis of the general rainfall-streamflow process. *Eagleson*

### 1.712 Hydrologic Analysis and Synthesis (A)

Prereq.: 1.07

Year: G (2)

3-0-6

Analysis and synthesis of hydrologic signals and systems. General structure of hydrologic time series. Correlation and spectral analysis of periodic and aperiodic signals. Sampling. Analysis of random signals including use of the extreme value distribution and order statistics, correlation and the variance spectrum. Decomposition of mixed signals. Signal synthesis. Functional and parametric representation of stationary linear and non-linear systems. System identification. Linear and non-linear simulation of hydrologic processes. Time and space definition in hydrologic modeling. Criteria for instruments and networks. *Eagleson*

### 1.72 Flow in Porous Media (A)

Prereq.: 1.05, 1.06

Year: G (1)

2-0-4

Hydrodynamics of flow through porous media with emphasis on the physical processes in seepage and ground water hydrology. Continuum approach to porous media. Continuity conditions and equations of motion. Consideration of non-homogeneous and non-isotropic media. Representation of boundary conditions by means of the hodograph method. Analytical methods for steady and unsteady seepage in confined and free surface aquifers. Seepage through embankments and earth dams. Dupuit approximation in phreatic aquifers. Pumping and recharge wells and multiple well systems. Analysis of well tests. Models and analog methods in groundwater hydrology. Saline intrusion in coastal aquifers. Hydrodynamic dispersion in porous media, analytical and numerical methods in groundwater quality. *Harleman*

- 1.731 Water Resource Systems I (A)**  
 Prereq.: 1.05, 1.143  
 Year: G (1) 3-0-6  
 Application of systems methodology to the analysis, design, and operation of surface and subsurface reservoirs, networks of pipes and channels, and multipurpose river basin developments. Identification of objectives and system definition. Synthesis of hydrologic inputs, operating rules, optimal design and operation, characteristics of systems performance. *Schaake*
- 1.732 Water Resource Systems II (A)**  
 Prereq.: 1.05, 1.711T  
 Year: G (2) 0-3-6  
 Organization for machine solution of comprehensive problems in hydraulics, hydrology and water resource systems. Analog or digital solution of such problems as flood forecasting, flood routing, transients in closed conduits, reservoir design and operation, water quality forecasting. (A knowledge of computer programming at the FORTRAN level assumed.) *Perkins, Schaake*
- 1.77 Water Quality Control (A)**  
 Prereq.: 1.05  
 Year: G (2) 2-2-4  
 Application of fluid mechanics to analysis of problems in water quality and water pollution control. Emphasis is on the mixing, dilution, and dispersion of pollutants discharged into lakes, rivers, estuaries, or oceans. Development of basic mass transfer equations. Analytical and finite difference computer methods for one-dimensional concentration distributions in rivers and estuaries. Biochemical oxygen demand and dissolved oxygen as water quality indicators. Offshore outfalls and diffusion in the ocean. Analysis of stratified flow systems, selective withdrawal, salinity intrusion in estuaries. Thermal pollution, recirculation and heat dissipation problems associated with fossil fuel and nuclear power plants. Thermal stratification in lakes and reservoirs and its effect on water quality. Optimal design for water quality control. Computation periods and laboratory experiments. *Harleman*
- 1.95 Advanced Civil Engineering (A)**  
 Prereq.: —  
 Year: G (1) 0-3-6  
 Consideration in depth of design and construction problems involving more than one discipline of civil engineering. Consideration of the influences of social, political, legal and economic factors. Solution of a problem by the student and comparison of his solution with that on the actual project; or prediction by the student of some aspect of performance and comparison of his prediction with measured field performance. Individual's work or work in small groups with presentation of the results in both oral and written forms. Instruction by M.I.T. staff with participation of engineers involved with the actual project under study. *Lambe*
- 1.96 Special Studies in Civil Engineering (A)**  
 Prereq.: —  
 Year: G (1 or 2) Arr.  
 Individual (or small group) study of advanced subjects under staff supervision. For graduate students wishing to pursue further study of advanced areas of civil engineering not covered in regular subjects of instruction. *Staff*
- 1.971T Research in Civil Engineering**  
 Prereq.: —  
 Year: G (1) Arr.
- 1.972T Research in Civil Engineering**  
 Prereq.: —  
 Year: G (2) Arr.
- 1.973T Research in Civil Engineering**  
 Prereq.: —  
 Year: G (S) Arr.  
 For research assistants in civil engineering in cases where

assigned research is not used for thesis but is approved for academic credit by the Department. Hours arranged with research supervisor. *Staff*

## 1.99 Special Studies in Civil Engineering

- Prereq.: —  
 Year: U (1, 2) Arr.  
 Individual study, research, or laboratory investigations under staff supervision for undergraduates. Arrangement of each program to suit the particular requirements of the student and interested members of the staff, subject to the approval of the instructor in charge. *Staff*

## 2.

### Mechanical Engineering

- 2.00 Introduction to Engineering Systems**  
 Prereq.: 8.02  
 Year: U (2) 3-3-6  
 Lectures and demonstrations concerning engineering activities, engineering problems, and representative techniques employed in their solution. Presentation of concepts basic to engineering including systems, models, fields, quantities, and units. Dimensional analysis and similitude with applications to design of engineering systems, planning of tests and experiments, and plotting of engineering data. Introduction to economic selections and proportions. Discussion of engineering materials and their properties. Brief treatment and use of modern computers. Examples and student projects on case studies of historical significance, as well as problems of current interest. *Paynter, I. Paul*
- 2.01 Mechanics of Solids**  
 Prereq.: 8.01, 18.02  
 Year: U (1, 2) 4-0-8  
 Extension of Newtonian particle mechanics to continuous bodies of finite size. Introduction to engineering applications of the mechanics of deformable continuous media with focus on the three-dimensional requirements of force equilibrium, geometric compatibility, and material behavior. Definition of the state of stress at a point in a continuum; tensor properties of stress. Definition of the state of strain and of rotation at a point in a continuum and development from the displacement field; tensor properties of strain, strain rate, and rotation rate. Development of idealized constitutive relations for materials exhibiting elastic, plastic, and viscous behavior. Applications to stress distributions and deformations in rods, beams, plates, shafts, and other simple structures of engineering interest. Emphasis on the process of constructing idealized continuous and lumped-parameter analytical models to represent actual physical situations. Concepts of stability of deformable systems. *Lardner*
- (A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## MECHANICAL ENGINEERING

### 2.015 *Mechanics of Solids*

Prereq.: —

Year: G (S)

2-0-4

Review for naval officers returning for graduate study; a shortened version of 2.01. (Primarily for students in Course XIII-A.)  
*Lardner*

### 2.02 *Introduction to System Dynamics*

Prereq.: 8.01, 18.02

Year: U (1, 2)

3-1-8

Dynamic modeling, by linear and non-linear lumped elements, of physical systems involving the storage and transfer of matter and energy. Formulation and solution of governing differential equations by direct analysis and by electronic analog and digital computer methods. Dynamic response and stability of linear systems. Exponential excitation, system functions and pole-zero configurations and their interpretation. Generalized impedance concepts, source equivalents and transformations, and loop and node formulation methods. Unified treatment of active and passive mechanical, fluid, thermal, electrical, and electronic systems and devices. Extensive use of physical examples from the fields of mechanical, electrical, chemical, civil, and aeronautical engineering, business administration, and naval architecture.  
*Richardson, Wormley*

### 2.023 *Dynamic Systems*

Prereq.: —

Year: G (S)

3-0-6

Review for naval officers returning for graduate study; a shortened version of 2.02. (Primarily for students in Course XIII-A.)  
*Richardson*

### 2.03 *Dynamics*

Prereq.: 2.02, 18.034

Year: U (1, 2)

3-0-6

Formulation of dynamic equations of motion in mechanical, electrical, and fluid systems by direct and variational methods. Three-dimensional kinematics, inertia tensor, rigid body dynamics. Electrical networks and electromechanical transducers. Treatment of lumped-parameter and continuous systems. Applications to vibrations, wave motions, and frequency response of transducers.  
*S. H. Crandall*

### 2.032 *Advanced Mechanics (A)*

Prereq.: 2.03 or 2.06

Year: G (1)

3-0-9

The foundations of dynamics leading to Lagrange's equations and Hamilton's principle. Gyroscopic effects in mechanical systems. Analysis of the stability of steady motions. Self-excited vibrations and non-linear vibrations.  
*Den Hartog*

### 2.06 *Vibrations*

Prereq.: 2.03

Year: U (2)

3-0-6

Analysis of vibrations in multidegree-of-freedom systems. Characterization of physical systems by mathematical models using matrices or partial differential equations. Concept of resonance and its engineering implications. Free vibrations and natural mode theory. Response of such systems to steady-state single-frequency excitation, to transient pulses, and to random vibration. Implementation of numerical techniques using a digital computer. Case studies of vibration analysis in machine and instrument design and in noise reduction.  
*A. D. Pierce*

### 2.061 *Random Vibration (A)*

Prereq.: 2.03, 18.05

Year: G (1)

3-0-9

Introduction to mathematical description of stochastic processes. Impulse response and frequency response of linear time-invariant dynamic systems. Autocorrelation

and spectral density of stationary response. Crossing rates and distributions of peaks and maxima. Markov processes and Fokker-Planck equation. Pulse processes triggered by Poisson random counters. Application to vibration problems in vehicles subject to wide-band random excitation. Measurement and simulation of random vibration. Failure under random loading due to fatigue and due to first crossing of a threshold.  
*S. H. Crandall*

### 2.062 *Wave Propagation (A)*

Prereq.: 2.03, 18.05

Year: G (2)

3-0-9

Wave concepts in applied mechanics with examples chosen from elasticity, acoustics, magnetohydrodynamics, and related subjects. Phase and group velocities, dispersion, energy density and intensity. Transmission, absorption, refraction, diffraction, and scattering of waves. Waves in inhomogeneous media, the WKB and eikonal approximations, ray theory versus full wave theory. The Lamb-Cagniard-Pekeris method. Non-linear waves, waves in moving or random media. Generation of waves during impact, surface waves, Rayleigh waves, Lamb's problem. Guided waves, normal modes, waves in stratified media.  
*A. D. Pierce*

### 2.063 *Sound and Structural Vibration (A)*

Prereq.: 2.03, 18.05

Year: G (1)

3-0-9

Derivation of acoustic wave equation, small-amplitude approximations. Acoustic intensity and energy density. Generation of sound. The statistical theory of room acoustics. Sound absorption and reverberation time. Direct and reverberant sound fields. Vibration of thin beams and plates. Radiation of sound from vibrating panels, fluid loading effects, critical frequency. Statistical theory of vibrations, response of many-degree-of-freedom systems. Coupling between sound fields and structural vibration; radiation resistance and generalized force. Estimation of average response and variations. (Alternate years.)  
*Manning*

### 2.065J *Flow Noise (A)*

(Same subject as 13.84J)

Prereq.: 1.05 or 2.201 or 16.02; 2.061 or 6.571; 6.35 or 13.81

Year: G (2)

3-0-9

Lighthill's theory of aerodynamic sound. Source, dipole and quadrupole radiation. Sound radiated from subsonic and supersonic jets. Curle's theory of the influence of solid boundaries. Aeolian tone, edge tone, feedback and resonator effects. Turbulent boundary layer noise: fluctuating wall pressure statistics, structural response and radiation, eddy Mach wave radiation. Comparison of theory with experimental results. Laboratory demonstrations.  
*Leehey*

### 2.071 *Introduction to Solid Mechanics*

Prereq.: 2.01, 2.30

Year: U (1)

3-0-6

Senior or graduate elective introduction to fundamentals of modern solid mechanics. Review of stress, equilibrium, displacement, strain, compatibility, theorem of virtual work. Laws of elasticity; applications of theorems of potential energy, complementary energy, Castigliano, and reciprocity. Antiplane strain application to torsion, fracture mechanics. Introduction to plasticity, yield conditions, associated flow rule. Limit analysis applied to composite materials, cracked bodies, structures. Fully plastic deformation in torsion; elements of plane deformation and slip line theory.  
*C.A. Berg*

**2.072 Solid Mechanics — Introduction to Mechanics of Continuous Media (A)**

Prereq.: —  
Year: G (1) 3-0-9

Geometric foundations of continuum mechanics, conservation laws of mechanics applied to continuous media. Constitutive relations for finite elastic deformation, viscous flow, viscoelasticity, plasticity. Basic theorems governing each area of material behavior — e.g. potential and complementary energy theorems of elasticity, correspondence theorem of viscoelasticity, limit theorems of ideal plasticity, and studies of critical problems in each area — e.g. classical solutions of finite elastic deformation, deformation about dislocations, elastic strain about notches, plastic and elastic properties of composite materials, elasto-plastic deformation about shear cracks with applications to fracture mechanics. C. A. Berg

**2.073 Solid Mechanics — Plasticity and Anelastic Deformation (A)**

Prereq.: 2.071 or 2.072  
Year: G (1) 3-0-9

Microscopic and macroscopic aspects of plastic deformation. Yield conditions, maximum plastic work principle and associated flow rule. Studies in fully plastic deformation; limit theorems applied to structures, cracked bodies, composites. Review of elasto-plastic torsion. Plane strain and slipline theory. Antiplane elasto-plastic strain about notches. High temperature creep and deformation theory plasticity with application to studies of strain fields near notches. The role of strain hardening in stability and uniqueness. Studies of role of plasticity in frictional contact, machining, and fracture, geophysics. C. A. Berg

**2.074 Solid Mechanics — Elasticity**

Prereq.: 2.072, 18.06  
Year: G (1) 3-0-9

Solution of elasticity problems with emphasis on analytical methods. Topics: introduction to tensor analysis; review of basic field equations; solution of finite deformation problems; solution of plane problems by complex potentials; three-dimensional problems; plate theory; and an introduction to shell theory, etc. Green and Zerna, *Theoretical Elasticity*. Shack

**2.075 Seminar in Applied Mechanics (A)**

Prereq.: 2.072  
Year: G (2) 3-0-9

Content varying from year to year depending upon current research activities in applied mechanics. For 1969-70, analytical methods in the solution of solid mechanics problems. Emphasis on the physical formulation of problems and attendant analytical methods of solution. Topics: perturbation methods, complex variable and transform methods applied to elastic crack and elastic contact problems, integral equations. Lardner

**2.083 Applied Elasticity (A)**

Prereq.: 2.01  
Year: G (2) 3-0-9

Review and development of equations of elasticity; clear distinction between linear and non-linear elasticity. Strain energy theorems, reciprocal theorems, stress functions. Two-dimensional problems, classical methods, complex variable techniques. Experimental methods. Finite element technique applied to two- and three-dimensional problems. Axisymmetric problems, torsion. Introduction to plate bending, axisymmetric linear, and non-linear shell theory, buckling. Survey of numerical methods for solution of elasticity and shell problems. Lardner

**2.092 Methods of Engineering Analysis (A)**

Prereq.: 18.05  
Year: G (2) 3-0-9

Study of the nature of complex problems in engineering analysis and of the means of obtaining practical solutions. Formulation of mathematical models for complex physical situations and the organization of computational programs for their solution. Examples chosen from mechanics, hydraulics, heat transfer, elasticity, compressible flow, etc. Numerical methods including iteration, relaxation, finite difference, and variational methods. S. H. Crandall

**2.10 Elementary Programming and Machine Computation**

Prereq.: —  
Year: U (1, 2) 2-2-2

Elements of automatic computation with emphasis on digital machines and use of FORTRAN programming language. Reduction of physical phenomena to mathematical models and solution of resulting equations by numerical methods using digital computers, particularly the Department's IBM 1130. Programming problems drawn from fields of current interest to students, including basic physics and mathematics. Parallel lectures with 2.101 for the first four weeks. (Limited enrollment; open to freshmen and upperclassmen.) D. P. Adams, Paynter

**2.101 Computer Models of Physical and Engineering Systems I**

Prereq.: —  
Year: U (1, 2) 3-3-6

Elements of automatic computation with emphasis on digital computers and FORTRAN as a programming language. Extensive laboratory experience using the 1130 computer. Aspects of the reduction of physical and engineering systems to simplified physical and mathematical models; representation using linear graphs, networks, logical operators, and reticular geometry. Manipulation of the resulting models using digital algorithms. Examples drawn from fields primarily of interest to scientists and engineers, with some attention to styles of problem solving. (Enrollment limited; preference given to pre-engineering students.) Paynter

**2.13 Electromechanical Fields and Systems**

Prereq.: 2.02 or 6.01  
Year: U (1, 2) 4-2-6

Elementary treatment of fields in vacuum and real materials with emphasis on energy principles and force relationships. Emphasis on quasi-static electromagnetic fields through application of Maxwell's equations with brief discussion of gravitational, thermal and fluid fields. Relation between field and lumped-circuit concepts. Multiport energy transformers and transducers. Practical applications to design and utilization of electromechanical devices and systems, including measuring instruments, control components, and rotating machines. Design and laboratory work illustrating practical and theoretical questions. (Not offered 1969-70.) Paynter

**2.14 Control System Principles**

Prereq.: 2.02, 2.201  
Year: U (1) 3-1-8

Dynamic analysis and feedback control of lumped-parameter linear systems. Modeling of various electromechanical configurations using scalar and state vector notation. Linearization of non-linear systems. Transient and frequency response to control and disturbance variables. Application of Laplace and Fourier transforms,

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## MECHANICAL ENGINEERING

stability criteria, root locus and other graphical techniques. Practice in design of control systems, using analog and digital computers and actual hardware.

*Paynter*

### 2.141 Modeling and Simulation of Dynamic Systems (A)

Prereq.: 2.03 or 2.14 or 6.213 or 16.30

Year: G (2)

3-0-9

Modeling of complex linear and non-linear, stationary and time-varying, mechanical, fluid, electrical, and thermal dynamic engineering systems. Emphasis on subdivision into simple multiported elements and representation by the energetic bond graph language. Direct, energetic, and experimental identification. Lumped-field representations. Analytic and graphical reductions and canonical forms, signal graphs, analog, digital and hybrid implementation. Examples including machine components, electromechanical transducers, electric and fluid circuits, and thermal systems.

*F. T. Brown*

### 2.151 Advanced System Dynamics and Control (A)

Prereq.: 18.05

Year: G (1)

3-0-9

Analytical descriptions of dynamic physical systems; concept of state; time and frequency domain representations, experimental methods for system identification. Behavior of unforced dynamic systems and excitation-response patterns; non-linear systems, linearization, response prediction techniques for linear systems. Modification of system characteristics by control techniques; feedback, feedforward, compensation, evaluation of closed-loop performance, physical control devices. Optimization of linear systems, parameter variation and performance evaluation, integral square and mean square criteria.

*Wormley*

### 2.152 Modern Control Theory and Applications (A)

Prereq.: 2.151

Year: G (2)

3-0-9

Formulation of optimal control problems from engineering situations. Analytical and computational techniques for solving optimization problems; dynamic programming, calculus of variations, maximum principle. Characteristics of optimal systems; bang-bang systems, optimal linear systems. Concepts and analytical treatment of controllability, observability. Control with some inaccessible state variables. Examples of engineering systems involving control of force and motion, thermal effects, and industrial processes.

*Whitney*

### 2.153 Distributed Systems (A)

Prereq.: 2.062 or 2.14 or 2.141 or 6.07 or 16.30

Year: G (1)

3-0-9

Power and signal flow in distributed media, with emphasis on one-dimensional structuring of engineering systems. Distributed, lumped and mixed modeling and identification of coupled and uncoupled kinetic strain, gravity, thermal, electric and magnetic energies in solids and fluids. Operational, classical, graphical, numerical and analog solution techniques. Frequency and transient response, dispersion and attenuation of wave-scattering variables, stability and control. Examples such as beam and plate dynamics, counterflow heat exchangers, fluid and electromagnetic lines, acoustic horns, fluidic systems, electrohydrodynamic and magnetohydrodynamic flow, chemical processes, etc.

*F. T. Brown*

### 2.154 Control of Rotating Machine Systems (A)

Prereq.: 8.03

Year: G (1)

3-0-9

Systematic study of the dynamic behavior and control of systems of rotating electrical machines together with

their power supplies and prime movers, as typically used for power and propulsion, as well as for instrumentation and control. Introduction to the concept of a generalized 4-winding electrical machine (GEM), which includes all familiar a-c and d-c machine types as special instances. Dynamic analysis and simulative modeling of the GEM. Field and armature control methods, including the use of solid-state active circuitry. Detailed investigation of a number of particular rotating machine systems involving speed and excitation control. Subject intended for students interested in power and propulsion systems, as well as for those concerned with automatic control applications.

*Paynter*

### 2.161 Analog/Digital Computation for Instrumentation and Control (A)

Prereq.: —

Year: G (2)

3-0-9

Analog, digital, and hybrid computer techniques for study of linear and non-linear differential equations. Iterative solutions, run functions, parameter optimization, scaling of non-linear equations, digital data logging and reduction, automatic setup and scaling, transport delay simulation, function generation and effective use of graphic output devices. Computer hardware, including differential amplifiers, comparators, D/A switches, gates, flip flops, and A/D converters. Use of simple analog hardware for direct instrumentation and control. Undergraduate background in mathematics, dynamics, control theory and circuit theory required.

*Paynter, Sidell*

### 2.171 Fluid Power Controls and Fluidics (A)

Prereq.: 2.14, 2.201

Year: G (1)

3-3-6

Theory and design of hydraulic and pneumatic control systems and components and their applications in aerospace, military, industrial, and other fields. Problems in the control and measurement of pressure, flow, speed, position, force, and other mechanical quantities. Application of basic principles to component and system design. Use of schematic and block diagrams. Solution of typical fluid power control system problems including non-linearities with aid of computers. Current development in the field of fluidics. Design and application of pure fluid amplifiers, logic elements and systems.

*S. Y. Lee*

### 2.173 Instruments for Measurement and Control (A)

Prereq.: 2.03

Year: G (2)

3-0-6

Presentation of basic concepts and principles important to the design and use of instruments for measuring various physical quantities. Analysis of dynamic behavior of instruments as elements in complex control systems. Detailed presentation of typical examples of digital as well as continuous types of instruments and control system components. Discussion of problems connected with signal amplification, remote indication, transmission and storage.

*S. Y. Lee*

### 2.18T Man-Machine Systems (A)

Prereq.: —

Year: G (1)

3-3-6

Models of man as a decision and control component in a physical system. Transmission and processing of information through the human organism. Quasi-linear models of the human operator in closed-loop control systems. Bayesian and other probabilistic models of human decision making and signal detection. Weekly laboratory experiments keyed to the theoretical presentations. Design of displays and controls for vehicles and man-computer interaction. Design exercises drawn from transportation, remote manipulation, computer-aided instruction and similar fields. (Permission of instructor required.)

*Sheridan*

**2.181J Life Support and Physiological Modeling in Manned Systems (A)**  
(Same subject as 16.43J)

Prereq.: —

Year: G (2)

3-3-6

Environmental control and physiological characteristics of man as related to unusual acceleration, thermal, atmospheric, radiation or other stresses. Advanced models of sensory and neuromuscular systems. Lectures and student critique of current research. Design of systems involving man. Student projects in small groups throughout the term. (Permission of instructor required.)  
*Sheridan, L. R. Young*

**2.191J Special Studies in Systems Engineering (A)**  
(Same subject as 1.16J, 6.604J, 13.47J, 17.818J)

Prereq.: —

Year: G (2)

2-4-6

Introduction to basic techniques employed in planning and design of complex systems. Detailed design of subsystems by individual student groups with emphasis upon use of parametric design principles in arriving at suitable tradeoffs between subsystems. Supplementing lectures covering general principles of the operational complex and subsystems by guest lecturers. The particular operational complex chosen for each term to be announced before start of the term. Students encouraged to discuss subject with staff prior to registration. (Previous projects: Group 1 — An integrated urban transportation system; Group 2 — A manned satellite inspection and retrieval system.)  
*Baumann, Seifert, Frankel, R. C. Wood*

**2.201 Fluid Mechanics**

Prereq.: 2.01, 18.034

Year: U (1, 2)

4-0-8

Introduction to the dynamics of incompressible fluids. Equations of mass conservation and motion for inviscid and viscous flows. Bernoulli equation. Momentum theorems. Applications to engineering problems. Potential flow theory. Navier-Stokes equations. Poiseuille flows. Couette and Rayleigh problems. Laws of similitude. Pipe friction. Boundary layer theory. Elements of turbulent flows. Separation and drag. Open channel flows.  
*Jaffrin*

**2.202 Gas Dynamics**

Prereq.: 2.201

Year: U (2)

3-0-6

Introduction to gas dynamics. Rankine — Hugoniot relations. One-dimensional steady and unsteady flow. Two- and three-dimensional subsonic, supersonic and hypersonic flows. Compressible flow in ducts and channels. Compressible viscous and heat-conducting boundary layers with heat transfer.  
*Hoult*

**2.25 Advanced Fluid Mechanics (A)**

Prereq.: 2.201, 18.05

Year: G (1)

3-0-9

Survey of principal concepts and methods of fluid dynamics. Statics. Continuity, momentum, and energy relations for continuous fluids. Kinematics of fluid motion. Governing equations for motion of non-viscous fluid. Vorticity and circulation. Kelvin's theorem. Helmholtz' vorticity equation and vortex laws. Crocco's theorem. Stream function. Potential flow. Conformal transformation. Theory of lift. Navier-Stokes equation for motion of real fluids and applications. Boundary layer theory. Turbulence. Drag. Wave propagation. Fluid mechanical instabilities. Applications to fluid machinery, propulsion systems, process industries, and aerodynamics.  
*A. H. Shapiro*

**2.261 Kinetic Theory of Gases and Plasmas (A)**

Prereq.: 2.273 or 2.46

Year: G (1)

3-0-9

Structure and interactions of atoms and molecules. Calculation of gas properties from statistical mechanical partition function. Collision theory and cross-sections. Derivation of macroscopic transport equations from Boltzmann equation including Lorentz force and radiation. Diffusion, viscosity, thermal, and electrical conductivity of pure gases, mixtures, and plasmas. Radiation transport. Gas-surface interactions and Debye sheath.  
*Keck*

**2.262 Reaction Kinetics of Gases and Plasmas (A)**

Prereq.: 2.261

Year: G (2)

3-0-9

General theory of gas phase reactions. Analytical and numerical methods for estimating rate constants and cross-sections for rotational and vibrational excitation, dissociation, ionization, and recombination. Line, band, and continuum radiation from atoms, molecules, and ions. Theory of line broadening. Experimental techniques for measuring reaction rates using shock tubes, pipe flows, flash photolysis, atomic and molecular beams, arcs, and discharges. Applications to re-entry, power generation and conversion, combustion, chemical processing, lasers, surface ablation, and atmospheric physics.  
*Keck*

**2.271 Compressible Fluid Mechanics (A)**

Prereq.: 2.201, 2.403, 18.05

Year: G (2)

3-0-9

Survey of gas dynamics. Fundamentals of wave phenomena. One-dimensional steady flow, with effects of area change, friction, heat transfer, chemical reaction. Shock waves. Supersonic diffusers and wind tunnels. Subsonic high-speed flow. Supersonic flows. Unsteady flows and waves in ducts. Experimental methods.  
*A. H. Shapiro*

**2.272 Viscous and Turbulent Flows (A)**

Prereq.: 2.25

Year: G (2)

3-0-9

Viscosity and dissipative phenomena; the Navier-Stokes and energy equations, their formulation, properties, and some exact solutions; creeping flows at low Reynolds numbers; flows through porous media; laminar boundary layers and their solution; laminar stability, transition, and turbulence; turbulent boundary layers; jets, wakes, and separated flows, thermal boundary layers; compressible boundary layers with chemical reactions, dissociation, and ionization; effects of mass addition and surface catalysis.  
*Probstein*

**2.273 Molecular Fluid Mechanics (A)**

Prereq.: 2.201, 18.05

Year: G (1)

3-0-9

Introduction to fluid flows from the molecular point of view, with emphasis on dilute gases. Molecular models and elementary kinetic theory of gases including pressure, mean free-path and transport phenomena. Gas-dynamic regimes. Equilibrium kinetic theory, Maxwellian velocity distribution, collisions and relaxation. Collisionless gas and interaction of a flowing gas with solid surfaces. Approach to thermodynamic equilibrium in fluid flows. Formulation of continuum conservation laws beginning with particle concepts. Transfer and model kinetic equations and their application to low-density flows. Dense gases and liquids; equilibrium theory and elementary kinetic theory of transport phenomena.  
*Probstein, Sonin*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

MECHANICAL ENGINEERING

- 2.275 Dynamic Fluid Machines (A)**  
*Prereq.:* 2.202 or 2.25  
*Year:* G (2) 3-0-9  
Momentum transfer in turbomachines. Axial compressors and turbines; design considerations, cascade aerodynamics including effects of viscosity and compressibility, three-dimensional flow, performance limitations; radial machines; transonic and supersonic compressors; pumps, including effects of cavitation; ducted jets.  
*Wilson*
- 2.276 Advanced Viscous and Turbulent Flows (A)**  
*Prereq.:* 2.272  
*Year:* G (1) 3-0-9  
Elements of singular perturbation theory with applications to viscous flows. Hydrodynamic stability and transition to turbulence. Turbulent shear flows including statistical theories and analysis of measurements. Additional topics selected from the following areas of interest: flows with suspended particles, inertial, and electrohydrodynamic boundary layers, and approximate solutions for non-similar boundary layers. Emphasis on applications to problems in dislocation, biomedical fluid mechanics and air and water pollution. (*Not offered 1969-70.*)  
*Hoult, Dewey*
- 2.277 Biomedical Fluid Mechanics**  
*Prereq.:* 2.25  
*Year:* G (1) 3-0-9  
Fluid mechanics of the circulatory, pulmonary and ureteral systems, with emphasis on engineering models and their utilization in describing in vivo observations. Analytic description of the analog models of the circulation, wave propagation in arteries, peristaltic pumping and diffusive transport across membrane walls. Additional topics: hemodialysis (as related to artificial kidneys), heart-assist devices, extracorporeal oxygenators and flow and pressure measurements techniques for human applications.  
*Dewey, Jaffrin*
- 2.281 Reacting Gas Dynamics (A)**  
*Prereq.:* 2.201 or 16.02 or 16.03  
*Year:* G (1) 3-0-9  
Fundamental treatment of problems in non-equilibrium gas dynamics involving simultaneous occurrence of chemical reaction and transport of mass, momentum and energy. Applied chemical kinetics. Conservation equations considering chemical reaction and multispecies diffusion. Relaxation phenomena. Method of characteristics for non-equilibrium flows. Acoustic waves, shocks, flames, detonations; their propagation and structure. High-temperature gas flow in jets, nozzles, hypersonic boundary layers. Chemical effects on turbulence. Engineering applications.  
*Toong*
- 2.282 Combustion (A)**  
*Prereq.:* 2.201 or 16.02 or 16.03  
*Year:* G (2) 3-0-9  
Comprehensive treatment of combustion principles. Combustion instability, linear and non-linear mechanisms, interactions of acoustic waves with non-uniform and fluctuating reacting flows. Laminar and turbulent flames. Exothermic hypersonic flows. Supersonic combustion. Reacting boundary layers with ablation. Electromagnetic effects.  
*Toong*
- 2.283 Fluid Mechanics of Pollution (A)**  
*Prereq.:* 2.25  
*Year:* G (2) 3-0-9  
Application of fluid mechanics to problems of air and water pollution. Properties and sources of air pollutants. Characteristics of atmospheric boundary layer. Turbulent mixing of buoyant plumes and diffusion of pollutants in stratified fluids. Effects of thermal stratification on flow and mixing in air and water. Thermodynamics of combustion processes. Pollution from energy and heat sources.  
*Fay, Hoult, Heywood*
- 2.29 Advanced Topics in Fluid Mechanics (A)**  
*Prereq.:* 2.25  
*Year:* G (1 or 2) *Arr.*  
Selected subjects relating to incompressible and compressible flows, steady and unsteady motion, friction and heat transfer, waves, rarefied gas dynamics, magneto-hydrodynamics. No formal lectures; assigned reading and special problems arranged on an individual basis in consultation with instructor.  
*Fay, Probstein, A. H. Shapiro, Toong*
- 2.291 Research in Combustion (A)**  
*Prereq.:* 2.281 or 2.282 or 10.70 or 16.052  
*Year:* G (1 or 2) *Arr.*  
Selected theoretical or experimental problems in combustion and high-temperature gas dynamics, including radiative and electromagnetic effects. Work arranged on an individual basis in consultation with instructor.  
*Toong*
- 2.30 Mechanical Behavior of Materials**  
*Prereq.:* 2.01, 3.141  
*Year:* U (1, 2) 3-2-4  
Mechanics of continua for elastic, plastic, viscoelastic, and creeping materials based on their molecular and dislocation structure and changes in the latter; limit analysis; discussion of selected case studies of service failures, illustrating both static and fatigue fracture at moderate temperatures and under creep conditions, in engineering structures. Laboratory emphasizing student-planned projects. McClintock and Argon, *Mechanical Behavior of Materials*.  
*Argon*
- 2.301 Advanced Mechanical Behavior of Materials (A)**  
*Prereq.:* 2.30  
*Year:* G (1) 3-0-9  
Emphasis on the quantitative prediction of mechanical behavior: plastic, viscous, and plastic deformation; crack formation and growth under monotonic and repeated loading; wear and friction; composite materials. McClintock and Argon, *Mechanical Behavior of Materials*, and selected readings from the current literature.  
*McClintock*
- 2.304 Physics of Strength and Plasticity (A)**  
*Prereq.:* 2.30, 3.141  
*Year:* G (2) 3-0-9  
Molecular mechanisms of rubber-elasticity, viscosity, viscoelasticity and plasticity. Deformation mechanisms in crystalline materials; theories of yield stress, yield phenomena, strain hardening, transient and viscous creep. Types of fracture and theories of fracture; fatigue.  
*Orowan*
- 2.332 Dislocation Theory (A)**  
*Prereq.:* 2.01; 2.30 or 3.141  
*Year:* G (1) 3-0-9  
Derivation from elastic theory of the properties of dislocations in isotropic and anisotropic materials. Interactions between dislocations and other imperfections. Dislocations in particular crystal structures. Applications to theories of yield points, solution hardening, work hardening, creep and fracture.  
*Argon*
- 2.34 Physics and Engineering Use of Adhesives (A)**  
*Prereq.:* —  
*Year:* G (2) 1-0-3  
Peel strength and fracture strength; bond strength and joint strength. Mechanics of joint failure; chemical factors and bond strength. Structural adhesives; simultaneous use of adhesives and fasteners. Adhesives as matrix of composite materials.  
*Orowan*

**2.398 Research in Materials**

Prereq.: 2.30

Year: U (1 or 2)

Arr.

Experimental or theoretical research on mechanical behavior (strength, plasticity, etc.) of metallic or non-metallic materials. Staff

**2.399 Research in Materials (A)**

Prereq.: 2.30

Year: G (1 or 2)

Arr.

Experimental or theoretical research on mechanical behavior (strength, plasticity, etc.) of metallic or non-metallic materials. Staff

**2.402 Thermodynamics**

Prereq.: —

Year: G (1)

4-0-8

Heat, work, the laws of thermodynamics. Entropy and absolute temperature. Properties of liquids, vapors, perfect gases and mixtures of gases and vapors. Applications to heat engine cycles. (Primarily for selected officers of the U.S. Navy and Coast Guard.) J. L. Smith

**2.403 Thermodynamics**

Prereq.: 8.02, 18.034

Year: U (1, 2)

4-0-8

Classical thermodynamics with emphasis on the relation of abstract concepts to physical situations. Work and energy for pure conservative and pure dissipative systems. Heat, temperature, first law of thermodynamics. Pure thermal systems. Equilibrium and reversibility. Thermodynamically coupled systems, second law of thermodynamics, thermodynamic temperature, entropy. Bulk flow and open systems. The pure substance, solid, liquid and gaseous phases. Mixtures of gases. Applications to engineering systems. J. L. Smith

**2.412 Heat Engineering**

Prereq.: 2.402, 2.54

Year: G (2)

3-3-6

Applications of fundamental principles of thermodynamics, fluid mechanics, and heat transfer. Design of power and propulsion cycles and processes, and the associated fluid machinery and heat transfer equipment for nuclear and fossil fuels heat sources. Economic and logistic optimization, off-design performance, and control problems of power equipment. Laboratory projects on related topics. (Primarily for selected officers of the U.S. Navy and Coast Guard.) J. L. Smith

**2.42 Elements of Classical and Statistical Thermodynamics**

Prereq.: 8.01, 18.02

Year: U (1, 2)

4-0-8

First and second laws applied to simple systems through the classical concept of state: heat, work, energy, reversibility, entropy, availability, equilibrium, thermodynamic temperature, chemical reactions, chemical potential, chemical equilibrium. The system as an assembly of molecules behaving reversibly. Mechanical state, work of identification of mechanical state, ensemble representation of information, irreversibility and loss of information, entropy of a system represented by an ensemble, application of the criterion of equilibrium to microcanonical and canonical ensembles, a few examples. (Not offered 1969-70.) Keenan

**2.451 Advanced Thermodynamics (A)**

Prereq.: 18.05

Year: G (1)

3-0-9

Equilibrium; first law, second law, state principle, and zeroth law; criteria of equilibrium; temperature, entropy, and availability; Maxwell relations; open systems; phase rule; systems of one and two components; idealized gases, mixtures, and solutions; equations of state; thermodynamic potentials; chemical reactions and chemical

equilibrium. Problems relating to power and propulsion, chemical processes, fluid flow, and metallurgy. Stickney, Hatsopoulos

**2.452 Advanced Thermodynamics (A)**

Prereq.: 2.451

Year: G (2)

3-0-9

Principles of quantum statistics; density matrix; coherence supermatrix. General definition of thermodynamic state; probabilistic and deterministic interactions; work; law of stable equilibrium; availability; entropy; principle of increase of entropy. Criterion for stability; general canonical distribution; microcanonical, canonical, and grand canonical ensembles. Ideal substances; Fermi-Dirac and Bose-Einstein gases; ideal crystals; the photon gas; adsorbed layers. Theory of non-equilibrium states. Linear irreversible processes; Onsager reciprocal relations; diffusion; electronic phenomena in solids, vacua, and plasmas. Hatsopoulos

**2.453 Advanced Projects in Heat and Thermodynamics (A)**

Prereq.: 2.451

Year: G (1, 2)

Arr.

Selected subjects of current interest in thermodynamics, mass transfer, and heat transfer. No formal lectures; assigned reading or experiment arranged on an individual basis in consultation with instructor. Rohsenow, Keck

**2.46 Statistical Mechanics (A)**

Prereq.: 2.42

Year: G (2)

3-0-9

Introductory subject for graduate engineering students. Classical mechanics of systems of particles and motion in phase space. Quantum mechanical concepts and energy of microscopic systems. Most probable distribution. Determination of thermodynamic properties of gases, crystals, black body radiation field. Application to dissociated gases, plasmas, thermionics, lasers, cryogenics. Appleton

**2.50 Heat and Mass Transfer**

Prereq.: 2.201, 2.403

Year: U (1, 2)

3-0-6

Heat, mass, and momentum transfer associated with laminar and turbulent flow of fluids in forced and free convection. Fully developed flows and boundary layer development in ducts, over flat plates and blunt bodies, through tube bundles and packed beds. Heat conduction in solids with and without heat sources; finned surfaces. Condensation. Boiling. Heat exchanger design; heat transfer in nuclear reactors, including liquid metals. Radiative heat transfer. Elementary statistical mechanics. Elementary kinetic theory of gases; distribution function; transport properties. Rohsenow

**2.53 Problems in Heat**

Prereq.: 2.403

Year: U (1 or 2)

Arr.

Selected experiments with laboratory investigation of problems connected with the industrial application of heat, such as thermal conductivity, thermal expansion, specific heat, ceramics, etc. Rohsenow

**2.54 Heat Transfer**

Prereq.: —

Year: G (2)

3-0-3

Fundamentals of conduction, radiation of heat, and the effects of convection, with applications to problems arising in practice. (Primarily for selected officers of the U.S. Navy and Coast Guard.) Rohsenow

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## MECHANICAL ENGINEERING

- 2.55 Advanced Heat Transfer (A)**  
*Prereq.:* 2.403, 18.05  
*Year:* G (1) 3-0-9  
Review of analogies among heat, mass, and momentum transfer. Free and forced convection from theoretical and experimental viewpoint for laminar and turbulent flows in ducts and over flat plates and blunt bodies. Heat transfer coefficients at high velocities and in rarefied gases. Heat transfer-friction relationship in heat exchangers. Film and dropwise condensation. Boiling with forced and natural convection. Radiative heat transfer; heat transfer between surfaces, in absorbing media. *Rohsenow*
- 2.56 Advanced Heat Transfer (A)**  
*Prereq.:* 2.403, 18.05  
*Year:* G (2) 3-0-9  
Steady-state and transient-state heat conduction and mass diffusion for various constant and variable boundary conditions. Solution of differential equations in rectangular, cylindrical and spherical coordinate systems by formal mathematics. Various approximated methods, integral method, finite difference technique, analogies, fixed and floating random walk methods. Moving boundaries; problems in freezing and melting. Thermal stresses resulting from non-uniform temperature distribution. Thermal contact resistance. *Mikic*
- 2.57 Two-Phase Flow and Boiling Heat Transfer (A)**  
*Prereq.:* 2.201 or 2.25 or 10.52; 2.50 or 2.55 or 10.50  
*Year:* G (2) 3-0-9  
Phase change in bulk stagnant systems. Kinematics and dynamics of adiabatic two-phase flow. Dynamics and thermodynamics of forced-convection two-phase flow with boiling and/or evaporation. Thermal and hydrodynamic stability of two-phase flows. Associated topics, such as condensation and atomization. *Bergles, Rohsenow*
- 2.58 Radiation Heat Transfer (A)**  
*Prereq.:* 2.42 or 2.403; 18.05  
*Year:* G (1) 3-0-9  
Basic laws of thermal radiation. Radiation properties of solids; electromagnetic theory, dispersion, experimental results. Radiant interchange among surfaces separated by a transparent media; non-gray surfaces, specularly reflecting surfaces. Radiation properties of gases. Radiant interchange through absorbing, emitting and scattering media; radiative equilibrium, combined radiation and conduction; combined radiation and convection; approximate methods of solution. *Cravalho, Glicksman*
- 2.60 Applied Thermodynamics**  
*Prereq.:* 2.403 or 2.42  
*Year:* U (2) 3-0-6  
Case study of a situation applying the approaches and techniques developed in 2.42. Choice of cases providing introduction to heat and mass transfer and to the kinetic theory of rate processes. Study of simple concepts in boundary-layer fluid mechanics and in diffusion and viscosity. *D. G. Wilson*
- 2.611 Elementary Internal Combustion Engines**  
*Prereq.:* 2.02, 2.403  
*Year:* U (1) 3-0-6  
Application of engineering principles to analysis of engine performance. Spark ignition and Diesel cycles. Combustion, friction, cooling, carburetion, and other factors affecting power, efficiency, and general performance. *Rogowski*
- 2.612 Internal Combustion Engines**  
*Prereq.:* 2.611  
*Year:* U (2) 3-0-6  
For students interested in research, development, or design in connection with engines and other complex mechanical devices. Review of basic engine theory. Philosophy of design and design procedure. Role of theoretical training, judgment, and experience. Choice of optimum thermodynamic cycle, fuel, cooling, shape, and size to satisfy a given performance specification. Dimensional analysis, engine balance, stress concentration, fatigue, choice of materials. *Rogowski*
- 2.614 Internal Combustion Engine Laboratory**  
*Prereq.:* 2.611  
*Year:* U (2) 0-4-4  
Experimental investigation of problems selected from the entire field of internal combustion engines for their educational value and current interest. Application of basic engine theory stressed; experience gained in use of modern methods of measurement and rational analysis of data. Work groups given considerable responsibility for planning and execution of projects. *Rogowski*
- 2.615 Advanced Internal Combustion Engines (A)**  
*Prereq.:* 2.02, 2.403  
*Year:* G (1) 3-0-9  
Similar to 2.611, but for students with some previous training or experience in this field. Analytical approach to the engineering problems and performance estimation, of diesel, spark ignition and mixed cycle engines. Study of fluid flow, thermodynamics, combustion and other factors affecting power and efficiency. *Rogowski*
- 2.616 Advanced Internal Combustion Engines (A)**  
*Prereq.:* 2.611 or 2.615  
*Year:* G (2) 3-0-9  
Continuation of engine theory. Philosophy of design and design procedure. Synthesis of the optimum design to satisfy given performance specifications. Similar to 2.612 but includes an individual engine design project, with application and specifications selected by the student. *Rogowski*
- 2.617 Special Problems in Internal Combustion Engines (A)**  
*Prereq.:* 2.611; 2.615  
*Year:* G (1 or 2) Arr.  
For students with previous training or experience in this subject. Selection of a particular problem by student on which he works independently but under guidance of instructor in field of gas turbines or reciprocating engines or motor vehicles. Work to be summarized in written report. *Rogowski*
- 2.618 Automotive Vehicles**  
*Prereq.:* 2.03  
*Year:* U (2) 3-0-6  
Analytical approach to vehicle performance, handling, and riding qualities. Design of body, chassis, suspension, engine, and transmission to meet vehicle requirements. Individual study of a special problem related to automobile design. Demonstrations of vehicles and components. *Larrabee*
- 2.621 Gas Turbines (A)**  
*Prereq.:* 2.202; 2.403 or 2.42; 2.60  
*Year:* G (1) 3-0-9  
Application of engineering science to the design and development of gas turbines. Thermodynamics and fluid mechanics for flow phenomena in turbines and compressors. Problems of mechanical strength and vibrations encountered in rotating machinery and blading of turbines and compressors. Design of turbines, compressors, heat exchangers and combustion chambers. Operating characteristics of gas turbine power plants and consideration of special problems encountered in aircraft. *D. G. Wilson*

**2.632 Research in Lubrication (A)**

Prereq.: —

Year: G (1 or 2)

Arr.

Opportunity for the student to select a research problem (which may be independent of or closely related to the program in progress in the Surface Laboratory), such as lubrication proper, bearing design, surface finish, or fundamental studies of mechanism of friction from experimental and theoretical standpoints. *Rightmire*

**2.641 Food Engineering**

Prereq.: 8.01

Year: U (1)

3-2-3

Primarily for students in nutrition and food science. Fundamental principles of thermodynamics including laboratory work. Development of basic refrigeration cycles and their application. *Hesselschwerdt*

**2.642J Food Engineering**

(Same subject as 20.13J)

Prereq.: 2.641

Year: U (2)

4-0-5

Quantitative study of selected unit operations of the food industry with consideration of basic principles governing each operation, as well as of important applications. Emphasis on refrigeration and freezing, fluid flow, heat transfer, evaporation, dehydration and filtration. *Hesselschwerdt, Karel*

**2.643 Air Conditioning**

Prereq.: 2.403

Year: U (1)

3-0-6

For students who have had a basic subject in thermodynamics. Physiological aspects of air conditioning. Air and water vapor mixtures, load estimates for heating, boilers, radiators, and heating systems. Complete and part air conditioning systems, including air handling equipment. *Hesselschwerdt*

**2.644 Environmental Control —****Air Conditioning**

Prereq.: 8.02

Year: U (2)

3-0-5

Primarily for students in architecture. Physiological and functional aspects involved in producing and controlling a thermal environment. Relationship of space and enclosure to climate and weather. Development and analysis for heating, cooling, ventilation, and air distribution. Principles and techniques of cooling. Evaluation of allocation of space for equipment and systems in the building source and conveyance media. Lecture material supplemented with plant and site trips. *Hesselschwerdt*

**2.645 Advanced Air Conditioning (A)**

Prereq.: 2.643

Year: G (2)

3-0-9

Psychrometry and its application to problems involving heat and mass transfer in spray equipment. Cooling load estimates and extended surface coils for cooling and dehumidification. Consideration of typical air conditioning equipment and control systems in relation to specific problems. *Hesselschwerdt*

**2.646 Refrigeration**

Prereq.: 2.403

Year: U (2)

3-0-6

Discussion of refrigerating cycles. Refrigeration at more than one level. Operation and ratings of various types of compressors, evaporators, condensers, and automatic controls used in commercial refrigerating systems. Heat flow problems in condensers, evaporators, and cooling towers. *Hesselschwerdt*

**2.647 Vehicle Environmental Control**

Prereq.: 2.201 or 2.50 or 16.02; 2.403

Year: G (1, 2)

3-0-6

Environmental requirements for equipment and for human habitation. Psychological and physiological principles of the interrelation between a human and his surroundings. Consideration of the limitations imposed upon the environment by the mission, such as in a space vehicle, supersonic aircraft or submarine. Thermodynamics of heat and mass transfer in air mixtures as related to the control of temperature, humidity, and purity. Study of the basic characteristics of various types of equipment, such as heat exchangers, compressors and expansion engines, and control devices. System integration and optimization. Extensive study of a particular system with emphasis on the application of fundamental principles to the design of a practical environmental control system. *Hesselschwerdt*

**2.649 Low Temperature Refrigeration (A)**

Prereq.: 2.403 or 2.42

Year: G (1 or 2)

3-3-6

Thermodynamic processes for producing low-temperature refrigeration. Problems of heat exchangers, insulation and rectification. Applications of low-level refrigeration to purification of oxygen and nitrogen. Laboratory projects on related topics according to individual interests. *J. L. Smith*

**2.652 Experimental Stress Analysis**

Prereq.: 2.01

Year: U (1 or 2)

2-3-4

Common experimental methods of analyzing stress distributions. Photoelasticity, birefringent coatings, brittle lacquers, strain gage techniques and instrumentation, as applied to problems involving static, dynamic, and residual stress distributions. *Murray*

**2.653 Research in Experimental Stress****Analysis (A)**

Prereq.: 2.652

Year: G (1 or 2)

Arr.

Application of experimental methods to the solution of special problems; current development of theory and technique. *Murray*

**2.654 Physical Measurement and Analysis**

Prereq.: 8.02, 18.02

Year: U (1, 2)

2-6-4

Experimental techniques presented for observation and measurement of fundamental engineering quantities such as: displacement, force, torque, time, velocity, acceleration, temperature, pressure, and flow. Quantities for carrying out these measurements including the following: electrical (resistive, inductive, capacitive), mechanical, pneumatic, hydraulic, radio-tracer, and optical. Emphasis on a physical (and analytical) understanding of the static and dynamic behavior of measurement systems. Discussion includes statistical and dynamic analysis of data as well as dynamic analysis of the physical systems. Development in lectures of the background required for conducting the laboratory projects. Grading based primarily on laboratory reports. *Cook, Rabinowicz, Syniuta*

**2.67 Design and Experiment**

Prereq.: 8.02, 18.02

Year: U (1)

2-6-4

Student-defined research tasks relevant to an over-all goal of current interest. Definition of tasks, formulation of analytical models, and design and execution of ap-

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## MECHANICAL ENGINEERING

paratus, research plans, and experiments by small student groups under individual faculty counsel. Results periodically related to goal through student presentation and critique. *D. G. Wilson*

### 2.672 *Experimental Engineering I*

*Prereq.:* 2.01, 2.02, 2.201; 2.403 or 2.42

*Year:* U (2)

1-3-2

Engineering laboratory subject for mechanical engineering juniors. Major emphasis on the interplay between analytical and experimental methods in the solution of research and development problem. Groups of four students to work together on four problems for the term. Introduction to Mechanical Engineering Laboratory. *Glicksman*

### 2.673 *Experimental Engineering II*

*Prereq.:* 2.672

*Year:* U (1)

0-4-2

Engineering laboratory subject for mechanical engineering seniors. Continuation of 2.672, consisting of a single project to be worked on by a group of students under the supervision of a staff member. A report and presentation required at the end of the term. *Glicksman*

### 2.711 *Geometric Design*

*Prereq.:* —

*Year:* U (1, 2)

0-4-2

Introduction to the design of structures, products, and mechanisms in which geometry is an intrinsic factor. Exploration and discovery of the features of exemplary current designs. Instruction in design procedures through the assignment of a variety of challenging problems providing real experience in the formulation and development of original ideas. Applications of the fundamentals of statics and kinematics to evaluate proposed designs. Techniques of problem definition, analysis, and solution. Methods of display and model making to animate and validate finished designs. Typical design problems: geodesic structures, developable hulls and fusilages, containers for appliances, contemporary furniture, sports vehicles, geometric sculpture, and special-purpose mechanisms and tools. *Lent*

### 2.724 *Nomography*

*Prereq.:* —

*Year:* U (1, 2)

2-0-4

Graphical and computer-time-saving solutions of equations through using "alignment" diagram forms based upon determinants. Methods for more than three variables. The general projective transformation, cross-ratio, theory and use of central projection, determinant operators, dualities of point and line, point and plane, axis of homology, Quasi-alignment diagrams, near-canonical forms, empirical data. Answer-locus other than a straight line. Countable-bit representation of nomographic functional behavior. Nomographic solutions of non-linear differential equations, ordinary and partial, using Runge-Kutta methods. *D. P. Adams*

### 2.726 *Computer-Aided Design (A)*

*Prereq.:* 18.05

*Year:* G (2)

3-0-9

Study of newly emergent techniques for manipulation of large-scale digital computers in connection with the design process. Graphical input and output programs with their influence on techniques of shape description. Mathematics and graphics of general curved surfaces, curve fitting, curve smoothing. Graphical and symbolic methods for communication of the logical structure of problem solutions. *Staff*

### 2.731 *Engineering Design*

*Prereq.:* 2.02, 2.861

*Year:* U (1)

3-3-6

Instruction and experience in the integrated aspects of creative design and design analysis. In the context of an over-all system theme, individual students define and design interrelated projects, with original concepts and thorough engineering analysis equally stressed; lectures devoted to background information, competitive approaches, and pertinent disciplinary and theoretical material; frequent student presentations and critiques culminate in formal "professional" presentation to experts from industry and government. *Paul*

### 2.732 *Design Concepts*

*Prereq.:* 2.731

*Year:* U (1)

2-2-5

The concept-development stage of engineering design, centered around the planning and critical analysis of engineering systems. Case studies, drawn from problems of current and anticipated technological significance, carried out by student groups in cooperation with participating industrial organizations and academic laboratories within the Institute. Such topics as automated production equipment; analog and digital computation techniques in the design and control of engineering systems; data processing and materials handling; and the dynamics, control, and design of transport systems. Objectives: development of ability to plan, organize, and lead engineering projects of broad scope, basing decision on fundamental physical laws, experimental data, experience, and engineering judgment. *Baumann, Richardson*

### 2.733 *Special Problems in Systems and Design*

*Prereq.:* —

*Year:* U (1, 2)

*Arr.*

For undergraduates desiring to carry on substantial projects of own choosing in the areas of engineering design, system analysis or automatic control. Special lectures and seminars to be arranged when appropriate. Projects arranged on individual basis in consultation with instructor. *Mann*

### 2.734 *Advanced Projects in Systems and Design (A)*

*Prereq.:* —

*Year:* G (1, 2)

*Arr.*

For graduate students desiring to carry on substantial projects of own choosing in the areas of engineering design, system analysis or automatic control. Special lectures and seminars to be arranged when appropriate. Projects arranged on an individual basis in consultation with instructor. *Richardson*

### 2.737 *Theory of Modern Kinematics (A)*

*Prereq.:* 18.05

*Year:* G (2)

3-0-9

Classical and modern methods of kinematic analysis and synthesis with applications to mechanism design. Properties of plane rigid-body motion, centrodes, inflection and return circles, Ball's point, Euler-Savary and Bobillier Laws. Four-bar properties, coupler-curves, Roberts' theorem, cubic of constant curvature. Approximate straight-line techniques. Synthesis of mechanisms by Hain's point-position-reduction techniques. Number synthesis, kinematic pairs. Burmester theory, finitely and infinitely close points under a unified theory. Bottema's analysis of the instantaneous situation. Veldkamp's curvature theory. Tolerances and clearances in design, torque and force transmission techniques. Quaternions, motors. Dimenberg's screw calculus, dual quaternions. Uicker's matrix operators for plane and space displacements, velocity, acceleration and other problems. *D. P. Adams*

**2.74 Topics in Biomedical Engineering**

Prereq.: —

Year: G (2) 3-3-6

Examples, drawn from departmental research, of the application of engineering disciplines and techniques to significant problems in biology and medicine, e.g., fluid mechanical studies of the cardiovascular system, ultrasonic neural surgery, neuromuscular-machine control integration in artificial limbs, engineering properties of biological materials. Treatment of both engineering and physiological aspects of topics. *Mann*

**2.86 Manufacturing Project Laboratory**

Prereq.: —

Year: U (1, 2) 2-3-1

Discussion and laboratory experience covering modern methods of manufacture. First laboratory sessions directed towards development of the capabilities and limitations of manufacturing methods. Later laboratory sessions involving experimental investigation in depth of particular manufacturing operations with emphasis on the effects of material properties, friction and wear, and cost. Grading on the basis of laboratory work and reports. *P. A. Smith, Cook*

**2.861 Engineering Design and Manufacture**

Prereq.: —

Year: U (2) 4-4-4

Design principles applied to machine components. Philosophy of design stressing the creative approach to engineering problems. Comprehensive design project integrating functional requirements, proportions of elements and methods of production. Description and mechanics of manufacturing processes. Determination and application of materials test data to process analysis. Application of economic principles to manufacturing. *Lent, Cook*

**2.862 Machine Tool Fundamentals**

Prereq.: 2.86 or 2.861

Year: U (1) 2-1-2

Analysis of manufacturing processes with emphasis on manufacturing economics. Tool life studies, optimization of material removal rates, process and equipment selection based upon capabilities and minimum cost. Principles of quality control. Discussion of industrial organization and personnel problems associated with manufacturing. *P. A. Smith*

**2.865 Theory of Material Interface Phenomena (A)**

Prereq.: —

Year: G (1) 3-0-9

Theory of surfaces and interfaces, and influence of surface geometry and surface chemistry. Transmission of force, heat, electricity, mass. Phenomena of friction, wear, lubrication and adhesion. Characteristics of materials particularly suitable for interface action. Experimental investigation of interface phenomena. *Rabinowicz, Rightmire*

**2.866 Application of Material Interface Phenomena (A)**

Prereq.: —

Year: G (2) 3-0-9

Theories of metal processing including new electrical methods. Sliding systems including hydrodynamics, hydrostatics, gases, rolling contacts, and gears. Instrumentation applicable to this field. Statistical analysis of interface phenomena, and deduction of events occurring at the interface. *Cook, Nayak*

**2.869 Research in the Mechanical Processing of Materials (A)**

Prereq.: —

Year: G (1 or 2) *Arr.*

Opportunity for the student to work on a special problem of his choice in the general area of mechanical

processing, including: material removal, displacement or addition; the alteration of surface properties; or the measurement of processed parts. *Cook*

**2.901 Polymer Materials Science**

Prereq.: 5.01

Year: U (1) 3-0-9

Principles of macromolecular structure, their relation to properties of polymers and application to the design of engineering materials. Statistics of macromolecules and experimental determination of their sizes and shapes. Model structures: helices, extended chains, folded-chains and random coils. Theories of rubber elasticity, glass transitions and crystalline melting transitions. Melt rheology and extrusion theory. Survey of engineering properties of rubbers, proteins, glasses, plastics, and fibers. *Yannas*

**2.903 Elements of Textile Materials and Processes**

Prereq.: —

Year: U (1) 3-0-6

Characteristics of fibers as affecting processing and performance of textile intermediate and end products. Principles of textile manufacturing: treating operations such as blending, carding, combing, drafting, twisting, etc., and their combination into processes for natural and man-made fibrous materials. Principles of structural design of twisted, woven, knitted, braided, and felted materials. *Backer*

**2.904 Fiber Processing Dynamics**

Prereq.: 2.03

Year: U (2) 3-0-6

The mechanical interaction between fiber process manufacturing operations and the fiber, yarn, or fabric in process. Dynamics of fiber process operations, including analysis of ring spinning mechanics, balloon dynamics, traveller ring interactions, spindle vibration, shuttle dynamics, tension control, and fabric guiding and winding control. Process theory relating to product irregularity, blending statistics, drafting mechanics, and breakage probabilities. *Backer*

**2.905 Mechanics and Optics of Polymers (A)**

Prereq.: 2.30; or 2.901; or 5.01, 8.02

Year: G (1) 3-0-6

Theory of linear viscoelasticity and applications to the relaxation, creep, dynamic and stress-strain behavior of amorphous polymers. Principles of time, temperature and concentration superposition applicable to the small strain behavior of amorphous polymers. Principles of interaction of electromagnetic radiation with matter and their application to structural problems in amorphous and paracrystalline polymers. Specification of chain and crystallite orientation by X-ray diffraction, infrared dichroism and birefringence. Combined mechanical, thermal and optical studies of yielding, cold drawing and fracture phenomena in polymers, polymeric composite materials and biomedical materials. *Yannas*

**2.906 Principles of Macromolecular Physics (A)**

Prereq.: 2.30; or 2.901; or 5.01, 8.02

Year: G (2) 3-0-6

Elements of probability theory and their systematic application to the distribution of molecular weights, conformations and shapes of macromolecules; emphasis on the systematic construction of conceptual chains. Statistical mechanical theories of the glass transition, the helix-coil transition, crystalline melting, and rubber elasticity. Experimental testing of structural models and of statistical theories for synthetic as well as for biological macromolecules. *Yannas*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

METALLURGY AND MATERIALS SCIENCE

## 2.911 Polymer Physics Laboratory (A)

Prereq.: —  
Year: G (1 or 2) 3-6-3  
Determination of viscoelastic and physicochemical constants of synthetic polymers and biopolymers. Application to current research problems in the relation of molecular structure to the macroscopic properties of fibers, plastics, glasses, rubbers and proteins. Design of novel instruments for polymer research. (Limited enrollment. Open to advanced undergraduates by permission of instructor.)  
Yannas

## 2.912 Fiber Research Laboratory (A)

Prereq.: 2.913  
Year: G (2) 3-3-2  
Application of the research group method to solution of experimental problems. Exercise in analysis of material and structural properties affecting intermediate or end product behavior and in design of apparatus and/or experiments in fiber mechanics.  
Backer, Valko

## 2.913 Fibers and Polymers Seminar (A)

Prereq.: 2.30  
Year: G (1) 2-0-2  
Discussions of current problems in applied mechanics of fibrous assemblies. Differential geometry of twisted structures; translation of fiber properties into yarn behavior; role of fiber variability; mechanics of paper and other fibrous sheet materials; interaction of yarn and fabric structures. Analysis of woven, knitted, laminate, and composite materials used in engineering and apparel applications.  
Backer

## 2.914 Fibers and Polymers Seminar (A)

Prereq.: 2.913  
Year: G (2) 2-0-2  
Student and staff participation in critical discussions of important problems in fiber and polymer rheology, applied mechanics of fiber structures, and dynamic interactions between fibrous structures and manufacturing processes, together with reviews of the current literature and the results of researches in these fields at the Institute.  
Backer

## 2.951 Industrial Practice

Prereq.: —  
Year: U (S) 40 h.p.w.

## 2.952 Industrial Practice

Prereq.: —  
Year: U (1, 2) 0-8-0  
Approximately six months of practical work carried out by the Cooperative students in manufacturing, engineering, research, and development at the plants of the organizations which are participating in the Cooperative program.  
Murray

## 2.96J Legal Aspects of New Technology

(Same subject as 15.62J and 16.79J)  
Prereq.: —  
Year: G (1) 3-0-6  
Intellectual property and the law. The nature and progress of invention past and present, the evolution of relevant legal doctrines as an expression of public policy, and present legal doctrines for the treatment of intellectual property as trade secrets, proprietary data, copyrighted materials and patents. Critical analysis of the patent and copyright systems and pending legislation. The impact of selected new technologies—computer technology and xerography. The role of the Federal agencies—with emphasis on the Department of Defense and NASA. The employer-employee relationship, incentives for innovation, employment restraints and employee mobility. Term paper or project required.  
Baran

## 3.

### Metallurgy and Materials Science

## 3.00 Thermodynamics of Materials

Prereq.: 5.01 or 3.091  
Year: U (2) 4-0-8  
Essential concepts of thermodynamics and their application to the behavior of metals and materials. The first law of thermodynamics; thermochemistry; enthalpies of reaction, transformation, and solution. Introduction to the second law, entropy, the third law, work functions, chemical potential, and the phase rule. An introductory treatment of statistical thermodynamics.  
deBruyn

## 3.01 Thermodynamics and Statistical Mechanics

Prereq.: 3.00, 18.034  
Year: U (1) 3-0-9  
Intermediate thermodynamics and elementary statistical approaches. State properties and Jacobians; the first and second laws, heterogeneous and homogeneous equilibrium. Solutions. Electrochemistry. Surfaces and fields. Phase space; ergodicity; Maxwell-Boltzmann, Fermi-Dirac, and Bose-Einstein statistics. Equipartition; specific heats of classical and degenerate systems. Boltzmann transport equation; irreversible thermodynamics.  
R. M. Rose, Russell

## 3.02 Chemistry of Materials

Prereq.: 3.00, 5.01 or 3.091  
Year: U (2) 3-3-6  
Chemical characteristics of useful materials, elemental and compound. Relation of chemical properties to atomic structure and bonding. Quantitative measures of reactivity. Preparation of pure materials. Reaction of materials with environment, including protection.  
T. B. King, Rosof

## 3.03 Chemical Metallurgy

Prereq.: 3.01, 3.02  
Year: U (1) 3-0-6  
Application of principles of 3.02 to treatment of important metallurgical processes according to stoichiometric, thermodynamic, and kinetic viewpoints. Gas-solid reactions such as reduction of oxides. Slag-metal reactions in smelting. Gas-liquid processes such as distillation. Refining processes such as precipitation, segregation, vacuum melting and degassing.  
T. B. King

## 3.04 Materials Research Laboratory

Prereq.: 8.01  
Year: U (1, 2) 1-3-2

## 3.05 Materials Research Laboratory

Prereq.: 8.01  
Year: U (1, 2) 2-6-4  
Laboratory work on structure-property relations in materials. Introduction for all students to structure analysis techniques such as metallography (examination by light microscope) and X-ray crystallography, followed by assignment of each student to an individual faculty member and research project in one area, such as: mechanical properties, crystal growth, surface chemistry, electronic materials, superconductivity, electron microscopy, ceramics, chemical processing, electron diffraction, magnetic properties, high-temperature alloys, crystal imperfections. Periodic classroom discussion of laboratory project.  
Gatos

**3.06 Ceramics**

Prereq.: 3.00, 5.01, 18.034

Year: U (2)

3-0-6

Introduction to ceramics as a class of materials, emphasizing both advantages and disadvantages for selected uses. Application of structural knowledge, thermodynamics, and theories of deformation and transport processes to the analysis and understanding of selected ceramic processes, including fabrication of glasses and glass-ceramic materials, slip casting, plastic forming and sintering. *Mogab, Uhlmann*

**3.07 Physical Ceramics I**

Prereq.: 3.13 or 3.141

Year: U (1)

3-0-6

Characteristics of vitreous and crystalline non-metals. Relationships of atom arrangements and interactions to thermal, mechanical, and electrical properties. Application of phase equilibria, surface properties, atomic mobility, nucleation, and crystal growth to development of structure during fabrication, shaping, heat treatment, and use. Relationship of structures to thermal, electrical, and mechanical properties. *Kingery, Wuensch*

**3.08 Principles of Materials Separation**

Prereq.: 3.00

Year: U (2)

3-0-6

Separation of materials in solid, liquid, or gaseous form according to bulk or surface properties. Consideration of physical separations according to size, density, surface characteristics, magnetic and electrical properties. Chemical separations including adsorption, dissolution, precipitation, solvent extraction, and electrolysis. Application of principles to representative processes. (Not offered 1969-70.) *de Bruyn*

**3.091 Introduction to Solid-State Chemistry**

Prereq.: —

Year: U (1, 2)

5-0-7

Chemical and physical properties of solids as related to bonding, crystal structure, and structural imperfections. Mechanisms and energy changes in chemical reactions and phase transformations. *Wulff, Witt*

**3.10 Electrons and Atoms in Solids**

Prereq.: —

Year: U (2)

4-0-8

Crystals and chemical bonding. Electrons and waves in molecules and crystals. Electrical and magnetic fields in solids and liquids. Semiconductors, semiconductor devices and materials. Thermoelectricity. Magnetism. Dielectric and optical materials. Lasers and quantum electronics. Superconductivity. *R. M. Rose*

**3.11 Mechanics of Materials**

Prereq.: 8.01, 18.02

Year: U (1)

4-0-8

Response of materials and devices to applied forces interpreted on different structural bases, from the idealized continuum to the imperfections in natural crystals and molecular arrays. The transition from particle to continuum mechanics. Problems in statics. Structure of crystals. Elasticity: states of stress and strain; problems in rod- and sheet-like sections. Plasticity: behavior of crystals; combined-stress yielding in isotropic and anisotropic materials; strain hardening. Fluidity and viscosity. Fracture: theory and control in real materials. *Backofen*

**3.12 Principles of Crystallography and X-ray Diffraction**

Prereq.: 8.02, 18.02

Year: U (1)

4-3-5

Introduction to the nature of the solid state. Crystal geometry; space lattices, crystal systems, symmetry classes, and space groups. Atomic arrangements in

crystals and their determination by X-ray diffraction. Application of the reciprocal lattice in the solution of X-ray diffraction problems. The use of X-ray diffraction in the study of crystals by the Laue, rotating crystal, and powder methods. The role of atomic arrangements in polymorphism, order-disorder, phase transformations, deformation, and crystal growth. *Ogilvie, Wuensch*

**3.13 Materials Science I**

Prereq.: 3.01, 3.11, 3.12

Year: U (2)

4-3-5

Principles underlying the physical, mechanical and chemical properties of metals, ceramics, and polymers. Equilibrium and non-equilibrium phase relationships in one-, two-, and three-component systems; relation of symmetry to physical properties of crystals; mechanisms and kinetics of diffusion; structural imperfections and their influence upon mechanical properties; oxidation and corrosion. Emphasis upon correlation of properties with crystal structure and microstructure, including quantitative metallography. Use of laboratory experiments on some of the basic techniques to evaluate the structure and properties of materials. *Cohen, Breedis*

**3.14 Physical Metallurgy I**

Prereq.: 3.13 or 3.141

Year: U (1)

4-3-5

Extension of the principles of materials science to the metallic state; nucleation and growth; diffusion-controlled and diffusionless transformations; heat treatment and hardenability; thermal and transformation stresses; relaxation processes; continuous and discontinuous yielding; shear and cleavage fracture; quench aging and strain aging; engineering alloy systems. Laboratory experiments planned and conducted by the students in small groups; providing introduction to research in physical metallurgy; emphasis on report writing, in cooperation with the Department of Humanities. *Bever, Cohen*

**3.141 Science of Materials**

Prereq.: 8.01

Year: U (1, 2)

4-3-5

Principles underlying the structure and properties of materials. Lecture and laboratory work in atomic, molecular, crystal, and phase structure of solids. Emphasis on equilibrium and non-equilibrium transformations in multicomponent systems. Study of the kinetics of nucleation and diffusion in relation to recovery, recrystallization, and grain growth. Correlation of structure in metals, ceramics, and polymers with chemical and mechanical behavior. Laboratory experiments concerned with structure and properties of materials. *Flemings, R. M. Rose*

**3.144 Physical Metallurgy I**

Prereq.: 3.13 or 3.141

Year: U (1)

4-0-4

Same as 3.14 but without laboratory. *Bever, Cohen*

**3.15 Materials Science II**

Prereq.: 3.13, 8.03, 18.034

Year: U (2)

4-3-5

Introduction to the physics of solid materials from a phenomenological or experimental point of view. A brief discussion of the quantum theory of atomic structure, followed by a treatment of solids invoking free electron and nearly free electron concepts. Topics discussed: electrical and thermal properties of metals, semiconductors and insulators; optical properties; magnetic properties, including the simpler theories of dia-, para-

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

METALLURGY AND MATERIALS SCIENCE

and ferromagnetism. Treatment centered on the effect of structure, both atomic and microscopic, on physical properties. Selected experiments performed in the laboratory; a time-sharing computer used for problem solving, employing the MAP system, and requiring no prior computing experience. *Kaplow, Moss*

### 3.16 Physical Metallurgy II

Prereq.: 3.14 or 3.144

Year: U (2)

2-4-4

Factors affecting mechanical, chemical, and physical behavior of materials in service. Property, processing, and economic considerations in materials selection. Laboratory on commercial metals and alloys, with emphasis on microstructures and their interpretation. Classes of alloys; examination of normal and defective materials. *Pelloux*

### 3.17 Case Histories in Engineering Science

Prereq.: —

Year: U (2)

3-0-3

Study of actual processes leading to induction of generalizations and their subsequent application in science and engineering. Discussion in depth of a few case histories of recent and current investigations in which M.I.T. metallurgy and materials science faculty have played an active role. Participation by the students in evaluating key factors leading to scientific and engineering success on the basis of these detailed case histories. *Kingery*

### 3.18 Materials Processing

Prereq.: 3.13 or 3.141

Year: U (1)

4-3-5

Fundamentals of heat flow applied to hardening metals, tempering glass, foundry mold design, and splat cooling. Heat and material flow applied to solidification of metals and alloys, forming glass, zone refining and welding. Emphasis on control of structure and texture. Material flow applied to glass drawing, metal rolling, extrusion of materials, vapor growth of crystals, powder processing of metals and ceramics, hot pressing, and metal-ceramic sealing. Choice of experiments from current laboratory processing studies and operations. *Coble*

### 3.188 Materials Processing

Prereq.: 3.13 or 3.141

Year: U (1)

4-0-4

Same as 3.18 but without laboratory. *Coble*

### 3.19 Techniques of Metal Sculpture

Prereq.: —

Year: U (1, 2)

0-4-2

Workshop devoted to learning techniques for the translation of design to modern metal sculpture: brazing, welding, forming, cutting; mechanical and chemical finishing, and patinas. Basic materials involved: steels, aluminum, brass, copper, and stainless steel, in the simple forms: tubing, rod, sheet, strip and bar. Complex industrial shapes will also be utilized, as well as junk sculpture. (Limited enrollment.) *Staff*

### 3.20 Thermodynamics in Metallurgy (A)

Prereq.: 3.01

Year: G (1)

4-0-8

Advanced treatment of the thermodynamic properties of inorganic materials. Introductory statistical thermodynamics and surface thermodynamics. Application of the laws of thermodynamics to the chemical behavior of elements, compounds and solutions. Discussion of heterogeneous equilibria, chemical reactions, effect of different potential fields and the thermodynamics of structural defects. *Rosof*

### 3.21 Kinetics in Metallurgy and Materials Science (A)

Prereq.: 3.01, 3.13

Year: G (1)

4-0-8

Unified treatment of kinetics from phenomenological and atomistic viewpoints. Diffusion in metals and non-metals, including boundary value problems in growth, coarsening, and homogenization; mechanisms, high diffusivity paths, and diffusional instabilities. Rate laws, consecutive and competing reactions, absolute rate theory. Homogeneous and heterogeneous nucleation kinetics including condensation, film deposition, solidification, precipitation and diffusionless transformations. Frequent introduction of examples to illustrate principles discussed. *Cahn, Elliott*

### 3.22 Defects in Solids (A)

Prereq.: 3.01, 3.13

Year: G (2)

4-0-8

Point, line, and surface defects considered primarily from a theoretical viewpoint. Tensor elasticity treated as prelude to dislocation theory. Theory of perfect and disassociated dislocations and their interactions with surroundings. Surface thermodynamics with regard to equilibrium forms, kinetics, and stability. Equilibrium configuration, formation, and removal of point defects in metallic and non-metallic materials. *Russell, Mogab*

### 3.23 The Structure of Matter (A)

Prereq.: 3.12

Year: G (2)

3-0-9

Atomic arrangements and symmetry elements which describe crystalline and non-crystalline liquids and solids; physical and chemical properties for a number of significant cases to emphasize the important features of these structures. Brief treatment of methods used in determining structures as they apply to each class of materials; principal objective, to provide a systematic treatment of atomic configurations in order to introduce a structural basis for the discussion of electrical, magnetic, and other physical properties. *Averbach*

### 3.24 Structure and Properties of Metals (A)

Prereq.: 3.12; 3.14 or 3.144

Year: G (2)

3-0-6

Systematic treatment of the relations between the structure of metals and their properties. The elements of structure, especially grain structure; substructure, preferred orientation and the morphology of multiphase systems, with emphasis on quantitative aspects. The structural features of order phenomena, coherency and cold worked metals. Analysis of the effects of structural variables on mechanical, electrical, magnetic and other selected properties. *Bever*

### 3.30 Strengthening Mechanisms in Metals (A)

Prereq.: 2.332 or 3.22

Year: G (1)

2-0-4

Theories of strength of perfect and imperfect crystals, solid-solution hardening, strain hardening, crystal-size effects and precipitation hardening. Emphasis upon both the fundamental and applied aspects of achieving high strengths in metals through control of composition and structure. Frequent reference to current literature. *Breedis*

### 3.31 Phase Transformations in Metals (A)

Prereq.: 3.20, 3.21

Year: G (2)

3-0-9

Advanced treatment of phase transformations, including solidification, crystal growth, precipitation, eutectoids, recrystallization and grain growth, order-disorder and martensite. Emphasis on phenomenological understanding of kinetics and resultant morphology in terms of thermodynamics, transport processes and interface structure. *Cahn*

**3.32T Introduction to Electron Optics and Electron Microscopy (A)**

Prereq.: 3.12, 3.13

Year: G (2)

2-4-6

Detailed treatment of the design, construction, and application of electron optical instruments such as the electron microanalyzer, scanning electron microscope, and the transmission electron microscope; principles of electron interaction with matter, and in particular the study of diffraction contrast effects in foils containing lattice defects or precipitates. Emphasis on the use and reliability of methods employed in the study of materials. Laboratory work stressing use of the instruments and specimen preparation.

*Ogilvie, Breedis***3.34 Advanced X-ray Metallurgy (A)**

Prereq.: 3.12

Year: G (2)

1-3-2

More detailed treatment of principles discussed in 3.12T. Short research projects that deal with the study of particle size, strain, phase diagrams, diffusion, hardening and related topics carried out in the laboratory.

*Ogilvie***3.35 Solidification Processing (A)**

Prereq.: 3.13 or 3.141

Year: G (2)

2-0-4

Principles of control of structure, properties, and shape in processes involving liquid-solid and vapor-solid transformations. Heat flow, solute redistribution, nucleation, growth kinetics. Resultant structures and properties. Examples drawn from commercial processes, including metal casting, zone refining, electrodeposition, and crystal growth from the melt, vapor, and solution.

*Flemings***3.36J Welding Engineering (A)**

(Same subject as 13.151J)

Prereq.: 3.13 or 3.141

Year: G (1)

3-0-6

Detailed study of processing variables involved in joining materials by welding, brazing, and adhesive bonding. Synthesis of elementary physical phenomena such as transient heat flow, phase transformations, and dimensional changes into the complex over-all reactions associated with joining. Testing, inspection, and properties of finished joints. Laboratory demonstrations of arc, electron beam, resistance, and other electric welding processes.

*Masubuchi***3.37 Deformation Processing (A)**

Prereq.: 3.11; 3.13 or 3.141

Year: G (2)

2-0-4

Processing for shape change and property control by plastic deformation and fracture. Analyses of processing systems in terms of basic, interacting problem areas. Strength and plasticity in isotropic and anisotropic or textured states; slip-line field and limit analysis. Boundary conditions of friction and lubrication in a two-metal interface. Material behavior at high temperature and strain rate; structural changes, plastic instability and fracture; viscous forming. Resulting microstructure, texture, and properties. Apparatus and control as related to process choice and trends in processing. Examples for discussion from a wide range of industrial operations.

*Backofen, D. L. Holt***3.38 Behavior of Metals at Elevated Temperatures (A)**

Prereq.: 3.13 or 3.141

Year: G (1)

2-0-4

Study of metal and alloy behavior above the minimum recrystallization temperature. Creep, stress rupture and fatigue interpretation. Relationships between structure and properties in terms of strength and ductility. Strengthening mechanisms. Nature of high-temperature deformation and fracture.

*Grant***3.39 Fracture Mechanisms in Metals (A)**

Prereq.: 2.30 or 3.11

Year: G (2)

2-0-4

Advanced treatment of the mechanisms of brittle and ductile fracture in metals. Relation of fracture toughness to microstructure, environment, and time-dependent factors. Application to fracture of engineering structures and fracture in processing. Emphasis on recent research.

*D. L. Holt, Pelloux***3.40J Laboratory in Physics of Solids (A)**

(Same subject as 6.641J)

Prereq.: 3.15 or 6.08; 8.04 or 8.211

Year: G (1, 2)

0-8-4

Experimental investigations on the physical properties of materials closely related to current research; brief lectures on the basic theories and experimental methods. Experiments in areas of X-ray diffraction, galvanomagnetic effects, superconductivity, ferroelectricity, crystal growth, infrared absorption, Mössbauer effect, thermal properties, magnetic resonance, dielectric properties, carriers in semiconductors, elastic constants, defect structures.

*Moss, A. C. Smith***3.41T Introduction to Theoretical Methods in Physics of Solids**

Prereq.: —

Year: G (1)

4-0-8

Unified treatment of fundamental physical and mathematical concepts prerequisite to developing an understanding of the quantitative theories of solid-state phenomena. Lectures on basic topics in classical electrodynamics, quantum mechanics, and statistical physics. Special topics: the semiclassical theories of the interaction of electromagnetic radiation with matter; the application of quantum statistics to the electron and photon gases.

*K. H. Johnson, Averbach***3.42J Physics of Solids (A)**

(Same subject as 6.651J)

Prereq.: 3.41T; or 6.03T and 8.211

Year: G (1)

3-1-8

First term of a two-term sequence presenting the basic concepts of the quantum theory of crystalline materials. Emphasis on mathematical methods and physical models which have proven to be generally useful in obtaining quantitative descriptions of physical quantities. Student use of a computer console to solve quantitative problems; no programming experience necessary. Topics include: diffraction of X rays, electrons, and neutrons by solids; periodic structures and reciprocal space; lattice dynamics, normal modes and phonons; quantum statistics; electron states in solids, Bloch waves and energy bands; perturbation theory; classification of solids.

*Kaplow, A. C. Smith***3.43J Physics of Solids (A)**

(Same subject as 6.652J)

Prereq.: 3.42J or 6.651J

Year: G (2)

3-1-8

Second term of a two-term sequence presenting the basic concepts of the quantum theory of crystalline materials. Topics: dynamics of electrons in solids, effective mass theorem; transport phenomena, electrical conductivity; magnetic phenomena, angular momentum and spin; paramagnetism, diamagnetism, ferromagnetism; interaction of radiation with solids, optical properties, resonance phenomena.

*Sellmyer, A. C. Smith*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

METALLURGY AND MATERIALS SCIENCE

## 3.50 *Thermodynamics in Process Metallurgy (A)*

Prereq.: 3.03, 3.20

Year: G (2)

3-0-6

Advanced treatment of the thermodynamic properties of metallurgical systems with emphasis on molten metals, slags, and mattes. Reactions of molten iron, steel, and other metals with slags and gases. Problems in the refining and solidification of metals, and other selected topics. Use of computer time sharing in metallurgical problems. (Alternate years.) Elliott

## 3.51 *Process Metallurgy (A)*

Prereq.: 3.03

Year: G (2)

3-0-6

Study of integrated metallurgical processes. Application of the fundamental treatment of 3.03 to the extractive metallurgy of the more common metals, such as iron, copper, zinc and aluminum, and of less common metals such as titanium, molybdenum, and chromium. T. B. King

## 3.52 *Dynamic Behavior of Metallurgical Systems (A)*

Prereq.: 3.01, 18.034

Year: G (2)

3-0-6

Interpretation of the behavior of metallurgical systems by application of the methods of process analysis and control theory. Modeling of systems and exploration of their characteristics with digital and analog computers. (Alternate years. Not offered 1969-70.) Elliott

## 3.53 *Electrochemistry (A)*

Prereq.: 3.01

Year: G (1)

2-0-4

Development of principles underlying galvanic cells, conductance, electrode kinetics, double layers; with assignment of typical numerical problems. Discussions of application to practice, including electro-analysis, electroplating, electro-winning, primary and secondary cells, electrophoresis. Uhlig

## 3.54 *Corrosion (A)*

Prereq.: 3.01

Year: G (2)

3-0-5

Quantitative application of electrochemical principles to corrosion reactions. Effect of metallurgical factors; atmospheric, soil, or aqueous environments; oxidation and tarnish; stray currents; cathodic and anodic protection; metallic, inorganic and organic coatings; inhibitors; treatment of water and steam systems; selection of materials. Uhlig

## 3.55 *Mineral Engineering*

Prereq.: 3.08

Year: G (1)

2-0-4

Application of the principles discussed in 3.08 to mineral engineering problems. Emphasis on the case system of study of actual operations. Sample topics: magnetic concentration of taconites and formation of quality pellets for iron smelting; flotation of porphyry copper ores and recovery from the copper concentrates of molybdenite by-product; manufacture of sulphuric acid from smelter gases and its fixation by phosphate-rock concentrates to obtain various phosphatic fertilizers; leaching recovery of uranium and gold from low-grade ores; recovery of gem diamonds from alluvial or beach deposits; flotation and leaching recovery of potassium chloride from sylvinitic ores. Gaudin

## 3.60 *Physical Ceramics II (A)*

Prereq.: 3.07

Year: G (2)

3-0-6

Effects of composition and structure on properties of crystalline ceramics. Anisotropy, tensor representation of properties, and effect of crystal symmetry. Applica-

tion to piezoelectricity and elastic properties of ceramics. Propagation of elastic waves in crystals. Discussion of thermal conductivity, heat capacity, magnetic and ferroelectric behavior, with emphasis on real materials and influences of microstructure. Wunsch

## 3.61 *Physical Ceramics III (A)*

Prereq.: 3.60

Year: G (1)

3-0-6

Structure of amorphous solids. Effects of composition and thermal history on properties of glasses, including discussions of recent publications. Uhlmann

## 3.62 *Electrical and Optical Properties of Ceramics (A)*

Prereq.: 3.07, 3.60

Year: G (1)

3-0-6

Discussion of the electrical and optical properties of crystalline ceramics in terms of defect chemistry, band theory and transport theory. Emphasis on effects of composition and microstructure on the properties of real materials. Mogab

## 3.63 *Ceramic Processes (A)*

Prereq.: 3.06 or 3.07; 3.20; 3.21

Year: G (2)

3-0-6

Phase equilibria and ceramic phase diagrams applied to microstructure development. Description and analysis of various kinetics of microstructure development and ceramic forming processes. Critical aspects of processing as related to property development and control. Coble

## 3.64 *Special Problems in Ceramics (A)*

Prereq.: —

Year: G (1, 2)

Arr.

Advanced work in this field. Lectures, conferences, assigned readings, and laboratory work. Kingery

## 3.65 *Ceramics Seminar (A)*

Prereq.: 3.06 or 3.07

Year: G (1, 2)

1-0-2

Individual talks followed by group discussion on current research and developments in ceramics by staff, students, and invited speakers. Uhlmann

## 3.70 *Special Problems in Metallurgy (A)*

Prereq.: —

Year: G (1, 2)

Arr.

Minor investigation in one of the special branches of metallurgy. (Open only to graduate students properly qualified in the special field.) Staff

## 3.701J *Properties of Metals*

(Same subject as 13.161J)

Prereq.: —

Year: G (2)

4-1-6

Properties of metals with reference to materials used in ship construction. Microstructure, processing, heat treatment, joining and corrosion resistance of non-ferrous and ferrous metals. (Primarily for selected officers of the U. S. Navy and Coast Guard.) Floe, Masubuchi

## 3.72J *Nuclear Fuels (A)*

(Same subject as 22.72J)

Prereq.: 3.13 or 3.14 or 22.71

Year: G (1)

2-0-6

Behavior of nuclear fuels and fuel element cladding materials in reactor cores. Experimental observations and

theory of radiation damage to metals and ceramics of practical interest. Processes for fabricating fuel elements and fuel assemblies; fuel fabrication costs. Recent developments of advanced reactor core materials. (*Alternate years.*) *Ziebold*

**3.721J Radiation Damage in Crystalline Solids (A)**  
(Same subject as 22.721J)  
*Prereq.:* 3.13 or 3.14 or 22.71  
*Year:* G (1) 2-0-6

Theory of atomic displacements, cascades, and spike phenomena produced in metals and ceramics by high-energy radiation bombardment. Recovery of damage related to mobility and structure of crystalline imperfections. Discussion of radiation damage experiments of technological importance and basic experiments designed to test the theory of damage production and recovery. Consideration of special problems associated with damage in fissionable materials. Brief outline of the role of materials in nuclear reactor design. (*Alternate years.*) *Not offered 1969-70.* *Ziebold*

**3.73 Applications of Digital Computers (A)**  
*Prereq.:* —  
*Year:* G (1) 3-1-4

The theory and practice of computer programming and digital computation techniques with examples of analysis useful in research. Series expansion, integration, table look-up and interpolation, iterative solutions, matrix operations, least-square fitting, Fourier transforms, differential equations, relaxation procedures, policy improvement, Monte Carlo methods. IBM 360/65 computer used. *Kaplow*

**3.75 Structure and Properties of Interfaces (A)**  
*Prereq.:* 3.01  
*Year:* G (1) 3-0-6

Examination of the salient physical and chemical characteristics of surfaces from a macroscopic and atomistic viewpoint. Emphasis on the thermodynamic description of systems with plane and curved surfaces, the kinetics of surface processes, atomic and electronic configuration of interfaces and the electrochemical nature of phase boundaries. Application of principles to wetting and spreading, adhesion, electrode processes, measurement of surface tension of solids. Discussion of the role of surfaces in nucleation, crystal growth, catalysis. (*Not offered 1969-70.*) *de Bruyn*

**3.76J Electronic Materials (A)**  
(Same subject as 6.64J)  
*Prereq.:* 3.15; or 6.02 and 6.13; or 6.02 and 6.341  
*Year:* G (2) 2-0-6

Various aspects of electronic materials such as preparation, purification, crystal growth, crystal structure, characterization, electronic properties, band structure and device applications. Special emphasis on relationships between structural characteristics, atomic bonding and physical properties in classes of materials such as elemental and compound semiconductors, thermoelectrics and superconductors. Extensive rather than intensive coverage. *Gatos, Witt*

**3.77 Laboratory Measurement and Control**  
*Prereq.:* —  
*Year:* G (1) 2-1-3

Discussion of laboratory techniques. Instrument characteristics. Basic electrical circuits. Transducers for force, stress, pressure, displacement, flow, and temperature input. Vacuum techniques. Special methods such as radio tracers, ultrasonic, laser. Control and recording systems. Analysis of experimental data. *Blucher*

## 4. Architecture

**4.011 Graphics Laboratory I**  
*Prereq.:* —  
*Year:* U (1) 0-3-2

Freehand drawing exercises to develop accurate observation and skill in graphic representation. Linear, light and shadow, detail and perspective renderings of varied subject matter. Control of line, value, color, texture and form using pencil, pen, and brush. (*Not offered 1969-70.*) *Preusser*

**4.012 Graphics Laboratory II**  
*Prereq.:* —  
*Year:* U (2) 0-3-2

Continuation of practice in representational techniques. Exercises employing graphic devices useful in all types of freehand drawing. Use of charcoal pencil, pen and ink, and water color as effective means to create the graphic equivalent of what is observed or visualized. (*Not offered 1969-70.*) *Preusser*

**4.013 Graphic Composition**  
*Prereq.:* 4.032  
*Year:* U (1) 2-4-6

Study of visual abstraction based on graphic images. Study projects centering on aesthetics of surfaces, visual counterpoint, optical illusions, pictorial motion, compositions of positive and negative area relationships, the concrete and the amorphous, analogous and complementary, exploration of symbolic images. Objective: realization of visual meaning and composition through synthesis of graphic imagery. *Staff*

**4.021T Visual Design Problems I**  
*Prereq.:* —  
*Year:* U (1, 2) 1-4-4

Studio participation in problems of visual invention, organization, and expression. Development of visual awareness, imagination, and creative insight focused upon subjective qualitative values. Experimentation in application of materials, tools, and processes unique to each student's professional field encouraged as means of gaining confidence and ability to create visual form. *Kraynik*

**4.022T Visual Design Problems II**  
*Prereq.:* 4.021T or 4.051T or 4.071T  
*Year:* U (2) 1-4-4

Visual design experiments with emphasis on inventive use of media. Studio procedures individually directed enabling students to formulate and execute independent projects. Opportunity to explore industrial materials, tools and techniques, physical processes, natural forces, mathematical ideas and scientific instruments as means for innovating visual art forms. *Kraynik*

**4.023 Visual Design Projects**  
*Prereq.:* 4.032  
*Year:* U (2) 2-4-6

Investigation of visual potential inherent in science and technology. Inventive manipulation of materials, tools, and techniques as means for broadening basis of visual thinking and clarifying interaction between concept, media, and design principles. Specific problems of visual form with special attention given to relationship of art to architecture and urban environment. *Staff*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## ARCHITECTURE

### 4.031 *Form and Design I*

Prereq.: —

Year: U (1) 2-4-6

Study of the visual elements of form to understand the processes of form synthesis. Studio experiments and lectures on proportion, shape, rhythm, visual quality of materials and three-dimensional composition. Emphasis on imagination and visual sensitivity directed to enlarge the individual's ability to create an aesthetic form.

Filipowski

### 4.032 *Form and Design II*

Prereq.: 4.031

Year: U (2) 2-4-6

Three-dimensional experiments and lectures on the organization of quantities, unit to volume relationships, modularity and form, volume and structure, surface structure of volume, space composition, point, line, plane composition, and sculptural composition. Emphasis on architectonic and sculptural aesthetic of form.

Filipowski

### 4.033 *Form and Color I*

Prereq.: 4.031

Year: U (1, 2) 2-0-4

Examination of color in natural form followed by experiments involving the color and form relationship to proportions, percentages, repetition, directions, quantity organization, structural order, angle position, and volume composition. A study to gain knowledge of color for the refinement of architectural form.

Filipowski

### 4.034 *Form and Color II*

Prereq.: 4.032

Year: U (1, 2) 2-4-6

Study of color in relation to visual refinements of form — hue, value and chroma relationship from the general to the particular. Sequence of study projects involving color and area, texture, periodic patterns, random configurations, color depth, black and white, visual vibrations, color and natural form, volume, structure, motion, object and the color environment, and the visual influence of color on spaces.

Filipowski

### 4.04 *Light and Color*

Prereq.: 4.031

Year: U (2) 0-9-11

Study of light and color in all aspects relevant to their creative manipulation in art and architecture. Studio work supplementing a survey of the physical, physiological, and psychological phenomena of light and color. Analysis of the historical use of these elements and exploration of new tools and media.

Kepes

### 4.041 *Light and Color I*

Prereq.: 4.032

Year: U (1) 2-4-6

Study of psychological and physiological phenomena of light and color. Lectures, demonstrations and exercises to determine the vocabulary of these elements, their relevance to communication and use in creating visual form. Utilization of photography to analyze light as a form-giving element and creative tool. Advances in techniques for generating light and producing color investigated and utilized in studio work.

Kepes

### 4.042 *Light and Color II*

Prereq.: —

Year: G (2) 0-9-11

Content same as 4.04.

Kepes

### 4.051T *Creative Photography I*

Prereq.: —

Year: U (1, 2) 2-6-1

Exposure of the beginning student to photographic technique involving camera, light, film, chemicals and paper.

Development of a sense for composition through visual exercises and analysis of photographic images. Development of the student's awareness of his own way of seeing through exposure to many photographic images — his own, his instructors', exhibited gallery prints, and those of our mass media. (*Limited enrollment.*) G. C. Thomas

### 4.052T *Creative Photography II*

Prereq.: 4.051T

Year: U (1, 2) 2-6-1

Examination of the photograph as a visual statement about the human condition, in which moments related to time are converted into images related in space. Lectures and class discussion on technical, psychological, and graphic-layout problems followed by ten weeks of individual photographic projects resulting in completed visual or audio-visual presentations. (*Limited enrollment.*)

G. C. Thomas

### 4.053T *Evaluating Photography*

Prereq.: 4.031 or 4.051T

Year: U (1, 2) 3-1-5

Introduction to an existential basis of criticism for photography. Investigation of public response to photographs and critical standards. Photography that evokes as well as communicates. Involvement with existing images instead of making photographs. (*Also open to exchange and special students with design and humanities backgrounds by consent of instructor. Limited enrollment.*)

M. White

### 4.054 *Advanced Photography*

Prereq.: 4.032

Year: U (1, 2) 2-4-6

Application of both the recording and transforming powers of the camera to the problems of direct contact with subject matter and the indirect use of photometaphor for the varied purposes of visual evocation. (*May be repeated for credit. Limited enrollment.*)

M. White

### 4.055 *Problems in Photography*

Prereq.: —

Year: G (1, 2) Arr.

Theoretical and practical studies in seminar, studio, and field to introduce and develop the full scope of photography as craft, art, and public medium. (*Limited enrollment.*)

M. White

### 4.06 *Advanced Visual Design (A)*

Prereq.: —

Year: G (1, 2) Arr.

Studio projects in the visual arts as elements in an architectural setting; visual communication through exhibition design, posters, and architectural use of lettering and signs; visual documentation, or the graphic presentation of environmental situations and ideas.

Kepes

### 4.071T *Painting*

Prereq.: —

Year: U (1) 1-4-4

Practice in the art of painting coordinated with theory related to contemporary concepts in the light of historical development. Language of art with emphasis on structure and content advanced by lectures and demonstrations as framework for studio activity. Creative capacity and analytical ability challenged by studio and seminar participation. Manipulation of the visual elements in painting utilizing principles of organization to realize individual expression through pictorial means. Primary goal: experiencing the artist's process and understanding visual values and meaning of art in culture.

Staff

- 4.081 Plastic Composition**  
*Prereq.:* 4.032  
*Year:* U (1, 2) 2-4-6  
 Study of plastic sculptural form based on continuity of surfaces, synthesis of diverse geometries, group form relationships, object and the landscape, and the optimum three-dimensional relationship of the object. Studies directed toward inventiveness and meaning of sculptural form.  
*Filipowski*
- 4.091J Introduction to Film Making**  
 (Same subject as 21.994J)  
*Prereq.:* —  
*Year:* U (1, 2) 4-6-2  
 Workshop exploration of the potentialities of the motion picture as documentary and as a means of personal and political expression. Series of exercises combining filming, editing, and sound. Viewing and discussion of many films. Ample opportunity for students to experiment with various film techniques.  
*Pincus*
- 4.121 Architectural Design<sup>1</sup>**  
*Prereq.:* —  
*Year:* U (1) 2-5-5
- 4.122 Architectural Design<sup>1</sup>**  
*Prereq.:* 4.121  
*Year:* U (2) 2-5-5  
 Establishment of basic attitudes to architectural organization and its reflection in form. Small-scale problems whose imposed conditions of site, program, and building system emphasize the interrelationship of fundamental elements in the pattern of decision making that constitutes design. Presentations fully developed in drawings and models.  
*M. K. Smith*
- 4.131 Architectural Design<sup>1</sup>**  
*Prereq.:* 4.122  
*Year:* U (1) 0-6-6
- 4.132 Architectural Design<sup>1</sup>**  
*Prereq.:* 4.131  
*Year:* U (2) 0-6-6  
 Development of awareness of the principal issues facing the contemporary architectural designer and the range of possibilities available for effective satisfaction of common environmental needs. Work on separate building units with definitely stated use patterns with study of appropriate structural systems and search for the uses of building materials most expressive of their physical properties.  
*Staff*
- 4.143 Architectural Design (A)**  
*Prereq.:* 4.132, 4.32  
*Year:* G (1) 0-12-8
- 4.144 Architectural Design (A)**  
*Prereq.:* 4.143  
*Year:* G (2) 0-12-8  
 Study of more intensive and extended space uses, the grouping of buildings, buildings of multi-story construction, mass circulation movements, and areas requiring specialized space forms or equipment or having multiple uses. Consideration of the thermal problems of buildings, the distribution of daylight and artificial light, and the control of sound in buildings as they influence the design concepts and also in the installations associated with them.  
*Staff*
- 4.151 Architectural Design<sup>1</sup>**  
*Prereq.:* 4.144  
*Year:* U (1) 0-12-8  
 Emphasis on the setting of architectural work as part of an organized community in projects having to do with built-up areas as well as those on new sites. Study of plans for long-range development giving students increasing experience in the analysis of real-life situations requiring program research.  
*Staff*
- 4.153 Thesis Research**  
*Prereq.:* —  
*Year:* U (1, 2) 0-6-0  
 Selection of subject and site for undergraduate Bachelor in Architecture thesis project and determination of the requirements and conditions to be met in the solution. Independent work under the guidance of the Thesis Advisors.  
*Staff*
- 4.155 Architectural Design (A)**  
*Prereq.:* 4.144  
*Year:* G (1) 0-12-8  
 Same content as 4.151.  
*Staff*
- 4.157 Thesis Research (A)**  
*Prereq.:* 4.144  
*Year:* G (1, 2) 0-6-0  
 Selection of subject and site for graduate Bachelor in Architecture thesis project and determination of the requirements and conditions to be met in the solution. Independent work under the guidance of the Thesis Advisors.  
*Staff*
- 4.161 Architectural Design (A)**  
*Prereq.:* 4.151  
*Year:* C (1) 0-15-20  
 Advanced projects focused on development of a theme proposed by the section instructor, these themes being statements of professional opportunities and challenges of the next generation. Selection of sections and themes insofar as practicable by the student.  
*Catalano, Caminos*
- 4.162 Urban Design I**  
*Prereq.:* —  
*Year:* C (1) Arr.  
 Series of studio projects including observation, evaluation, and reporting of actual environments in use, the designing of prototypical urban design projects, and the predicting of the consequences of a design; emphasis on the development of basic urban design attitudes, methods and tools.  
*Myer, Porter*
- 4.163 Urban Design II (A)**  
*Prereq.:* 4.162  
*Year:* G (2) Arr.  
 Advanced projects in urban design such as the design of new towns, universities, urban renewal, and integrated urban transportation systems. Emphasis on the method, prediction, and evaluation of the design.  
*Staff*
- 4.17, 4.171 Architectural Design, Special Problems**  
*Prereq.:* —  
*Year:* U (1, 2) Arr.  
 Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.  
*Staff*
- <sup>1</sup>**Note about the subjects in Architectural Design**  
 The sequence in Architectural Design is a cumulative program. Its successful completion by the student is subject to the evaluation of the staff independently of formal grades accumulated.
- (A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## ARCHITECTURE

### 4.19 *Special Problems in Architectural Design* (A)

Prereq.: —  
Year: G (1, 2)

Arr.

### 4.191 *Special Problems in Architectural Design* (A)

Prereq.: —  
Year: G (1, 2)

Arr.

Supplementary design work for graduate students. Registration subject to prior arrangement for subject matter and supervision by staff. Staff

### 4.30 *Structures I*

Prereq.: 8.02, 18.02  
Year: U (2)

3-3-6

Introduction to the static behavior of structures. Determination of loads, deformations of determinate and indeterminate structures. Definitions of stress and strain at a point with an introduction to material behavior. Applications to stress distributions and deflections of slender elements in twisting and bending. Considerations of stability of structures in both elastic and plastic situations. The qualitative use of models to illustrate basic concepts as well as for solution of complex problems. Laboratory work giving students opportunity to produce creative designs for solving structural problems, with execution of these designs by building models and testing them. Groisser

### 4.31 *Structures II*

Prereq.: 4.30  
Year: U (1)

2-2-4

Comparative study of strength, stiffness, and stability of building elements of wood, metals, and reinforced concrete. Principles of connections in building elements. Study of structural systems including framed structures, pinned-truss structures, and two- and three-dimensional surface structures. Detailed study of systems using sawn timbers, laminated timbers, and plywood. Groisser

### 4.32 *Structures III*

Prereq.: 4.31  
Year: U (2)

2-2-4

Detailed study of design of metal structures. Simple frames, welded continuous frames, two- and three-dimensional trusses, plate girders, and cable structures. Methods of statically indeterminate analysis. Traum

### 4.331 *Structures IV (A)*

Prereq.: 4.32  
Year: G (1)

2-2-2

Detailed study of design of reinforced concrete structures. Floor systems, continuous frames, shell roofs, and plate systems. Principles of prestressed and precast concrete systems. Zalewski

### 4.341 *Structures V (A)*

Prereq.: 4.331  
Year: G (2)

2-0-4

Special structural problems. High-rise buildings including design for wind forces. Long-span roof structures. Optimum design of structural elements and systems. Application of electronic computers to planning and analysis of building structures. Staff

### 4.402 *Building Process*

Prereq.: —  
Year: U (2)

3-3-6

Principal building systems as affected by environmental and legal conditions, materials, and industrial constraints. Interrelationships among the parts of the system. Fundamental systems of enclosure, load distribution and environmental control; air, heat, light, sound. Assembly processes and principles of project control. Problems, projects, and field trips to illustrate principles. Dietz

### 4.42 *Materials*

Prereq.: 1.02  
Year: U (2)

3-2-3

Emphasis on newer materials and combinations. Development of properties and applications from fundamental structure of materials. Plastics and other polymeric materials. Engineering adhesives and principles of bonding. Wood derivatives and bonded structures. Ceramics. Glass. High-performance masonry. Metals and alloys. Composites of several materials: fiber-reinforced, laminates, and sandwiches. Principles of combined behavior. Deterioration of materials, protection against attack. Dietz

### 4.43 *Environmental Control — Acoustics*

Prereq.: 8.02  
Year: U (1)

3-0-5

Principles of acoustical design for good hearing conditions and control of noise in rooms and buildings; design criteria; analysis of sound absorption and transmission; acoustical properties of room shapes, structures, and surface materials; laboratory demonstrations. R. B. Newman

### 4.431 *Special Problems in Architectural Acoustics (A)*

Prereq.: 4.43  
Year: G (1 or 2)

Arr.

Broad study of functional acoustic design in architecture (based on project work in actual buildings where possible), sound distribution and diffusion in rooms, and sound transmission through building structures. R. B. Newman

### 4.601T *Topical Studies in the History and Theory of Art*

Prereq.: —  
Year: U (1)

3-0-6

Painting, sculpture, and architecture from pre-history to the present. The different motivations for visual art, its cultural implications, the various forms it has assumed, and the means of its production investigated relative to time and place. Theories of art and art history and methods of criticism presented and analyzed in lectures and discussions, and on visits to Boston area museums. W. V. Andersen

### 4.602T *Introduction to Modern Art*

Prereq.: —  
Year: U (2)

3-0-6

Painting and sculpture from the late eighteenth century to the present. An investigation of the theoretical basis for such different styles as neo-Classicism, Romanticism, Impressionism, Cubism, Constructivism, Surrealism, etc., and including the recent events of Abstract Expressionism and its aftermath. Presented both historically and topically. Problems of interpretation and criticism. W. V. Andersen

### 4.603T *Painting and Sculpture in the Middle of the Nineteenth Century*

Prereq.: —  
Year: U (1)

3-0-6

Art and artists in Paris around 1850, preceding the formulation of Impressionism in the late sixties and seventies. Manet, Degas, Pissarro, Monet, Renoir, the early Cézanne — their background and their achievements, their continuity into the eighties and importance for later phases of modern art. Special emphasis on nineteenth century color theory. W. V. Andersen

### 4.604T *Modern Art from Post-Impressionism to Cubism*

Prereq.: —  
Year: U (2)

3-0-6

Cézanne, Gauguin, Van Gogh, and Seurat presented against a background of Impressionism and other nine-

teenth century styles. Their relationship to the Synthetist, Nabis, and Symbolist groups. Required readings from letters and other writings by the artists, their artist and writer friends, and their critics. *W. V. Andersen*

**4.605T *Painting in the Twentieth Century***

Prereq.: ——— 3-0-6  
Year: U (2)

Cubism, Futurism, Constructivism and other phases of early twentieth-century art during which the theories, styles, and attitudes of contemporary art were formulated. Dadaism, Surrealism, and other intermediate phases leading to Abstract Expressionism in New York. Post-Painterly Abstraction styles, Pop Art, and the recent Optical Art Movement, considered both historically and critically. *Krauss*

**4.606T *Sculpture in the Twentieth Century***

Prereq.: ——— 3-0-6  
Year: U (2)

Development, against a background of Rodin and late nineteenth century sculpture, of the trends leading to the present-day situation. Special emphasis on Maillol and the "large-figure" style, Brancusi and direct carving; cubist, futurist, and constructivist sculpture. One-third of the subject devoted to American sculpture since 1930. *Krauss*

**4.607T *Twentieth-Century Art Theories***

Prereq.: ——— 3-0-6  
Year: G (1 or 2)

Seminar on the origin and interaction of the movements which established the formal vocabulary of most twentieth-century art. (*Open also to advanced undergraduates with consent of instructor. Not offered 1969-70.*) *W. V. Andersen*

**4.608T *Symbolism in Modern Art***

Prereq.: ——— 3-0-6  
Year: G (1 or 2)

Seminar on selected topics in the analysis of the content and meaning of modern art. (*Open to qualified students with consent of instructor.*) *Staff*

**4.61T *Architecture in the Ancient World***

Prereq.: ——— 3-0-6  
Year: U (2)

Analysis of role of mass, space, structure, light, surface, and related social, political, and economic factors in architecture and urban design from prehistory through Roman times. *Millon*

**4.62T *Architecture 1400-1750***

Prereq.: ——— 3-0-6  
Year: U (1)

Same as 4.61, but covering the period from the beginning of the Renaissance to the end of the Rococo. (*Not offered 1969-70.*) *Millon*

**4.621T *Origins of Contemporary Architecture in the Eighteenth Century (A)***

Prereq.: 4.601T or 4.62T or 4.64T 3-0-6  
Year: G (1)

Seminar surveying the principal works of architecture and major theoretical statements of eighteenth-century architects and writers in order to define, understand, and examine the origins of contemporary theoretical positions. *Millon, S. Anderson*

**4.63T *Architecture in the Middle Ages***

Prereq.: ——— 3-0-6  
Year: U (2)

Selected buildings and urban complexes from the time of Rome's conversion to Christianity to the beginning of the Renaissance. Special attention given to the influence on the builders of architectural traditions as well as significant religious, social, political and economic factors. *Staff*

**4.64T *Architecture from 1750 to the Present***

Prereq.: ——— 3-0-6  
Year: U (2)

Same as 4.63, but covering the period from the mid-eighteenth century to the present. *S. Anderson*

**4.641T *Modern Architecture in Germany from 1895 to the Bauhaus (A)***

Prereq.: 4.601T or 4.64T 3-0-6  
Year: G (1)

Art and architecture in Germany from the late nineteenth century to the time of the Nazi repression of modern art. Intensive study of the men, the works, and the controversies from which the European "modern movement" emerged, leading in turn to the transformation of American architecture. (*Not offered 1969-70.*) *S. Anderson*

**4.65T *Studies Toward a Theory of Architecture (A)***

Prereq.: ——— 3-0-6  
Year: G (1)

Seminar with the intent to stimulate thought about our contemporary theoretical position. Reports by seminar members either in the context of, or in criticism of, the thesis of the seminar. *S. Anderson, Millon*

**4.66T *Criticism of Architecture (A)***

Prereq.: ——— 3-0-6  
Year: G (2)

Seminar surveying the various approaches (social, environmental, economic, compositional, structural, functional, etc.) and bases for the criticism of architecture. Principal emphasis on formal bases of criticism. History of criticism, relation of criticism and history, value of criticism to the profession, criticism as a means of achieving quality in architecture, and criticism as a rational and emotional response to architecture. *S. Anderson, Millon*

**4.67T *History of Urban Form (A)***

Prereq.: ——— 3-0-6  
Year: G (2)

History of the city as an architectural form. Study of the physical growth of cities as an expression of a developing social structure as well as with reference to artistic ideals. *Staff*

**4.671J *Elements of Urban Evolution***

(Same subject as 21.92J)  
Prereq.: One first-year Humanities sequence 3-0-6  
Year: U (1)

Consideration of the forces, in different periods, determining the character and principal functions of cities — military, religious, commercial, political, industrial and utopian. Readings in literary, artistic, and historical sources. Independent individual student projects with a wide range of choice for production of term papers dealing with a particular city over a manageable time span, usually less than a century. Lectures and seminars. (*Limited enrollment.*) *Burchard*

**4.672J *Great Cities: Paris***

(Same subject as 21.93J)  
Prereq.: One first-year Humanities sequence 3-0-6  
Year: U (2)

Study of one great city as a non-static environment, relating the history of its physical form to social, economic

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## CHEMISTRY

and cultural forces. Survey of the major building complexes of Paris and the changing character of its environment from its founding to the present but with special emphasis on the time from the founding of Roman Lutetia, first century A.D., to the siege of Paris (1870-1871) and the subsequent Commune. Examination also of the later International Exhibitions, the Metro and the most recent developments. (*Limited enrollment. Not offered 1969-70.*) Burchard

### 4.681T *Theory and Method in the History of Art and Architecture*

*Prereq.:* — 3-0-6  
*Year:* U (1, 2)  
Selected research with written report. Intended primarily to prepare the student for graduate studies. (*Open only to advanced students in Program 4.*) Staff

### 4.691-4.695 *Selected Topics in the History of Art and Architecture (A)*

*Prereq.:* 4.601T, 4.602T; or 4.61T, 4.62T, 4.63T, 4.64T Arr.  
*Year:* G (1, 2)  
Special topics in the history of art and architecture, varying at the discretion of the instructor. Staff

### 4.701 *Architectural Communication*

*Prereq.:* — 4-2-2  
*Year:* U (1, 2)  
Communication with self (visualization), with others (presentation), and with machines (manipulation). Introduction to orthography, perspective, projective geometry, matrix algebra, descriptive geometry, diagrams, and models. Relationship between communication media and process or product. Negroponte

### 4.704 *Computer-Aided Urban Design (A)*

*Prereq.:* — 3-0-6  
*Year:* G (2)  
A workshop subject with students embarking on research projects of their choosing within the context of architect-machine communication as an aid to the design of urban environments. Special emphasis on machine partnership and programs of evolution. (*Note: Experience in programming a necessary prerequisite.*) Negroponte, Groisser

## 5.

## Chemistry

### 5.01 *Chemistry*

*Prereq.:* — 5-0-7  
*Year:* U (2)  
Structure of individual molecules, based on quantum theory of atomic energy levels. Methods of determining their structures through the use of spectroscopy. Dynamics of molecular collisions, and how these affect gas and liquid properties and the kinetics of chemical reactions. Coryell, Steinfeld

### 5.03 *Principles of Inorganic Chemistry I*

*Prereq.:* 5.41T; 5.63 or 8.04 3-0-9  
*Year:* U (2)  
Presentation of the theoretical principles of chemical bonding and molecular structure, and their application in a survey of the chemistry of all the elements of the periodic system. Emphasis on the lighter non-transition elements. Davison

### 5.04T *Principles of Inorganic Chemistry II*

*Prereq.:* 5.03 3-0-6  
*Year:* U (1)  
Theory and descriptive material relating to the heavier elements and the transition elements. Special emphasis on ligand field theory. Holm

### 5.065 *Advanced Inorganic Chemistry (A)*

*Prereq.:* 5.03 3-0-6  
*Year:* G (2)  
Extended treatment of some special topics of current interest in modern inorganic chemistry, organometallic compounds, and hydrides; treatment in terms of modern electronic and structural theory. (*Not offered 1969-70.*) Seyferth

### 5.067 *Chemical Applications of Group Theory (A)*

*Prereq.:* 5.04T 2-0-4  
*Year:* G (1)  
Elements of group theory and its application to problems of molecular structure; treatment of vibrational spectra of inorganic compounds; introduction to ligand field theory and its use in the interpretation of spectral and magnetic properties of compounds of the transition elements; other current problems in theoretical inorganic chemistry, as time permits. Cotton

### 5.09 *Radiochemistry (A)*

*Prereq.:* 5.62 3-0-6  
*Year:* G (1)  
Introduction to nuclear science of interest to chemists. Radioactivity, nuclear structure and reactions, radiation detection and measurement, preparation and separation of radionuclides, techniques and applications in nuclear chemistry. Coryell, Walters

### 5.091 *Radiochemistry Laboratory (A)*

*Prereq.:* 5.09 0-3-3  
*Year:* G (1)  
Laboratory study of special topics including radiochemical analysis, the fission process, and the reactions following nucleogenesis. Walters

### 5.121J *Planetary Physics and Chemistry I*

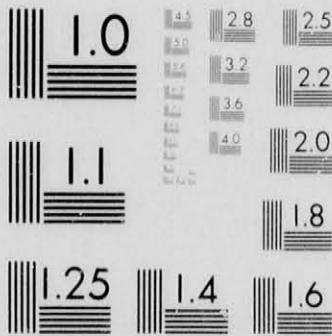
(Same subject as 8.291J and 12.131J) 3-0-9  
*Prereq.:* 8.02, 18.02  
*Year:* U (1)

### 5.122J *Planetary Physics and Chemistry II*

(Same subject as 8.292J and 12.132J) 3-0-9  
*Prereq.:* 8.02, 18.02  
*Year:* U (2)

Study of the planetary system: evolution, composition, present configuration, dynamics, interiors, surfaces, atmospheres, and magnetospheres of the planets and, where appropriate, similar aspects of the satellites, asteroids, and comets. Stress on use of space-probes and modern ground-based optical, radio and radar techniques for diverse planetary observations and the interpretations. First term: a general description of the solar system and its origin and a comprehensive discussion of the outer planets. Second term: solar system dynamics, the interplanetary medium, and the interiors, surfaces, and atmospheres of the inner planets.

J. S. Lewis, I. I. Shapiro



MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

M. I. T. ANNUAL CATALOGUES AND BULLETINS

1969/70

04  
OF  
55

**5.125J Planetary Atmospheres (A)**

(Same subject as 12.631J)

Prereq.: —

Year: G (1)

3-0-6

Discussion in light of recent spectroscopic and space probe data of compositions, structures, and origins of the atmospheres of the planets. Thermodynamics of atmospheric structure, cloud precipitation, and mineral buffers of pressures of reactive gases. Photolysis; escape rates, mineralogy of surface rocks. Chemical behavior of a solar-composition atmosphere; the solar nebula, the interiors of the major planets. Models for the origin and development of planetary atmospheres. (*Permission of instructor required. Alternate years. Not offered 1969-70.*)

J. S. Lewis

**5.129J Current Research in Meteoritics (A)**

(Same subject as 12.636J)

Prereq.: —

Year: G (2)

Arr.

Discussion of current research and special problems in meteoritics. Composition and structure of important classes of meteorites; meteorite dating methods and their results; thermodynamics of meteoritic minerals. Isotopic chemistry of meteoritic material. Evidence concerning the origin of meteorite classes and proposed genetic relationships. Conditions in the solar nebular.

J. S. Lewis

**5.194 Design and Analysis of Experiments (A)**

Prereq.: —

Year: G (2)

2-0-4

Principles and applications of statistical design and analysis in chemistry and related fields. Significance testing, analysis of variance, correlation and regression. Sampling, sequential analysis, block designs, factorial design, fractional replication and determination of optimum conditions.

Hume

**5.195 Interpretive Spectroscopy (A)**

Prereq.: 5.42, 5.63

Year: G (1)

3-0-6

Discussion of spectrometric techniques and their application to the identification of chemical compounds. Major emphasis on complementary use of infrared, nuclear magnetic resonance and mass spectrometry. Discussion of other techniques including ultraviolet spectrometry and molecular emission spectra.

Biemann

**5.20 Laboratory Problems in Chemistry**

Prereq.: —

Year: U (1, 2)

1-3-2

**5.21 Laboratory Problems in Chemistry**

Prereq.: —

Year: U (1, 2)

1-6-5

Laboratory work with guidance of the chemistry department staff. Projects of chemical nature involving the determination of properties of a system or the reactivity of combinations of systems. Available topics:  $\Delta S$  of a reaction by temperature dependence of e.m.f.,  $\Delta H$ 's by calorimetry, colligative properties of liquids, mass spectrometry, chemical kinetics, X-ray interpretation and model building, construction and use of a photoelectric calorimeter and adaptation for optical rotation experiments, simple harmonic oscillator model, dipole moment by heterodyne beat method, chromatography, gas diffusion, construction of a simple NMR detector, quantum yield and actinometry of a photochemical reaction, organic and inorganic syntheses, radiochemical studies and investigation of the accuracy of analytical methods. Topics for organic-biochemical specialization: synthesis, enzyme kinetics and chromatography. (*Enrollment limited. Third- and fourth-year students must consult instructor before registering.*)

Swain

**5.31 Introduction to Chemical Experimentation**

Prereq.: 5.01, 5.41T

Year: U (1)

2-8-2

Introduction to the methods of experimental chemistry which emphasizes modern procedures for the preparation, isolation, purification, analysis, and characterization of substances, solid and liquid.

Staff

**5.32 Intermediate Chemical Experimentation**

Prereq.: 5.31, 5.42, 5.60

Year: U (2)

2-8-2

More advanced experimental work with emphasis on equilibria, thermochemical measurements, and measurements of properties of gases. Introduction to the construction of simple apparatus, to simple electrical measurements, to the measurement and interpretation of infrared, visible, and ultraviolet spectra, and to chromatographic separations. (*Enrollment limited to 120 students.*)

Staff

**5.33 Advanced Chemical Experimentation**

Prereq.: 5.32, 5.63

Year: U (1)

2-12-4

Advanced experimentation with particular attention to the syntheses of compounds, the measurement of kinetic phenomena, and the use of modern instrumentation. Some of the topics to be included: interpretation of nuclear magnetic resonance spectra and mass spectra, use of electronic equipment, application of computers to the solution of chemical problems, and use of the chemical literature.

Staff

**5.34 Introduction to Chemical Research**

Prereq.: 5.03, 5.33, 5.62

Year: U (2)

2-12-4

Project-oriented laboratory in which the student may select a program of experimentation from among projects that illustrate contemporary research methods in synthesis and in physicochemical measurement. Areas to be represented: atomic and molecular spectroscopy, transport properties of gases, molecular dynamics and interactions, electric and magnetic properties, properties of macromolecules, solid-state structure and properties, surface phenomena, and the preparation of relatively complex inorganic, organic and organometallic substances, etc. Full use of the techniques and instrumentation employed in the modern research laboratory including the application of computers to the solution of chemical problems. (*Not offered 1969-70.*)

Staff

**5.41T Introduction to Structure, Bonding and Mechanism**

Prereq.: —

Year: U (1)

4-0-8

Correlation of chemical properties with a minimal set of empirical observations and theoretical principles. Electronic structures of atoms and molecules, structural chemistry, elementary concepts of energetics and kinetics. Description and prediction of acid-base behavior. Concept of mechanism with examples drawn from organic and inorganic chemistry. Generalized substitution reactions. Chemistry of the carbonyl grouping.

Kemp

**5.42 Organic Chemistry**

Prereq.: 5.41T

Year: U (2)

4-0-8

Study of organic reactions, with emphasis on the relation between structure and reactivity.

Chipman

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## CHEMISTRY

- 5.43 Organic Chemistry**  
Prereq.: 5.42  
Year: U (1) 3-0-6  
Study of reaction mechanisms, synthetic methods and an introduction to the chemistry of natural products.  
*F. D. Greene*
- 5.51 Advanced Organic Chemistry: Synthesis (A)**  
Prereq.: 5.53  
Year: G (1) 3-0-6  
Organic reactions and the methods by which they are applied to synthetic problems in organic chemistry.  
*W. R. Moore*
- 5.53 Molecular Structure and Reactivity (A)**  
Prereq.: 5.32, 5.42  
Year: G (1) 3-0-6  
Introduction to the theoretical interpretation of reactivity, reaction mechanisms, and molecular structure of organic compounds. Applications of spectroscopy to the determination of structure.  
*Whitesides*
- 5.54T Physical Organic Chemistry (A)**  
Prereq.: 5.53  
Year: G (2) 2-0-4  
Mechanisms of representative organic reactions in homogeneous liquid systems. Kinetic and other physical methods useful in studying organic reactions. Types of experimental evidence upon which current theoretical interpretations of reactivity are based.  
*Whitesides*
- 5.55T Organic Chemistry: Natural Products (A)**  
Prereq.: 5.51  
Year: G (2) 2-0-4  
The chemistry and physiological action of natural products. Methods of isolation; determination of structures and synthesis.  
*Büchi*
- 5.56 Special Topics in Organic Chemistry (A)**  
Prereq.: 5.51, 5.53  
Year: G (2) 3-0-6  
Advanced topics of special current interest.  
*Sheehan*
- 5.60 Chemical Equilibrium**  
Prereq.: 18.02  
Year: U (1, 2) 4-0-8  
Equilibrium properties of macroscopic systems. Basic thermodynamics — system, state of system, state variables. Work, heat, first law of thermodynamics, thermochemistry. Second and third law of thermodynamics — entropy, Gibbs function. Equilibrium phase rule, colligative properties of solutions, homogeneous and heterogeneous chemical equilibrium of reactions in the gas phase and solutions. Term 1: *Garland*. Term 2: *Amdur*
- 5.62 Physical Chemistry**  
Prereq.: 5.60  
Year: U (2) 4-0-8  
Elementary kinetic theory and statistical mechanics; transport properties of gases and liquids; rates of chemical reactions.  
*Shoemaker*
- 5.63 Physical Chemistry**  
Prereq.: 8.02, 18.02  
Year: U (1) 4-0-8  
Introductory quantum chemistry: elementary atomic spectra; particles and waves; wave mechanics; atomic structure and the Periodic Table; valence theory; experimental methods of determining molecular structure; structure of crystals and liquids; photochemistry.  
*J. S. Waugh*
- 5.68 Kinetics of Chemical Reactions (A)**  
Prereq.: 5.62  
Year: G (2) 3-0-6  
Experimental and theoretical aspects of advanced topics including: collision and transition state theories, homogeneous reactions in gas and liquid phases, enzymatic reactions, very fast reactions in solution, gas phase reactions in shock tubes and in molecular beams. (Not offered 1969-70.)  
*Amdur, Schimmel*
- 5.70 Introduction to Statistical Thermodynamics (A)**  
Prereq.: 5.62  
Year: G (1) 3-0-6  
Review of classical thermodynamics and an introduction to elementary statistical mechanics, with applications to simple physical and chemical systems.  
*Beenakker*
- 5.71 Chemical Thermodynamics I (A)**  
Prereq.: 5.62  
Year: G (1) 2-0-4  
Fundamental definitions and concepts; first and second laws of thermodynamics with applications to chemical systems, ideal and real gases, ideal and real solutions; partial molar quantities, chemical equilibrium; third law of thermodynamics and applications to chemical systems; free energy calculations.  
*Stephenson*
- 5.72 Statistical Mechanics (A)**  
Prereq.: 5.70, 5.73, 18.05  
Year: G (2) 3-0-6  
Principles and methods of statistical mechanics. Classical and quantum statistics, grand ensembles, fluctuations, molecular distribution functions, and other topics in equilibrium statistical mechanics. Advanced topics in thermodynamics, including irreversible processes.  
*Garland, J. Ross*
- 5.73 Introductory Quantum Mechanics I (A)**  
Prereq.: 5.63, 8.03  
Year: G (1) 3-0-6  
Fundamental concepts of quantum mechanics; wave properties, uncertainty principle, Schrödinger equation. Basic applications to: harmonic oscillator, hydrogen atom, WKB method. Perturbation theory and variation method. Pauli principle and spin. Introduction and use of operator and matrix methods.  
*Lord*
- 5.74 Introductory Quantum Mechanics II (A)**  
Prereq.: 5.73, 18.05  
Year: G (2) 3-0-6  
Continuation of 5.73. Permutation symmetry and angular momentum. Molecular dynamics. Time-dependent problems, radiation and matter. Scattering by a central field. Many-electron systems, approximate molecular and atomic wave functions.  
*Silbey*
- 5.76 Molecular Spectra and Molecular Structure (A)**  
Prereq.: 5.63, 18.05  
Year: G (2) 3-0-6  
Rotational, vibrational and electronic spectra of molecules; use of spectra to find dissociation energies, force constants, inter-atomic distances, molecular symmetry and related quantities; other techniques for study of molecular structure such as dipole moments, magnetic susceptibilities, and nuclear magnetic resonance.  
*Lord*
- 5.80 Special Topics in Chemical Physics (A)**  
Prereq.: 5.70, 5.73  
Year: G (1, 2) Arr.  
Advanced topics of special or current interest. The specific areas announced in advance of each term.  
*J. A. Ross*
- 5.81 Advanced Topics in Chemical Biophysics (A)**  
Prereq.: 5.70, 18.05  
Year: G (1 or 2) Arr.  
Structures and properties of biopolymers. Statistical mechanics of biopolymers; matrix methods; conformational energies and configurational statistics; cooperative

phenomena. Dynamics of biological processes; rates of enzymatic reactions; theory of chemical relaxation spectrometry with applications to biological reactions; rates of configurational changes in biopolymers. (Offered occasionally. Consult instructor.) Schimmel

**5.82 Advanced Topics in Solid State Chemistry (A)**

Prereq.: 5.70, 5.73  
Year: G (1 or 2)

Arr.

Selected topics from areas such as: structure of crystals, surface structure, symmetry groups, diffraction methods, lattice dynamics, order-disorder and magnetic phenomena, molecular motions in solids, relaxation phenomena, optical properties and exciton theory. (Offered occasionally. Consult instructor.) Garland, Shoemaker, Silbey, Stephenson

**5.83 Advanced Topics in Statistical Mechanics and Kinetic Theory (A)**

Prereq.: 5.70, 5.73  
Year: G (1 or 2)

Arr.

Fundamental concepts of the statistical mechanics of irreversible processes, and the kinetic theory of gases in relation to molecular interactions and collision dynamics. (Offered occasionally. Consult instructor.)

Amdur, I. Oppenheim

**5.84 Advanced Topics in Spectroscopy and Quantum Mechanics (A)**

Prereq.: 5.74  
Year: G (1 or 2)

Arr.

Topics varying from year to year, including magnetic resonance, beam spectroscopy, non-linear optics, kinetic applications, and quantum field theory. (Offered occasionally. Consult instructor.) Lord, Silbey, Steinfeld, J. S. Waugh

**5.89 Special Problems in Chemistry for Undergraduates**

Prereq.: —  
Year: U (1, 2)

Arr.

Program of study, either experimental or theoretical, to be arranged by the student and a departmental faculty member. Research for an undergraduate thesis may be arranged in this subject.

Term 1: K. W. Bowers  
Term 2: Takats

**5.90 Special Problems in Chemistry (A)**

Prereq.: —  
Year: G (1, 2)

Arr.

Directed research and study of special chemical problems. (For graduate students only.) Berchtold

**5.913 Seminar in Organic Chemistry (A)**

Prereq.: —  
Year: G (1)

1-0-2

**5.914 Seminar in Organic Chemistry (A)**

Prereq.: —  
Year: G (2)

1-0-2

Discussion of current journal publications in organic chemistry by graduate students and staff members.

Berchtold

**5.915 Seminar in Analytical Chemistry (A)**

Prereq.: —  
Year: G (1)

1-0-2

**5.916 Seminar in Analytical Chemistry (A)**

Prereq.: —  
Year: G (2)

1-0-2

Discussion of topics of current interest in analytical chemistry by graduate students and staff members.

Hume

**5.931 Seminar in Physical Chemistry (A)**

Prereq.: —  
Year: G (1)

1-0-2

**5.932 Seminar in Physical Chemistry (A)**

Prereq.: —  
Year: G (2)

1-0-2

Discussion of topics of current interest in physical chemistry by staff members and students.

Steinfeld

**5.941 Seminar in Inorganic Chemistry (A)**

Prereq.: —  
Year: G (1)

1-0-2

**5.942 Seminar in Inorganic Chemistry (A)**

Prereq.: —  
Year: G (2)

1-0-2

Discussion of current research in inorganic and nuclear chemistry by graduate students and staff.

Holm

**5.981J Seminar in Biochemistry (A)**

(Same subject as 7.74J)

Prereq.: —  
Year: G (1, 2)

1-0-2

Presentation by graduate students of critical reviews of recent publications in chemistry and biochemistry with application to selected biochemical problems. Discussions by staff and students.

Chemistry and Biochemistry Staff

**Research (A)**

Prereq.: —  
Year: G (1, 2)

Arr.

Research for any of the advanced degrees in chemistry.

Staff

## 6.

### Electrical Engineering

**6.00 Introduction to Computation**

Prereq.: —  
Year: U (1, 2)

2-2-2

Modeling of computational processes as sequential algorithms. Formal and informal techniques for the representation of these algorithms and their implementation on digital computers. Experience in programming and running of elementary problems in an algebraic and an assembler language.

S. J. Mason

**6.001 Elements, Systems and Computation I**

Prereq.: 8.02, 18.02  
Year: U (1)

4-0-8

First part of a two-term sequence, 6.001-6.002, which may be substituted for 6.01 (or 6.013) and 18.034 by students majoring in electrical engineering. Interconnection of basic network and logic elements into signal and information-processing networks and systems for computation, communication, and control. Characterization and analysis of continuous and discrete systems by input-output and state relations. Memory-less and memory systems. Continuous systems, linear and elementary non-linear electrical networks, their differential equations and their solution; system function and impedance. Discrete systems, logic-gate networks and elementary finite-state machines. Appropriate use made of computers.

Dertouzos, S. J. Mason

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## ELECTRICAL ENGINEERING

- 6.002 Elements, Systems and Computation II**  
*Prereq.:* 6.001 or 6.01  
*Year:* U (2) 4-0-8  
 Continuation of topics and philosophy of 6.001. High-order linear and non-linear dynamic systems and networks; their description by vector and matrix relations from the state-variable point of view. Elements of linear algebra. Analytical and algorithmic solutions for linear and non-linear algebraic, differential and difference equations. Numerical integration of differential equations. Convergence, stability, and error analysis of iterative algorithms. *Athans, Spann*
- 6.01 Introductory Network Theory**  
*Prereq.:* 8.02, 18.034  
*Year:* U (1, 2) 4-0-8
- 6.013 Introductory Network Theory**  
*Prereq.:* 8.02, 18.034  
*Year:* U (1, 2) 4-0-8  
 Fundamentals of network theory with emphasis on concepts and techniques which are important in and common to many areas of engineering and physics. Network model: Kirchhoff's laws; v-i characteristics of network elements; formulating equilibrium equations; Tellegen's theorem; energy and power. Time-domain analysis: state variables; formulating and solving state equations; natural frequencies and normal modes; impulse response and convolution integral. Frequency-domain analysis: system function; poles and zeros; frequency response curves; relations between forced response and natural behavior of networks; properties of system functions of networks; synthesis. *Huang*
- 6.02 Electronic Devices and Circuits**  
*Prereq.:* 6.001 or 6.01  
*Year:* U (1, 2) 4-0-8
- 6.023 Electronic Devices and Circuits**  
*Prereq.:* 6.013  
*Year:* U (2) 4-0-8  
 Modeling of electronic control valves or power modulators, and analysis of non-linear circuits. Physical electronics of semiconductor junction devices, and the development of circuit descriptions for these devices; relation of electrical behavior to internal physical behavior, and limitations of circuit models. Analysis of signal-processing circuits which employ control valves, with examples chosen from switching circuits, negative resistance oscillators, incrementally linear amplifiers, and power amplifiers. *Nelsen*
- 6.03T Electromagnetic Fields and Energy**  
*Prereq.:* 6.001 or 6.01; 8.03  
*Year:* U (1, 2, S) 4-0-8
- 6.033T Electromagnetic Fields and Energy**  
*Prereq.:* 6.001 or 6.01; 8.03  
*Year:* U (1) 4-0-8  
 Maxwell's equations and the Lorentz force law. Simple quasistatic electric fields and sources, electrical energy and its relation to forces on conductors. Integral and differential static electric field laws; Poisson's and Laplace's equations; boundary value problems in Cartesian and polar coordinates. Capacitance from field concepts, energy, and uniqueness of field solutions. Quasistatic magnetic fields; the law of magnetic induction. Integral and differential magnetic field laws and their solution; vector potential and vector Poisson's equation. Polarizable and magnetizable matter, non-linear media and magnetic circuits. Magnetic diffusion and charge relaxation. Fields and forces experienced by materials in motion. *Haus, Melcher*
- 6.04 Electrodynamic**  
*Prereq.:* 6.03T, 6.05  
*Year:* U (2) 4-0-8
- 6.043 Electrodynamic**  
*Prereq.:* 6.033T, 6.053  
*Year:* U (2) 4-0-8  
 Basic subject in electrodynamic, with emphasis on phenomena associated with wave propagation and radiation. Plane waves in three dimensions, radiation from current distributions and arrays, diffraction and interference. Guided electromagnetic waves, propagation and evanescence; energy flow and impedance matching. Pulse propagation in dispersive systems; energy and group velocity. Natural frequencies and modes of closed electromagnetic structures; resonance. Examples throughout taken from the fields of optics and microwaves. *Briggs, Parker*
- 6.05 Circuits, Signals, and Systems**  
*Prereq.:* 6.02, 18.05  
*Year:* U (1, 2, S) 4-0-8
- 6.053 Circuits, Signals, and Systems**  
*Prereq.:* 6.023, 18.05  
*Year:* U (1, 2) 4-0-8  
 Basic subject for students majoring in electrical engineering. Terminal behavior of linear circuits and systems. Impulse response, convolution, and superposition integrals. Complex frequency and system function. Fourier series and Fourier-Laplace integral representations for signals. Filtering and sampling, modulation and detection. Feedback systems and stability. Introduction to random signals and noise, correlation functions and spectra. *Siebert*
- 6.06 Fields, Forces, and Motion**  
*Prereq.:* 6.03T  
*Year:* U (1) 3-0-9
- 6.063 Fields, Forces, and Motion**  
*Prereq.:* 6.033T  
*Year:* U (1) 3-0-9  
 Basic subject dealing with electromagnetic fields in the presence of moving material bodies, power flow, and energy conversion. General properties of lumped-parameter electromechanical models. Field theory of electromechanical systems containing rigid and elastic bodies and incompressible and compressible fluids. *Melcher*
- 6.07 Energy Transmission and Radiation**  
*Prereq.:* 6.03T, 18.05  
*Year:* U (1) 4-0-8
- 6.073 Energy Transmission and Radiation**  
*Prereq.:* 6.033T, 18.05  
*Year:* U (1) 4-0-8  
 Basic subject in electrodynamic: wave propagation in one-, two-, and three-space dimensions with emphasis on time-space and frequency-wave-number descriptions. Uniform and non-uniform plane waves; closed and open waveguide structures; energy and energy flow; transmission lines and transmission-line resonators; potentials and Green's function for electromagnetic fields; radiation of dipole antennas and simple arrays; interference and coherence characteristics. *Briggs*
- 6.08 Statistical Mechanics and Thermodynamics**  
*Prereq.:* 8.04  
*Year:* U (1, 2, S) 4-0-8
- 6.083 Statistical Mechanics and Thermodynamics**  
*Prereq.:* 8.04  
*Year:* U (1, 2) 4-0-8  
 The statistical description of physical systems: phase space and ensembles; temperature, entropy and partition functions. The laws of thermodynamics developed from statistical mechanics: work, heat, generalized forces, machines, and Maxwell relations. Derivation of macroscopic properties from microscopic models. Noise, fluctuations and dissipation; Van der Pol oscillators,

thermodynamic limitations on electron devices. Fermi-Dirac, Bose-Einstein and Maxwell-Boltzmann quantum statistics; models of electron, photon and ideal gases, dipole systems and semiconductors. *Kennedy, Arntz*

**6.11 Project Seminar**

Prereq.: —

Year: U (1) 2-0-4

**6.12 Project Seminar**

Prereq.: —

Year: U (2) 2-0-4

Special activity for students in Course vi Program 2. Study and evaluation of professional literature, oral presentation and active open discussion of topics drawn from and extending beyond those treated in the regular curriculum. Flexible organization, comprising a few students under guidance of a staff member. *Eden*

**6.13T Electric and Magnetic Properties of Solids**

Prereq.: 6.03T, 8.04

Year: U (1) 3-0-9

Introduction to the physics of solids. Crystal structure, lattices and reciprocal lattices. Binding energies. Wave propagation in periodic lattices. Free electron and nearly free electron theory. Energy bands. Statistics of electrons and holes. Wave packets, charge carrier motion, the Boltzmann transport equation. Conductivity and Hall effect. Lattice vibrations. The dielectric and magnetic properties of solids. *D. J. Epstein*

**6.14T Introduction to Electronics**

Prereq.: 8.02

Year: U (1, 2) 4-2-6

An introductory subject suitable for students with little or no previous background in electronics. Elementary network theory, diode and transistor circuits, analysis and design of analog and digital circuits using integrated circuits. Examples emphasizing the uses of electronics in experimental science. Alternate week laboratory. *Senturia*

**6.20 Electronics in Instrumentation**

Prereq.: 6.05

Year: U (1, 2) 3-0-6

Analysis and design principles of electronic systems for measurement, instrumentation and control. Review of basic devices, circuits, and concepts employed in electronic instrumentation, including analog and digital electronics. Functional elements such as d-c, a-c, and operational amplifiers; regulators; modulators; demodulators; wave and pulse generators, shapers, and detectors; analog and digital gates; basic logic elements. Emphasis on feedback operational amplifiers in instrumentation. *T. S. Gray*

**6.202 Electronic Light Measurements**

Prereq.: 6.02

Year: U (1, 2) 2-2-5

Comprehensive treatment of the physics and engineering underlying the application of the photographic process as an instrument for creative expression, measurement and information display. Topics: physical phenomenology of photographic film and recording materials, photometry, sensitometry, light sources, xenon flash apparatus, photographic lenses and optics, camera function and design, photographic processing (development, printing and enlarging), color characterization, measurement and reproduction, elements of motion picture technology and laser holography. Illustration of the technique or process under consideration through laboratory exercises paralleling the classroom work. (For the project laboratory version of this subject see 6.714.) *Edgerton*

**6.213 Dynamic Systems, Control and Optimization**

Prereq.: 6.05, 18.05

Year: U (1) 3-2-7

**6.214 Dynamic Systems, Control and Optimization**

Prereq.: 6.213

Year: U (2) 3-2-7

A two-term elective sequence aimed at introducing the main ideas of modern system theory and its applications. Emphasis on problem formulation and synthesis methods. Modeling of systems and signals. State-space description of linear systems. Classical control system design. Quadratic performance criteria and optimal control. Filtering. Stability theory. Static optimization. Dynamic programming. The maximum principle. Laboratory and computer studies. *L. A. Gould*

**6.215 Feedback Control Laboratory**

Prereq.: 6.213

Year: U (1, 2) *Arr.*

Supervised investigation of special projects in feedback control system analysis and synthesis; laboratory investigations utilizing the facilities of the feedback control laboratory. Program and hours to be arranged with interested staff member, subject to approval of instructor. *L. A. Gould*

**6.231 Programming Linguistics**

Prereq.: —

Year: U (1, 2) 3-2-7

Study of linguistic constructs for the specification of algorithms, and practice in using them to build large semantic structures out of small ones. Initial introduction to and familiarization with a particular general purpose language; detailed analysis of the language and its relation to mathematical logic. Bound and free variables, substitution rules, recursion, structures, generalized jumps and labels; contrast and comparison with certain linguistic features of LISP, FORTRAN, ALGOL, PL/I. An introductory subject intended primarily for students whose major interest is computer science. Note: students are strongly recommended to have had programming experience with an algebraic language such as PL/I or FORTRAN. *A. Evans, Wozencraft*

**6.232T Computation Structures**

Prereq.: 6.001 or 6.01, 6.231 or 6.251

Year: U (1, 2) 4-0-8

Study of hardware and software means for implementing program linguistic features. Theory and design of sequential logic circuits; register transfer operations and logical design; implementation of arithmetic operations; practical memory systems and abstract memory models. Computation schemata. Monosequence and multi-processor implementation; code generation and optimization; process synchronization and determinism. Sharing and nesting of procedures; stacks and recursion. Information structures, dynamic storage allocation and free storage management. Programming generality and location independent addressing. *Dennis*

**6.233 Information Systems**

Prereq.: 6.232T

Year: U (2) 4-0-8

Sources of complexity in information systems, with particular emphasis on problems arising when a single information system serves a community of users. Contrast of problems intrinsic to purposes of use with those

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## ELECTRICAL ENGINEERING

related to technical limitations. Study of specific design objectives such as reliability, maintainability, information storage, controlled information sharing, ability to withstand change, and ease of administration. Effect of these and other design objectives on system implementation demonstrated in a model system. Comparison and contrast of model system with current state-of-the-art working systems, including both general purpose community computing facilities and information systems dedicated to a special task such as telephone line switching or air traffic control. *Graham, Saltzer*

### 6.241 *Engineering Problems*

Prereq.: —

Year: U (1, 2)

3-0-6

Elective subject at the third- or fourth-year level given by notable practicing engineers to show the whole problem faced by the engineer. May discuss economic, legal, and other non-technical aspects, as well as technical engineering. Faculty counselors to be consulted about availability, field, prerequisites and instructor. *Bruce*

### 6.243 *Inventions and Patents*

Prereq.: 14.01T, 21.012

Year: U (1)

3-0-6

History of private and public rights in scientific discoveries and applied engineering leading to the development of worldwide patent systems. The classes of invention protectable under the patent laws of the United States, including the procedures in protecting inventions in the Patent Office and in the courts. Review of past cases involving various electrical and electronic and other inventions, including the Bell Telephone cases and key radio, solid-state, and computer inventions. *Rines*

### 6.251 *Digital Computer Programming Systems*

Prereq.: 6.00 or 6.273

Year: U (1, 2)

3-2-7

Basic principles of programming systems. Techniques for translation from problem-oriented languages to machine languages. Computer organization, programming, program planning and organization. Construction of assemblers, interpreters, compilers, monitor, multiprocessed, multiprogrammed systems. The use and manipulation of data structures. Laboratory work in the preparation and testing of programs for the IBM 360 computer. Note: acceptable ability to program a computer will satisfy 6.00 or 6.273 prerequisite. *Donovan, Graham*

### 6.253 *Theoretical Models for Computation*

Prereq.: 6.00

Year: U (1, 2)

3-0-9

Study of the theoretical models with widest application to computer logic and programming, stressing equivalence between abstract machines and corresponding formal grammars. Specific topics include: Formal languages and grammars. Operations on sets of sentences. Finite-state machines. State diagrams and linear grammars. Regular expressions. Kleene's theorem on regular expressions and finite-state accepters. Limitations of the finite-state model. Counting and push-down automata. Context-free languages. Ambiguity. Recognition procedures. Turing machines. Elementary theory of recursive functions. Unsolvable decision problems with applications to formal linguistics. *Dennis*

### 6.256 *Applications of Combinatorial Mathematics*

Prereq.: 6.261 or 18.05

Year: U (2)

3-0-9

Topics in combinatorial mathematics that find frequent application in electrical engineering. Discussion of enumeration techniques will include: permutations and combinations, generating functions, recurrence relations, the principle of inclusion and exclusion, and Pólya's

theory of counting. Graph theory and its applications to be covered: Euler paths and Hamiltonian paths, planar and dual graphs, domination, independence, chromatic numbers, network flow and the theory of matching. Other topics to be discussed: linear programming, block design, and projective geometry. *Liu*

### 6.257 *Switching and Finite Automata Theory*

Prereq.: 6.232 or 6.271T

Year: U (1, 2)

3-0-9

Basic properties of Boolean functions, prime implicants the covering problem. Symmetric functions, their detection and implementation. Functional decompositions. Unate and linearly separable functions and their applications to threshold logic. Cellular logic, synthesis and applications. Diagnosis of combinational switching circuits. Redundancies in logical design and improvements in the reliability. The finite state model. State and machine identification experiments. Memory span and information losslessness of finite-state machines. Linear machines, properties and identification, minimization and synthesis, applications to error detection and correction. *Liu*

### 6.261 *Algebraic Foundations for Computer Science*

Prereq.: 6.002 or 18.034

Year: U (1)

4-0-8

Introduction to modern algebra for students interested in computer and information sciences. Emphasis on finite algebraic systems and their applications. Fundamentals of set theory. Natural numbers and induction. Elementary notions of cardinality. General features of algebraic systems: subsystems, isomorphism, homomorphism, quotient systems. Boolean algebras and propositional calculus, with application to logical design. Basic properties of groups. Fields as generalized arithmetic systems. Polynomial rings, congruences, and the construction of Galois fields. *Liu, Hennie*

### 6.262 *Computability, Formal Systems, and Logic*

Prereq.: 6.261 or 18.25

Year: U (2)

4-0-8

Study of the basic concepts underlying mathematical theories of computation, with applications to automata theory, programming, and theorem proving. General purpose algorithm schemes and their properties. Recursive derivations, Turing machines, and idealized computers. Universal algorithms and the design of universal machines. Computable and non-computable functions. Semantic and syntactic properties of formal systems. The undecidability of various syntactic problems, such as Post's correspondence problem and the tag problem. Logical systems, models, and valuation. Gödel's completeness and incompleteness theorems and their implications. *Hennie*

### 6.271T *Introduction to Digital Systems I*

Prereq.: 6.001 or 6.01

Year: U (1, 2)

4-3-5

Introduction to characteristics, specification, and design of digital systems. Boolean algebra, combinational logic, NAND-NOR synthesis and iterative arrays. Elementary properties of finite-state machines. Analysis and synthesis of sequential circuits with pulse and level inputs. Design examples including arithmetic elements, counters and shift registers. Related laboratory treats integrated circuits, static and dynamic properties of gates and flip-flops, synthesis of small digital systems. *Spann, Troxel*

**6.272 Digital Systems Project Laboratory**

Prereq.: 6.271T

Year: U (1, 2)

2-8-2

Introduction to some of the basic techniques used in the design of digital computing and control systems. Preliminary work by a combination of classes, homework, and associated laboratory experiments. Study of comparators, operational amplifiers, analog-digital interfaces, memory systems, and the transmission of digital signals. Implementation of all projects with integrated circuits. Oral presentation and written report on completion of project. Initial classroom material more advanced than that of 6.711 with accordingly higher standards in the character and scope of projects. (*Credit will not be given for both 6.272 and 6.711.*) *Spann, Troxel*

**6.273 Introduction to Digital Systems II**

Prereq.: 6.00; 6.232T or 6.271T

Year: U (1, 2)

3-3-6

Introduction to the structure of modern digital computers. Assembly language programming. Interaction and tradeoff between hardware, programming and processing time. Input-output and interrupt systems. Assemblers and loaders. Compilers. Data structures and list processing languages. Laboratory exercises centering around on-line computer usage. *F. F. Lee*

**6.274 Advanced Digital Systems Project Laboratory**

Prereq.: 6.272, 6.273

Year: U (2)

2-8-2

Logical design and construction of digital subsystems and their interface to digital computer for efficient and economical performance of specialized tasks. Projects implemented with integrated circuit digital modules and by programming in assembly language on a digital computer. Individual oral presentation and project report required. (*Enrollment limited. Permission of instructor required.*) *F. F. Lee*

**6.28 Probabilistic Systems Analysis**

Prereq.: 18.02

Year: U (1, 2)

4-0-8

Serves as a self-contained development of the theory and application of probabilistic concepts and provides the foundation for graduate subjects in engineering, management, and science. Presentation of the theory of probability on an axiomatic basis. Emphasis on sample space concept. Discussion of algebra of events, operations on random variables, discrete and continuous transform techniques, common distributions and stochastic processes, limit theorems, classical and Bayesian statistics. Consideration of implications of probability theory for decision making, data analysis, and system modeling. Presentation of applications concurrently with the development of the theory. *Drake*

**6.341 Principles of Transistors**

Prereq.: 6.02

Year: U (1)

3-3-6

Analysis and design of transistor circuits, based directly on the semiconductor physics and transistor circuit models developed in 6.02. The Photo-diode. Variations of hybrid pi model parameters with current, voltage and temperature. Physics, models, and circuit applications of field-effect transistors. High-frequency and low-frequency design calculations of multistage transistor and FET circuits using a computer. The charge-control model. Computer-aided analysis of switching transistors. Regenerative switching circuits. *Searle*

**6.342 Multistage Transistor Amplifiers**

Prereq.: 6.341

Year: U (2)

3-2-7

Computer-aided analysis and design of feedback amplifiers. Stability and transient response. Bipolar-transistor d-c amplifiers. Design and application of operational amplifiers with particular emphasis on available integrated-circuit units. Linear and switching power amplification and regulation. Analog signal switching techniques and application. *Roberge*

**6.343 Computer-Aided Circuit Design**

Prereq.: 6.341, 6.00

Year: U (2)

3-1-8

A supplement to 6.341 with particular emphasis on the use of computers in the analysis and simulation of electronic circuits. Computer models for semiconductor circuits; difference equation formulation of circuit problems; numerical methods for iteration, integration, and optimization; matrix representation of circuits and numerical methods for manipulating matrices; time and frequency-domain calculations. (*Permission of instructor required.*) *Thornton*

**6.344 Physical Principles of Solid-State Devices**

Prereq.: 6.03T

Year: U (2)

3-0-9

Physical principles of those solid-state devices which depend on volume rather than junction phenomena. Physical basis of the parameters describing the dielectric, magnetic and conductive properties of solids; frequency dependence, non-linearities and coupling effects. Case studies selected from the following topics. Piezoelectric and piezomagnetic coupling and applications to transducers. The drift model for conduction; Hall effect and Hall devices. Coupled flow phenomena; thermoelectric generators and coolers. Magnetic and dielectric amplifiers and modulators; magnetic memories and logic. Ferromagnetic resonance; non-reciprocal microwave devices. Magneto-optical and electro-optical properties; interaction of light with acoustical excitations; light modulation and beam deflection; non-linear optics. *D. J. Epstein*

**6.35 Acoustics**

Prereq.: 6.01, 18.05

Year: U (1)

3-1-6

General discussion of sound generation and propagation in elastic media. Conversion between acoustical, electrical, and mechanical energy. Lumped-parameter approximations. Sound in rooms, microphones, loudspeakers, and audio communications systems; noise and vibration control problems. Interaction of sound and man. *Bose*

**6.36 Sound, Speech and Hearing**

Prereq.: 6.03T, 6.05

Year: U (2)

3-0-9

Introduction to the physical, physiological and psychological bases of auditory communication. Physical acoustics, properties of neural and muscular elements, the vocal tract and speech generation, signal transmission in the auditory system, perception of attributes of speech and speechlike sounds, and the linguistic units that underlie speech events. *Klatt, Peake, Stevens, T. F. Weiss*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## ELECTRICAL ENGINEERING

### 6.37T *Sensory Communication*

Prereq.: 6.05

Year: U (1)

3-3-6

Examination of sensory performance from the viewpoint of the communication sciences. Principles, techniques, and problems relevant to the study of sensory performance introduced through intensive study of human hearing. Topics include absolute and differential thresholds, detection of signals in backgrounds of noise, filtering and integration, spatial localization, identification and recognition, scaling of subjective attributes, auditory memory, musical pitch, and hearing defects. Mathematical models involving detection theory and information theory. Introductory material on physiological encoding and signal processing, and attempts to relate sensory performance to sensory physiology. Consideration of other sensory systems for purposes of generalization and comparison. Laboratory experiments in which students serve both as experimenters and as experimental subjects. *Durlach, Rosenblith*

### 6.372 *Biophysics of Neuroelectric Potentials*

Prereq.: 6.01 or 6.14T; 8.03, 18.034

Year: U (1)

3-3-6

Introduction to basic phenomena of generation, transmission and interaction of signals in nervous systems. Discussion of the excitation and conduction of the nerve impulse along nerve fibers, synaptic transmission and transduction processes in receptors. Use of mathematical models—particularly electric circuit models—in describing the behavior of cell membranes. Laboratory experiments illustrating the relations between theoretical formulations and experimental data in this field and introducing some techniques of recording electric activity from nerve tissue. *Peake, Weiss*

### 6.39 *Image Transmission Systems*

Prereq.: 6.05

Year: U (1)

3-0-6

Efficient design of image transmission systems, which differ from other information systems both in the multi-dimensional nature of the inputs and the destination of the output, and therefore depend on a study of the properties of pictures, the properties of observers, and the effect of the parameters of the system on the quality of the transmission. Topics including historical developments, mathematical description of images, objective measures of picture quality, scanning and quantizing, picture processing and coding, color systems, and relevant properties of human vision. Term paper or project required. (Not offered 1969-70.) *Schreiber*

### 6.50 *Electrical Engineering Seminar (A)*

Prereq.: —

Year: G (1, 2)

Arr.

Oral presentation of student's objectives and work in his field of specialty; participation in group discussions of reports by others. For doctoral candidates. *Searle*

### 6.512 *Development of Inventions and Creative Ideas (A)*

Prereq.: 14.01, 21.02

Year: G (2)

3-0-9

The role of the engineer as patent expert and as technical witness in court and patent interference and related proceedings, with emphasis on actual experiences in the field of electrical and electronic engineering. Rights and obligations of engineers in connection with various types of employment contracts and employers, including educational institutions, government, and large and small businesses. Various manners of transplanting inventions into business operations, including the development of the New England electronics industry and its different types of institutions. American systems of incentive to creativity apart from the patent laws, including provi-

sions relating to inventions and ideas in the atomic energy and space fields. (For graduate students only; others see 6.243.) *Rines*

### 6.527 *Continuum Electromechanics (A)*

Prereq.: 6.06

Year: G (2)

3-0-9

Dynamics of continuous media in electric and magnetic fields with emphasis on electrohydrodynamics and magneto-hydrodynamics. Relaxation and diffusion phenomena in the presence of material motion. Continuum conduction, induction, and synchronous interactions in electric and magnetic field systems. Electromechanical dynamics in terms of waves and instabilities. Field-coupled forms of Rayleigh-Taylor and Kelvin-Helmholtz instability. Traveling wave energy conversion schemes, growing waves and non-linear wave phenomena. Integral conditions and variational methods in the study of instability. Introduction to the continuum feedback control of electromechanical systems. *Melcher*

### 6.535 *Structure of Computing Systems (A)*

Prereq.: 6.232T or 6.271T; 6.251 or 6.273

Year: G (2)

3-0-9

Study of the design of general-purpose digital computing systems in relation to programming languages used to specify procedures, the design of compilers, the devices and technology employed in fabrication, interaction between procedures and system environment, and the efficient utilization of resources. Trends in contemporary computer system design. Basic properties of procedures and their representation. Syntax and semantics of programming languages. Languages for describing the structure of digital machines. Modular hardware organization. Realization of arithmetic operations. Associative and pseudo-associative memories. Multi-programmed and multiprocessing computer system design. Allocation and scheduling techniques. *Luconi*

### 6.536 *Probabilistic Models in Systems*

*Engineering and Operations Research (A)*

Prereq.: 1.07 or 6.28 or 18.10 or 18.18; 15.092 or 18.05

Year: G (2)

3-0-9

Analysis of linear probabilistic systems. Application of linear system theory to the study of finite- and infinite-state, discrete- and continuous-time, stationary and non-stationary, Markov and semi-Markov processes. Optimization of probabilistic systems over short and long time periods by means of dynamic programming. Concurrent presentation of examples in the areas of system reliability, congestion processes, automatic control, maintenance and replacement policies, search procedures, inventory control, and other operating problems of systems. Discussion of unsolved problems and promising areas of research. *Drake*

### 6.537 *Computational Models (A)*

Prereq.: 6.271T

Year: G (1)

3-0-9

Basic properties and capabilities of finite-state machines. Graphical descriptions of machine behavior. Experiments for determining internal state or detecting malfunctions. Decomposition of machines into combinations of submachines. Regular expression descriptions of machine behavior. Analysis of systems with bi-directional information flow, including information lossless machines, iterative arrays, and coding schemes. Two-dimensional computations, including circuits for performing arithmetic operations. Space-time transformations and synchronization problems. *Hennie*

**6.538 Computational Models (A)**

Prereq.: 6.537

Year: G (2)

3-0-9

Study of basic ways of formulating computational problems, including machine models, functional models, and linguistic models. Comparison of these models and their properties, leading to an understanding of computability and decidability. Topics include: non-writing automata, push-down store automata, and Turing machines; computers and their relationship to Turing machines; recursive function theory; rewriting algorithms and context-free languages.

Hennie

**6.539 Mathematical Theory of Computation and Symbol Manipulation (A)**

Prereq.: —

Year: G (1)

3-0-9

Algorithms for symbolic manipulation, and theoretical results about such algorithms and computation in general. The LISP programming language. Theoretical considerations underlying systems for performing symbolic (non-numeric) mathematics; parsing algorithms; algorithms for matching algebraic expressions for equivalence; methods of simplification and integration. Lower bounds on the computational effort involved in common processes. Brief introduction to computability and unsolvability; Turing machines and recursive function theory; recursive unsolvability of the matching problem. This subject and 6.544J (18.16J) recommended as a two-term introduction to artificial intelligence.

Minsky, Moses

**6.541 Special Topics in the Computer Sciences (A)**

Prereq.: —

Year: G (1)

Arr.

**6.542 Special Topics in the Computer Sciences (A)**

Prereq.: —

Year: G (2)

Arr.

A seminar-type discussion of special topics in the computer sciences. Opportunity for graduate students and instructors to investigate a topic of common interest. Topic and staff announced each term. These subjects given independently or sequentially, as circumstances require. (Consent of instructor required.)

Fano

**6.544J Heuristic Programming and Artificial Intelligence (A)**

(Same subject as 18.16J)

Prereq.: —

Year: G (2)

3-0-9

The problem of making machines behave intelligently. Application of machines to problems of learning, induction, pattern-recognition, game-playing, theorem-proving, neural nets, self-organizing systems, and other areas where problems have been solved by heuristic programming. Problems in administration and allocation of effort within programs. Models of cognitive processes. Machine aids for human problem solving. (Ability to program a computer required.)

Minsky, Papert

**6.551 Power System Engineering I (A)**

Prereq.: 2.03 or 6.06; 2.062 or 6.07

Year: G (1)

3-0-9

Primarily for first-year graduate students. Introduction to power system engineering. Definition of an electric power system in terms of its principal functions and major components. Modeling of the following components — generating units, transformers, transmission lines, and circuit breakers using the concepts and techniques of field theory, circuit theory, etc. Use of these models to study those problems in which electrical behavior is quasi-steady-state, for example, load flow, overvoltage conditions, fault currents, and transient stability.

Woodson, G. L. Wilson

**6.552 Power System Engineering II (A)**

Prereq.: 6.551

Year: G (2)

3-0-9

Continuation of 6.551, Power System Engineering I. Refinement of component models to represent transient electrical phenomena such as switching surges and lightning impulses; surge control and protection; control systems for generators, turbines, and synchronous condensers; effect of excitation on system stability; corona and radio interference from transmission lines; direct current transmission.

Woodson, G. L. Wilson

**6.553 Special Topics in Power System Engineering (A)**

Prereq.: 6.552

Year: G (2)

3-0-9

Treatment in depth of special topics in power system technology by notable experts in the field.

Woodson, G. L. Wilson

**6.556 Dynamics of Electric Machines (A)**

Prereq.: 2.02 or 6.06

Year: G (2)

3-0-9

Treatment of transformers, electromechanical transducers, and rotating electric machines with emphasis on their dynamic performance in systems. Equivalent-circuit models and block diagrams for synchronous, induction, and d-c machines. Problems chosen to illustrate engineering applications. Discussion of new developments and current research. Solution of dynamic problems on a computer as part of the problem work.

Kingsley

**6.56 Electronic Circuits (A)**

Prereq.: 6.02, 6.05, 6.00

Year: G (1)

3-0-9

Theory and analysis of non-linear and active circuits with particular emphasis on the use of numerical methods. Matrix operations and transformations; realizability conditions; numerical methods for iteration, integration, and optimization; computer simulation in the frequency domain; sensitivity, noise, and tolerance considerations. Extensive use of digital computers.

Thornton

**6.561 Network Synthesis (A)**

Prereq.: 6.05

Year: G (2)

3-0-9

Introduction to the theory of linear network synthesis. The basic synthesis elements: resistors, capacitors, inductors, transformers, and gyrators. Internal and external description of networks via differential equations, impedances, admittances, and scattering parameters. Passivity and reciprocity. The classical driving-point synthesis procedures of Foster, Cauer, Brune, Darlington, and Bott-Duffin. n-port synthesis procedures based on matrix factorization. Reducing the n-port synthesis problem to a resistive synthesis using reactance extraction.

Brockett

**6.568 Principles of Communication (A)**

Prereq.: 6.05; 6.28 or 18.18

Year: G (1, 2)

3-0-9

Probabilistic formulation of the communications problem. Mathematical description of signals and noise. Decision regions and optimum receivers. Discrete modulation and signal design. Introduction to channel capacity and error-free communication over noisy channels. Performance and limitations of continuous modulation systems (AM, FM, PPM). Interchange of bandwidth and signal-to-noise ratio; threshold effects.

Hoversten

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

ELECTRICAL ENGINEERING

## 6.569J Space Communications (A)

(Same subject as 16.45J)

Prereq.: —

Year: G (1)

3-0-9

Study involving the important interaction between the orbital and dynamical characteristics of spacecraft, the transmission of electromagnetic signals over long distances and the concepts of modern communication theory. Stress on interplay between these diverse topics in practical space communication systems. Discussions of spacecraft dynamics, stabilization, attitude control, propagation effects and pertinent modulation and coding methods. (Some background in space dynamics or in communications assumed. Permission of instructor required.)

Harrington

## 6.57 Probability Theory and Linear Systems (A)

Prereq.: 6.01, 18.05

Year: G (1)

3-0-9

Combination of an elementary introduction to probability theory with a brief review of the methods for the representation and analysis of linear systems. Specifically intended for first-year graduate students who seek to strengthen their preparation for further studies in the area of statistical communication theory. Axiomatic foundations of probability theory, random variables, distributions, expectations, characteristic functions, transformations of variables, and laws of large numbers. Some simple applications to statistics. Linear systems in the time and frequency domains — convolution and Fourier-Laplace integral representations. Examples which illustrate important concepts and problems in modern communication.

Van Trees

## 6.571 Statistical Theory of Communication (A)

Prereq.: 6.05

Year: G (1, 2)

3-0-9

Messages and noise as stationary random processes. Elementary probability theory, statistical characteristics of messages and noise, particularly correlation functions and spectra. Measurement of correlation functions. Detection of signals in the presence of noise by correlation. Determination of impulse response of linear systems by correlation. Theory of the statistical optimum filter, predictor, compensator, differentiator, and general linear system operator. Synthesis of optimum linear systems by normal and orthogonal functions. Emphasis on practical applications.

Bose, Nelsen, Rafuse

## 6.573 Introduction to Random Processes (A)

Prereq.: 6.05, 6.28; 6.57

Year: G (1, 2)

3-0-9

Random processes: partial and complete characterization, stationary and ergodicity. Calculus of random processes: continuity, integration, and differentiation. Functions of random processes. Characterization of linear systems using impulse responses and state-variables. Input-output relations for random processes in linear systems. Differential equations driven by random processes. Process measurements and statistics: mean, distribution function, spectrum, and correlation function. Representation of processes: sampling theorem, orthogonal series, spectral decomposition. Poisson processes. Renewal processes. Gaussian processes. Markov processes: discrete time-continuous state and introduction to continuous time-continuous state. Emphasis on developing an ability to reduce engineering problems to a mathematical model, to solve the resulting probabilistic problem, and to appreciate the significance and limitations of the results.

Van Trees, Hoyersten

## 6.574 Transmission of Information (A)

Prereq.: 6.28 or 6.57 or 6.573 or 18.18

Year: G (1, 2)

3-0-9

Introduction to the quantitative study of communication processes, with emphasis on the concepts fundamental to the engineering of accurate, efficient communication systems. Definition of a measure of information and study of its properties; efficient representation of discrete message sources; communication channels and their capacity; encoding and decoding of data for transmission over noisy channels and evaluation of bounds to the probability of decoding errors.

Gallager

## 6.575 Advanced Topics in Information Theory (A)

Prereq.: 6.574

Year: G (2)

3-0-9

Further work on information processing and coding theory based on 6.574. Varying content. In 1969-70, exploration of applications to data processing, including such possible topics as information storage and retrieval and reliable computation with noisy computing elements. Term paper required.

R. S. Kennedy

## 6.576 Detection, Estimation, and Modulation Theory (A)

Prereq.: 6.57 and 6.573; or 6.573

Year: G (1, 2)

3-0-9

A unified approach to the areas of detection, estimation, and modulation theory. Classical detection and estimation theory: Bayes, Neyman-Pearson tests; Bayes estimation, maximum likelihood estimation. Process representations. Detection of signals in Gaussian noise. Fredholm integral equation theory. Signals with unwanted parameters, composite hypotheses. Estimation of continuous waveforms. Linear estimation. Wiener filters. Closed-form error expressions. Differential equation representation of linear systems. Kalman-Bucy filters. Non-linear modulation theory: phase-locked loops, optimum angle modulation, rate distortion theory. Comparison of various communication systems. Gaussian signals in Gaussian noise: detection and parameter estimation.

Van Trees

## 6.577T Communication Systems and Optical Channels (A)

Prereq.: 6.568 or 6.573; 6.574

Year: G (2)

3-0-9

Application of information and detection theory to important physical channels such as additive noise, filtered, and fading dispersive channels. Discussion of appropriate channel models, their fundamental performance limitations, and communication systems which approach these limits. Illustration of ideas in terms of the channels which are important at optical frequencies, followed by study of channels in which the fading may be non-Gaussian, in which the spatial variations of the received signal may be important, and in which the noise may be signal dependent. Emphasis on the coupling between the physical channel characteristics and the communication system.

Hoyersten, R. S. Kennedy

## 6.578 Advanced Topics in Random Processes (A)

Prereq.: 6.573

Year: G (2)

3-0-9

Additional study of the theory of random processes introduced in 6.573. Topics change from year to year at the discretion of the instructor in charge. (Not offered 1969-70.)

Van Trees, Snyder

## 6.579 Probability Theory and Random Processes (A)

Prereq.: 18.034 or 18.07

Year: G (1)

3-0-9

An introduction to the theory of probability and random processes with engineering applications. Probability as

a model for empirical averages. Random variables and probability distribution functions. Statistical averages. Elements of estimation and sampling theory. Correlation and characteristic functions. Passage of random processes through linear systems, definition of spectra. Basic properties of the simple random walk, Markov chains, and the Poisson and Gaussian random processes. Various additional applications at the discretion of the instructor. (*Restricted to Practicing Engineers in the Center for Advanced Engineering Study.*) *Davenport*

**6.58 Electrodynamics of Waves, Media, and Interactions (A)**

Prereq.: 6.06, 6.07 or 6.584

Year: G (1)

3-0-9

Intended for first-year graduate students whose major interest is in the interaction of electric and magnetic fields with charged particles and continuous media. Radiation and Cherenkov fields from moving charges. Wave propagation in continuous media and their dispersion relations; energy and energy flow associated with wave propagation in passive and active media. Coupling of modes in stable and unstable systems; general stability criteria and techniques for identifying and classifying wave-type instabilities. Examples are taken from plasma, magnetostatic, acoustic, electromechanical and electron-beam waves and interactions. *Bers*

**6.583 Advanced Topics in Continuum Electrodynamics (A)**

Prereq.: 6.03T or 6.584 or 8.311

Year: G (1)

3-0-9

Precise material to be covered and prerequisites to differ from year to year according to interest of the instructor in charge. Typical topics: electromagnetism of moving media, continuum electrohydrodynamics, antennas and propagation, waves in dispersive media. In 1968-69: fundamental macroscopic equations of electrodynamics of moving media, and the force of electromagnetic origin in polarized and magnetized bodies. Principle of virtual power and energy-momentum tensors, both non-relativistic and relativistic. Equivalence of various formulations of electrodynamics, especially the two models for magnetization. Topics for 1969-70 to be announced. *Penfield*

**6.584 Electromagnetic Theory (A)**

Prereq.: 6.02, 18.05

Year: G (1)

3-0-9

Selected topics from fields, energy and forces, energy transmission and radiation, treated from an advanced viewpoint. (*For first-year graduate students.*) *Chu*

**6.59 Bioelectric Signals (A)**

Prereq.: 6.372

Year: G (2)

3-0-9

For graduate students in the communication sciences. Neuroelectric activity in relation to complex behavioral processes, including learning, perception, sleep and movement. Emphasis on the study of neuroelectric signals from behaving organisms, including man. Analysis of cortical potentials and other neuroelectric events pertinent to major topics. Sensory processes as they apply to the control of behavior. (*Admission only by permission of instructor.*) *Rosenblith, Hall*

**6.591 Signal Transmission and Coding in the Auditory System (A)**

Prereq.: 6.03T, 6.05, 6.28, 6.372

Year: G (1)

3-0-9

Intended for graduate students with a serious interest in sensory physiology. Discussion centering on responses of the auditory system to acoustic stimuli. Presentation aimed at understanding of the physiological mechanisms involved in transmission and processing of signals. When

possible, consideration of the relations of physiological signals to psychophysical measurements. Major emphasis on the more peripheral parts of the system: signal transmission in the external ear, middle ear, cochlea, auditory nerve, cochlear nucleus, superior olivary complex. Some discussion of the anatomy and physiology of higher levels. (*Alternate years. Not offered 1969-70. Appropriate background other than the listed prerequisites may be accepted by the instructor.*) *Kiang, Peake, T. F. Weiss*

**6.592 Analytical Models for Human Processing of Sensory Inputs (A)**

Prereq.: 6.37T or 6.372

Year: G (2)

2-0-7

Evaluation and design of research procedures for the simulation of human perceptual processes. Review of relevant literature from psychophysics and theory of perception, considering both human perception and the evidence from the study of lower organisms. Application of this information to a critical evaluation of recent work in machine simulation of human perceptual processes, emphasizing studies of pattern recognition, abstracting, self-organizing systems as perceptual models, etc. Design of experimental research projects utilizing the technique of machine simulation with the goal of providing a perceptual model that satisfies the known constraints of human physiology and psychology. *Eden*

**6.593 Sensory-Neural Systems (A)**

Prereq.: —

Year: G (2)

3-0-9

Detailed consideration of a number of sensory-neural systems with respect to anatomy, physiology, and mode of operation. Reading of relevant papers and critical discussion of the methods and results described. Topics selected on the basis of their current research interest with emphasis on systems containing relatively few elements for which simple models relate physical input to sensory cell/neuron output. Examples from vertebrate and invertebrate species including mechanical, visual, and other modalities. (*Permission of instructor required.*) *Frishkopf*

**6.595 Communication Sciences Seminar (A)**

Prereq.: 6.05

Year: G (1)

3-0-9

**6.596 Communication Sciences Seminar (A)**

Prereq.: 6.05

Year: G (2)

3-0-9

Selected topics relevant to research areas in which the theory and techniques of communications, information, and control engineering bear upon problems in the life sciences. Intended mainly for electrical engineering graduate students interested in communications science, but also open to students in fields such as linguistics, psychology, and physiology. Reading, discussion, and the preparation of individual term papers. Material varying from term to term and year to year. *Eden, S. J. Mason*

**6.60 Analysis of Dynamical Systems (A)**

Prereq.: 6.05

Year: G (1, 2)

3-0-9

An integrated and rigorous approach to the analysis of forced and unforced dynamical systems from a state-space point of view. Preparatory for advanced study in control theory. Discussion of vector spaces and linear transformations. Basic existence and uniqueness theorems for differential equations, linearization of nonlinear differential equations about an equilibrium point and about a nominal trajectory, numerical solution of

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

ELECTRICAL ENGINEERING

differential equations. Linear constant systems and their solution in the time and frequency domain. Linear time-varying system and their solution in terms of the transition matrix. Properties of dynamical systems including controllability, output controllability, normality, observability, and the interpretation of these properties for linear systems. Introduction to quadratic optimization of linear systems in both the time and frequency domain. The stability of dynamical systems including the Routh-Hurwitz, Nyquist, and circle criteria. *Brockett*

## 6.601 Control System Theory (A)

Prereq.: 6.05; 6.57 or 6.57J or 6.573  
Year: G (1) 3-0-9

Introduction to basic theory for analysis and design of control systems. Emphasis on linear, infinite time-interval problems. Mathematical models for dynamic systems. Review of transforms and stability criteria. Analyses for transient and steady-state response. Root loci. Trial-and-error design techniques using frequency response methods. Optimization theory for stochastic and deterministic signals. Selected topics from: sampled-data theory, analytical tools for stability of non-linear systems, simulation and computation techniques, sensitivity analysis, and control system components. (For graduate students without prior background in control.) *Newton*

## 6.602 Non-Linear Dynamical Systems (A)

Prereq.: 6.60  
Year: G (2) 3-0-9

Introduction to basic non-linear phenomena and methods. Iteration and fixed-point theorems. Linearization, implicit function theorems and the method of averaging. Passivity in linear and non-linear systems. Stability concepts for feedback loops and stability criteria based on contraction, conic operators and passivity considerations. Study of time-varying and non-linear feedback loops including free and forced responses, jump phenomena, and subharmonic generation. Circle criterion, Popov's criterion and other frequency-domain stability criteria. Liapunov stability theory. Construction of Liapunov functions using path integrals. Applications drawn from mechanics, electronics, and automatic control. *Willems*

## 6.603 Seminar in Control Research (A)

Prereq.: 6.213 or 6.601  
Year: G (1, 2) 3-0-9

Further preparation for graduate research in the control field. Topics, such as non-linear theory, optimal control, and stability theory, e.g., selected according to student and staff interests. Reading and discussions supervised by one or more staff members and specialists. Specific topics and arrangements announced each term. Consent of instructor required. *Newton*

## 6.604J Special Studies in Systems Engineering (A)

(Same subject as 1.16J, 2.191J, 13.47J, 17.818J)  
Prereq.: —  
Year: G (2) 2-4-6

Introduction to basic techniques employed in planning and design of complex systems. Detailed design of subsystems by individual student groups with emphasis upon use of parametric design principles in arriving at suitable tradeoffs between subsystems. Supplementing lectures covering general principles of the operational complex and subsystems by guest lecturers. The particular operational complex chosen for each term to be announced before start of the term. Students encouraged to discuss subject with staff prior to registration. (Previous projects: Group 1 — integrated urban transportation system. Group 2 — manned satellite inspection and retrieval system.) *Seifert, Baumann, Frankel, R. C. Wood*

## 6.605 Simulation Methods for Analysis and Control (A)

Prereq.: 6.213 or 6.601  
Year: G (2) 3-0-9

Introduction to simulation methods for analysis of complex dynamical systems and their controls. Assumption of background of elementary control theory. Some knowledge of digital computer programming an asset. Treatment of analog, hybrid, and digital methods for simulation by means of case studies. Use of one or more special languages useful in digital simulations. Speed and cost of alternative computing procedures. Emphasis on analytical checking methods and pertinent questions of numerical analysis. Illustration of modern simulation methods by project-type problems using both analog and digital facilities. *Newton*

## 6.606 Stochastic Dynamic Systems (A)

Prereq.: 6.28 or 6.57 or 6.573 or 18.18; 6.60  
Year: G (1) 3-0-9

State-space approach to dynamic systems with uncertainties. Stochastic and non-probabilistic models for uncertainty. Linear, non-linear, discrete time, and continuous time models and analysis suitable for computer solution. Estimation and hypothesis testing based on Bayesian, Fisher, Kalman-Bucy, weighted least squares, and unknown but bounded concepts. Distance measures. Introduction to measurement and signal design, system identification, and stochastic control. *Schwepppe*

## 6.607 Special Problems in Control (A)

Prereq.: 6.05 or 6.213 or 6.601  
Year: G (1 or 2) Arr.

Supervised investigation of special topics in feedback control system analysis and synthesis, laboratory investigations supported by library research and analytical work utilizing the facilities of the feedback control laboratory. Program and hours to be arranged with interested staff member, subject to approval of instructor. *Newton*

## 6.608 Process Control (A)

Prereq.: 6.60 or 6.601 or 10.35  
Year: G (2) 3-0-9

Control of industrial processes with emphasis on applications in the chemical industries. Development of lumped and distributed models of processing units. Partial differential equations of linear convective processes and approximate methods of solution. Conventional regulation theory; cascade, feedforward, and non-interacting control. Modal analysis and state space representation of lumped and distributed systems; modal control. Introduction to optimal control of chemical reactors and distributed systems. *L. A. Gould*

## 6.609 Theory of Optimal Control (A)

Prereq.: 6.60  
Year: G (1, 2) 3-0-9

Review of state-space representation of dynamical systems. Definition of the optimal control problem. Necessary and sufficient conditions for optimality; the classical variational approach, the Maximum Principle of Pontryagin, the Hamilton-Jacobi theory. Existence and uniqueness theorems. Singular problems. Applications of the theory to minimum time and minimum fuel problems; the design of time- and fuel-optimal systems using switch curves and switch surfaces. The design of optimal linear regulators and tracking systems with respect to quadratic performance criteria; the matrix Riccati equation approach. Introduction to the Wiener-Kalman-Bucy filter theory. Introduction to computational techniques for the solution of optimization problems. *Athans*

**6.611 Digital Processing of Signals (A)**

Prereq.: 6.05

Year: G (1)

3-0-9

Representation, analysis and design of discrete signals and systems, z-transforms and the discrete Fourier transform. Difference equation and state-space representation of recursive and non-recursive systems. Representation of non-recursive systems by means of pole-zero cancellation or the discrete Fourier transform. Frequency-domain design techniques and examples for recursive and non-recursive systems. Implementation of discrete linear systems: discrete linear networks, effects of quantization, truncation and parameter inaccuracies. Noise performance of filter configurations. Computation of the discrete Fourier transform: Goertzel's algorithm, Bluestein's algorithm, the fast Fourier transform (FFT) algorithms. Effects of quantization, truncation, and parameter inaccuracies in the FFT. Implementation of non-recursive systems and interpolation of sequences using the FFT. Homomorphic filtering with applications. Selection of additional topics from the following: digital spectrum estimation, multi-dimensional signal processing, hardware considerations in the implementation of digital filters. Emphasis on an understanding of fundamental concepts. Selection of examples of practical problems from a variety of areas.

A. V. Oppenheim

**6.621T Microwave Circuits (A)**

Prereq.: 6.07

Year: G (2)

3-2-7

Electromagnetic wave propagation on uniform and periodic structures; apertures and obstacles; equivalent circuit representations; non-reciprocal ferrite devices. Cavity and confocal resonators; perturbation theory. Multipoint junctions. Solution of boundary value problems and orthogonal mode expansions plus qualitative discussion of more complex structures. Laboratory experiments.

Kuhl

**6.622 Antennas (A)**

Prereq.: 6.07

Year: G (2)

3-0-9

General theory of radiation and its application to the analysis of representative types of antennas; emphasis placed on the design of antenna arrays, microwave reflectors, and lenses.

Chu

**6.624 Detection and Measurement of Radio Astronomical Signals (A)**

Prereq.: 6.07

Year: G (1)

3-0-9

Detection and measurement of radiation typical of signals encountered in radio astronomy. Characterization and measurement of random electromagnetic fields, including their spatial, angular, time, and polarization correlation properties. Holograms. Angular filtering properties of antennas, including interferometers and aperture synthesis systems. Antenna temperature and gain. Statistical analysis of signal processors, including basic radiometers, spectrometers, interferometers, and certain digital systems. Noise characterization and analysis for n-port networks. The equations of radiative transfer and their inversion. Applications of parameter estimation theory.

Staelin

**6.625J Fundamentals of Radio Astronomy (A)**

(Same subject as 8.951J)

Prereq.: 6.624 or 8.05 or 8.211

Year: G (2)

3-0-9

Emission and absorption of radio energy in stellar and planetary atmospheres, gaseous nebulae, and the interstellar medium. Detailed development of emission mechanisms, including free-free transitions, spectral line radiation from H, OH, and other atoms and molecules, synchrotron radiation using classical relativistic electro-

dynamics. Theory and results of radio observations of the moon, planets, sun, discrete galactic sources, galactic background radiation, extra-galactic sources. Impact of radio astronomy on galactic structure, physics of the interstellar medium, origin of cosmic rays, cosmology. Radio astronomical observations and experiments from space vehicles. (No prior knowledge of astronomy or astrophysics required. Students who wish to do thesis work in this area are advised to take 6.624 and 6.625J.)

Staelin, Barrett

**6.631 Plasma Dynamics (A)**

Prereq.: 6.58

Year: G (2)

3-0-9

Introductory subject in plasma phenomena. Motion of charged particles in electric and magnetic fields; adiabatic invariants; drifts due to magnetic field gradients. Collision theory. The Boltzmann equation and derivation of the macroscopic transport equations. Plasma waves such as electromagnetic waves, whistlers, helicon waves, electron and ion acoustic waves. The magneto-hydrodynamic limit and Alfvén waves.

Briggs, Parker

**6.632 Electronic Instrumentation and Control (A)**

Prereq.: 6.05

Year: G (1, 2)

3-0-9

Transistors, other solid-state devices, and electron tubes in electronic instrumentation for control and measurement. Electronic conversion transducers; direct-coupled, pulse, and signal-processing amplifiers; modulators and demodulators; monostable and bistable switching circuits; gates; coincidence circuits; random-event counting and count-rate circuits. Illustrations from such applications as time-interval and frequency measurements, high-speed counting and recording instruments, computer components, strain gages, tachometers, and nuclear-reactor control.

T. S. Gray

**6.635 Semiconductor Electronics (A)**

Prereq.: 6.08, 6.341

Year: G (1)

3-0-9

Principles and applications of some of the electronic properties of semiconductors important for devices: Use of quasi-fermi levels in the description of p-n junctions and transistors; review of diode and transistor performance at high injection levels; statistics of recombination and trapping, and effect on diode and transistor characteristics; avalanche processes in p-n junctions and transistors; four-layer diodes and controlled rectifiers.

R. B. Adler

**6.636T Microelectronics (A)**

Prereq.: 6.341

Year: G (2)

3-0-9

Fabrication, design, and applications of microcircuits with particular emphasis on silicon monolithic integrated circuits. Introduction to the theory and technology of epitaxial growth, oxidation, diffusion, and alloying. Physical and electrical description of integrated components: transistors, diodes, capacitors, and resistors. Fundamental limitations of micro miniaturization. Circuit design philosophy for linear and digital integrated circuits (temperature and device matching, active versus passive device tradeoffs, component limitations, relationship of cost to area, etc.). The operational amplifier and the digital gate — basic integrated circuit building blocks. Discussion of recent designs to illustrate the design and application of integrated circuits, particularly in linear circuits. Additional topics such as the use of computer-aided design, active filter design, MSI and LSI as time allows. Possible requirement of a laboratory project or a term paper.

Smythe

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

ELECTRICAL ENGINEERING

## 6.638 Seminar on Solid-State Plasma Effects (A)

Prereq.: 6.08, 6.58

Year: G (2)

3-0-9

Intended for students with graduate background in either solid-state or plasma physics. Simple wave phenomena in solids: helicon, Alfvén, optical, and acoustic plasma waves. Emphasis on unifying role of frequency- and wavevector-dependent dielectric tensor as well as the similarities and differences between solid-state and gas plasmas. Treatment of resonant (Landau) and non-resonant damping from both classical and quantum points of view. Discussion of various types of growing waves and instabilities, including acoustic wave amplification, two-stream instabilities, pinching, helical density waves, and the Gunn effect. Use of plasma effects for band structure determination. Application of Landau Fermi-liquid theory to metals and semimetals.

McWhorter, Bers

## 6.639 From Atoms Toward Living Systems (A)

Prereq.: —

Year: G (2)

3-2-7

An attempt to bridge between the materials sciences and the life sciences. The electronic structures of atoms and the implications of the Periodic System, development of the theme in lectures and round-table discussions from gases to liquids and solids, from insulators to conductors, from the molecular architecture of static systems to the operation principles of dynamic systems and living cells.

von Hippel

## 6.64J Electronic Materials (A)

(Same subject as 3.76J)

Prereq.: 3.15; or 6.02 and 6.341

Year: G (2)

2-0-6

Various aspects of electronic materials such as preparation, purification, crystal growth, crystal structure, characterization, electronic properties, band structure and device applications. Special emphasis on relationships between structural characteristics, atomic bonding and physical properties in classes of materials such as elemental and compound semiconductors, thermoelectrics and superconductors. Extensive rather than intensive coverage.

Gatos, Witt

## 6.641J Laboratory in Physics of Solids (A)

(Same subject as 3.40J)

Prereq.: 3.15 or 6.08; 8.04 or 8.211

Year: G (1, 2)

0-8-4

Experimental investigations on the physical properties of materials closely related to current research; brief lectures on the basic theories and experimental methods. Experiments in areas of: X-ray diffraction, galvanomagnetic effects, superconductivity, ferroelectricity, crystal growth, infrared absorption, Mössbauer effect, thermal properties, magnetic resonance, dielectric properties, carriers in semiconductors, elastic constants, defect structures.

A. C. Smith, Moss

## 6.642 Special Topics in the Solid State and Its Application (A)

Prereq.: 8.321

Year: G (1)

3-0-9

## 6.643 Special Topics in the Solid State and Its Application (A)

Prereq.: 8.321

Year: G (2)

3-0-9

Primarily for those interested in research on solid-state materials and devices for electrical and electronic applications. Topics and staff to be announced each term. Given independently or sequentially as circumstances require. (Permission of instructor required.)

D. J. Epstein

## 6.644 Microwave Magnetics (A)

Prereq.: 6.06 or 6.07; 8.04

Year: G (2)

3-0-9

Introduction to the propagation and mutual interaction of microwave photons, magnons, and phonons in ferro-, antiferro- and ferrimagnetic crystals. Molecular field theory of ferrimagnetism. Quantum mechanical and semi-classical treatments of magnons including dipolar interactions; harmonic oscillator approximation of spin waves and Holstein-Primakoff transformations. Elementary domain theory. Linear and non-linear effects associated with magnetic resonance. Propagation of electromagnetic waves in ferrite-loaded waveguides; reciprocal and non-reciprocal microwave circuit elements such as rotators, isolators and circulators. Magnetoelastic wave propagation in exchange-coupled gyromagnetic media when magnetostriction is present. Detailed study of the electromagnetic, exchange, and elastic channels of power flow. Linear and non-linear mechanisms of magnon/photon and magnon/phonon conversion; applications to fundamental spectroscopy and to the field of microwave devices.

Morgenthaler

## 6.645 Topics in Semiconductor Device Research (A)

Prereq.: 6.08, 6.341; 6.651J or 8.511

Year: G (2)

3-0-9

Relationship of the electrical properties and band-structure of semiconductor materials to device performance. Device applications of the following phenomena: tunneling, heterojunctions and Schottky barriers, impurity- and impurity-band-conduction, hot electron effects including the Gunn effect, avalanche including avalanche transit time oscillators, injection luminescence including laser action, photo-detection including light-coupled amplifiers.

Rediker

## 6.646 Conduction Processes in Solids (A)

Prereq.: 6.08; 6.651J or 8.511

Year: G (1)

3-0-9

Topics in transport theory, including irreversible thermodynamics, Onsager relations, crystal symmetry, energy band theory, effective mass approximation, Boltzmann transport theory, electrical and thermal conductivity, thermoelectric, thermomagnetic, and galvanomagnetic effects.

D. Adler

## 6.647 Electronic Properties of Solids (A)

Prereq.: 6.651J or 8.511

Year: G (1)

3-0-9

## 6.648 Electronic Properties of Solids (A)

Prereq.: 6.647 or 8.511

Year: G (2)

3-0-9

Development of empty lattice, weak binding and tight binding approximations for energy bands, group theory with applications to solid-state problems, symmetry methods for energy band models, spin-orbit coupling. Survey of techniques for energy band calculations. Discussion of effective mass theory, Bloch electron in a magnetic field, deformation potentials. Illustrative discussion of the relationship of the above to transport properties, to optical and magneto-optical properties, and to the study of the Fermi surface.

Pratt

## 6.649 Quantum Electronics (A)

Prereq.: 6.651J or 8.05

Year: G (1)

3-0-9

Quantum states and energy levels. Time-dependent perturbation theory and relations to line broadening. The density matrix and its time evolution. Quantization of the electromagnetic field. Spontaneous and stimulated emission of radiation. Negative temperatures and population inversion as a driving source of an electromagnetic field. Lamb's theory of optical lasers. Coherence of

optical fields, fluctuations, photon statistics and noise. Gas and semiconductor lasers. Electro-optic effects and non-linear optics. *Pratt*

**6.65 Quantum Theory of Magnetism (A)**

*Prereq.:* 6.651J or 8.511

*Year:* G (2)

3-0-9

Magnetic properties of isolated atoms and ions. Crystal field theory. The spin Hamiltonian. Optical properties of paramagnetic crystals. Spin paramagnetism of metals. Diamagnetism of solids. The de Haas-van Alphen effect. Ferromagnetic exchange interactions. The Weiss and Heisenberg theories of ferromagnetism. The Bethe-Peierls-Weiss theory. Energy band theory of ferromagnetism. Superexchange coupling in antiferromagnetism. Ferrimagnetism. (*Not offered 1969-70.*)

*Pratt*

**6.651J Physics of Solids (A)**

(Same subject as 3.42J)

*Prereq.:* 3.41T; or 6.03T and 8.05; or 6.03T and 8.211

*Year:* G (1)

3-1-8

First term of a two-term sequence presenting the basic concepts of the quantum theory of crystalline materials. Emphasis on mathematical methods and physical models which have proven to be generally useful in obtaining quantitative descriptions of physical quantities. Student use of a computer console to solve quantitative problems; no programming experience necessary. Topics: diffraction of X rays, electrons, and neutrons by solids; periodic structures and reciprocal space; lattice dynamics, normal modes and phonons; quantum statistics; electron states in solids, Bloch waves and energy bands; perturbation theory; classification of solids. *A. C. Smith, Kaplow*

**6.652J Physics of Solids (A)**

(Same subject as 3.43J)

*Prereq.:* 3.42J or 6.651J

*Year:* G (2)

3-1-8

Second term of a two-term sequence presenting the basic concepts of the quantum theory of crystalline materials. Topics: dynamics of electrons in solids, effective mass theorem; transport phenomena, electrical conductivity; magnetic phenomena, angular momentum and spin; paramagnetism, diamagnetism, ferromagnetism; interaction of radiation with solids, optical properties, resonance phenomena. *A. C. Smith, Selmyer*

**6.681T Introduction to Electrical Engineering Research**

*Prereq.:* —

*Year:* G (1)

*Arr.*

Lectures on research currently under way in Department of Electrical Engineering. Opportunity for individual study, under a staff member, of advanced subjects related to electrical engineering not otherwise included in the curriculum. Program to suit individual requirements by the student and staff members interested, subject to approval of the professor in charge. (*Restricted to entering graduate students in the Department of Electrical Engineering.*) *D. J. Epstein*

**6.682T, 6.683T Special Studies in Electrical Engineering**

*Prereq.:* —

*Year:* G (1 or 2)

*Arr.*

Opportunity for individual study, under a staff member, of advanced subjects related to electrical engineering not otherwise included in the curriculum. Program to suit individual requirement by the student and staff members interested, subject to approval of the professor in charge. (*Registration of non-Course VI students subject to approval of professor in charge.*) *D. J. Epstein*

**6.684-6.689 Special Subjects in Electrical Engineering (A)**

*Prereq.:* —

*Year:* G (1 or 2)

*Arr.*

Opportunity for group study of advanced subjects related to electrical engineering not otherwise included in curriculum. Programs subject to approval of professor in charge. *D. J. Epstein*

**6.691J Speech Communication (A)**

(Same subject as 23.768J)

*Prereq.:* —

*Year:* G (2)

3-0-9

Survey of structural properties of natural languages with special emphasis on the sound pattern. Survey of physiology of speech production, articulatory phonetics. Acoustical theory of speech production: the vocal tract as a generator of acoustical signals; acoustical correlates of vocal-tract configurations, both stationary and dynamic; acoustical and articulatory descriptions of phonetic features. Perception of speech: the auditory capabilities of man; evidence for perceptual correlates of phonetic categories. Mechanical recognition and generation of speech. Speech transmission and compression; the concept of intelligibility; effects of distortion on intelligibility. Recommended prerequisites: engineering and science students, 6.36; linguistics students, mathematical background equivalent to 6.05 or 18.05. Others admitted by permission of instructor. (*Not offered 1969-70.*) *Stevens, Halle*

**6.70 Electronic Components and Measurements**

*Prereq.:* 6.01

*Year:* U (1, 2, S)

1-4-1

Required laboratory for electrical engineering students. Laboratory work concerned with meters, components, oscilloscopes and other equipment necessary to make common measurements of electrical parameters. *Roberge*

**6.71 Electronic Circuits and Signals Laboratory**

*Prereq.:* 6.70

*Year:* U (1, 2, S)

1-4-1

Experiments on electric and electronic circuits and systems. *Schreiber*

**6.711T Digital Systems Project Laboratory**

*Prereq.:* 6.01, 6.70

*Year:* U (1, 2)

3-7-2

Introduction to some of the basic techniques and devices used in the design and implementation of digital computing and control systems. Preliminary work by a combination of classes, homework, and associated laboratory experiments with digital integrated circuits. Detailed study of logic design, including Boolean algebra, synthesis of combinational logic, iterative logic realizations, and techniques for description and syntheses of sequential circuits; other topics, such as memory devices, if time permits. Implementation of all projects with microcircuit logic elements. Oral presentation and written report on completion of project. (*Registration limited to 40 students.*) *Troxel*

**6.712 Bioelectronics Project Laboratory**

*Prereq.:* 6.01, 6.02

*Year:* U (1)

2-8-2

Emphasis on design of electronic systems useful in medicine, biology, or psychology. Throughout the term one lecture each week on the life sciences and a second lecture on electronic systems. Coordination of

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## ELECTRICAL ENGINEERING

lectures and laboratory work. In any particular term, focusing of all projects on one specific problem area (e.g. the analysis of electrocardiograms). Students working individually or in pairs on the specification, design, construction and evaluation of a complex electronic system. Emphasis on the description, on the interaction of the functional components comprising a system, and on the over-all performance of the system rather than on the design of circuitry. Extensive use of integrated circuits and functional components. Oral presentation and written report on completion of project. (*Registration limited to 20 students. Alternate years.*) Burns

### 6.714 Electronic Light Measurements Project Laboratory

Prereq.: 6.02

Year: U (1, 2)

2-8-2

Project version of 6.202. Opportunity for investigation in project form of advanced photographic, photo-optical or photo-optical-electronic processes and devices. Topics include color photographic processes and reproduction, electronic photometry, electronic (xenon-stroboscopic) flash apparatus, ultra-high-speed photography, electronic imaging and image conversion techniques, etc. Instruction on a weekly seminar basis with a written report or essay upon completion of the subject. Edgerton

### 6.715 Power Systems Project Laboratory

Prereq.: 6.01, 6.03T, 6.70

Year: U (1, 2)

2-8-2

Introduction to the concepts and techniques used in power systems engineering. First three weeks: lectures describing power system technology and the projects currently available. Student's choice (either alone or with lab partners) of a project; independent work involving linear and non-linear circuits both passive and active, electromagnetic phenomena, electromechanical phenomena, etc., all in a power system context. (*Limited enrollment.*) Woodson, G. L. Wilson

### 6.716 Particle Optics Project Laboratory

Prereq.: 6.03T

Year: U (2)

2-8-2

Special projects involving low energy electrons and ions and their interactions with fields and surfaces. Typical projects: design and testing of mass spectrometers, low magnification electron microscopes, high power beams, electron multipliers, and special cathode ray tubes. Other studies concern secondary emission, electron diffraction, microminiaturization of computer components using electron-induced chemistry, thin films, or other areas of interest. (*Not offered 1969-70.*) Crawford

### 6.717 Audio Frequency Communications Project Laboratory

Prereq.: 6.05, 6.71

Year: U (1, 2)

2-8-2

Introduction to some of the more common techniques and methods for the transmission or storage of information carrying signals. Application of systems analysis, information theory, and circuit design to the development of communications systems. Emphasis on the interrelationship between bandwidth, noise, energy, cost, size, reliability, effectiveness, etc. Illustrative examples, including RF transmitters and receivers, tape recorders, compactors, vocoders, compressors, human speech, to be discussed in seminar-like recitations. Laboratory experiments related to classroom discussions with oral and written presentations of the projects. Student self-motivation desired. Troxel

### 6.719 Semiconductor Devices Project Laboratory

Prereq.: 6.02, 6.70

Year: U (1, 2)

2-8-2

Introduction to some of the basic techniques and processes used in the fabrication of microcircuits with particu-

lar emphasis on monolithic silicon integrated circuits. Classes, homework, and preliminary laboratory projects on the theory and techniques of oxide masking, diffusion, and thin-film deposition. Individual project in one of the above areas, or in the fabrication of such semiconductor devices as integrated capacitors or resistors, bipolar transistors, JFETS, MOSFETS, Schottky-barrier diodes, or delay lines. Smythe

### 6.722 Modern Optics Project Laboratory

Prereq.: 6.03T, 6.05

Year: U (1, 2)

2-8-2

Emphasis on coherent optical systems, quantum electronics, and optical information processing and transmission. Lectures and demonstrations preliminary to projects: properties of light, imaging and transforming properties of a lens, practical optical systems, optical measurements, lasers, optical detectors, holography, optical modulation and communication. Project areas: optical filtering, holography, optical communication, lasers, and quantum noise. Oral presentation and written report. (*Limited enrollment.*) Hoversten

### 6.723 Image Transmission Systems Project Laboratory

Prereq.: 6.02

Year: U (2)

0-12-0

Student use of facilities of the Image Processing Laboratory of the Cognitive Information Processing Group in R.L.E. for projects related to picture transmission or reproduction systems. Facilities available for computer simulation studies as well as hardware projects. Possible topics: enhancement of images, such as X-rays, by analog or digital filtering; production of a series of standard images for use in image quality evaluation studies; computer generation of images for study of optical illusions; character recognition; picture noise suppression; study of optimum filtering of sampled images, etc. Schreiber

### 6.74 Advanced Electrical Energy Conversion Laboratory (A)

Prereq.: 6.06

Year: G (1 or 2)

Arr.

Graduate subject planned for the individual student; special problems on electrical energy converters and modulators. Woodson

### 6.79 Special Problems in Computation

Prereq.: 6.00

Year: U (1, 2)

Arr.

Individual work in computer science at the undergraduate level. Note: Acceptable ability to program a computer will satisfy the 6.00 prerequisite. Saltzer

### 6.80 Special Studies in Electrical Engineering

Prereq.: —

Year: U (1, 2)

Arr.

Opportunity for individual study at the undergraduate level related to electrical engineering not covered by other subjects offered by the Department. Responsibility of students for initiation of arrangements. Davenport

### 6.801-6.809 Special Subjects in Electrical Engineering

Prereq.: —

Year: U (1, 2)

Arr.

Opportunity for group study of undergraduate subjects related to electrical engineering not otherwise included in curriculum. Programs subject to approval of professor in charge. Davenport

### 6.81 Electrical Engineering Laboratory

Prereq.: —

Year: U (1, 2)

Arr.

Opportunity for individual experimental work at the undergraduate level related to electrical engineering

not covered by other subjects offered by the Department. Responsibility of students for initiation of arrangements.

*Troxel, Roberge*

**6.82 Undergraduate Thesis Presentation**

*Prereq.:* —

*Year:* U (1, 2)

*Arr.*

Registration for written and oral presentation of the undergraduate thesis when the thesis work is an extension of a project laboratory.

*Kyhl*

**6.831T-6.839T Teaching Electrical Engineering**

*Prereq.:* —

*Year:* G (1, 2)

*Arr.*

For qualified graduate students interested in teaching as a career. Laboratory, tutorial, or classroom teaching under the supervision of a faculty member. Students selected by interview. Total enrollment limited by availability of suitable teaching assignments.

*Bruce*

**6.841T-6.849T Research in Electrical Engineering**

*Prereq.:* —

*Year:* G (1, 2)

*Arr.*

For Research Assistants in electrical engineering in cases where the assigned research is approved for academic credit by the Department. Hours arranged with research supervisor.

*Searle*

**6.852-6.858 Project Study**

*Prereq.:* —

*Year:* U (1, 2)

0-12-0

Extended participation in the work of a research group, including activities such as independent study of the literature, direct involvement in the group's research commensurate with the student's skills and preparation, or project work under an individual faculty member extending over more than one term. Admission by arrangement with individual electrical engineering faculty member.

*Smullin*

**6.881-6.883 Industrial Practice at**

**AVCO Corporation**

*Year:* U (1, 2, S)

0-9-0

**6.884 Industrial Practice at**

**AVCO Corporation**

*Year:* G (S)

0-9-0

Work at Everett, Massachusetts, in high-temperature gas dynamics. Research areas including space-vehicle re-entry missile defense, space propulsion, electric power generation through magnetohydrodynamics (MHD), and fundamental investigations of interplanetary plasma characteristics. Work organized into aerophysics, dealing with solution of aerodynamic-flow problems involving physical phenomena inherent in high-temperature gases; atomic physics, dealing with atomic and molecular processes of high-temperature gases (principally air and its constituents); magnetohydrodynamics, dealing with interactions between plasmas and magnetic fields.

*J. A. Tucker*

**6.885 Industrial Project at AVCO Corporation**

*Year:* U (2)

0-12-0

Project to satisfy requirements of S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only.

*J. A. Tucker*

**6.891-6.893 Industrial Practice at**

**Radio Corporation of America**

*Year:* U (1, 2, S)

0-9-0

**6.894 Industrial Practice at**

**Radio Corporation of America**

*Year:* G (S)

0-9-0

Work at Research Center and Astro-Electronics Division of R.C.A. Laboratories in Princeton, New Jersey. Exploration of electronically active solid materials; application of new principles in solid-state devices; creation of

new or improved equipment for communications and broadcasting; research in energy conversion; development of new computing techniques, devices, and systems; studies in electron-tube and plasma devices; applied research, development, and design of space-vehicle systems; antennas; thermodynamics; optical systems; systems synthesis and analysis; data processing for operations research analysts and programming analysts.

*J. A. Tucker*

**6.895 Industrial Project at Radio Corporation of America**

*Year:* U (2)

0-12-0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only.

*J. A. Tucker*

**6.90 Industrial Project at the General Electric Company**

*Year:* U (2)

0-12-0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only.

*J. A. Tucker*

**6.901-6.903 Industrial Practice at the General Electric Company**

*Year:* U (1, 2, S)

0-9-0

**6.904 Industrial Practice at the General Electric Company**

*Year:* G (S)

0-9-0

Locations at Pittsfield, Schenectady, and Philadelphia. Work in electronic circuitry, solid-state physics, control and guidance systems, and computer applications as applied to research and development of commercial and government communication and control systems and ordnance equipment.

*J. A. Tucker*

**6.905-6.907 Industrial Practice at the International Business Machines Corporation**

*Year:* U (1, 2, S)

0-9-0

**6.908 Industrial Practice at the International Business Machines Corporation**

*Year:* G (S)

0-9-0

Work at an IBM plant in Poughkeepsie. Student participation in computer development, design, and application. Work in advanced circuit theory, solid-state physics, game theory.

*J. A. Tucker*

**6.909 Industrial Project at the International Business Machines Corporation**

*Year:* U (2)

0-12-0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only.

*J. A. Tucker*

**6.911-6.913 Industrial Practice at Honeywell, Incorporated**

*Year:* U (1, 2, S)

0-9-0

**6.914 Industrial Practice at Honeywell, Incorporated**

*Year:* G (S)

0-9-0

Work assignments at the Electronic Data Processing Division, Wellesley, Massachusetts; Radiation Center, Boston, Massachusetts; and at plant locations in Minneapolis, Minnesota. At Wellesley, opportunities relating principally to the design and development of digital computer circuits and systems and computer software. At the Radiation Center, assignments involving electro-optic sensors and related control, and information pro-

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

ELECTRICAL ENGINEERING

cessing systems. In Minneapolis, assignments involving a wide variety of experiences in automatic control, electronic circuitry and systems, and instrumentation for space, military, and industrial applications.

*J. A. Tucker*

**6.919 Industrial Project at Honeywell, Incorporated**

Year: U (2) 0-12-0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only.

*J. A. Tucker*

**6.921-6.923 Special Industrial Practice**

Year: U (1, 2, S) 0-9-0

**6.924 Special Industrial Practice**

Year: G (S) 0-9-0

Special assignments outside the regular Cooperative program.

*J. A. Tucker*

**6.931-6.933 Industrial Practice at the Raytheon Company**

Year: U (1, 2, S) 0-9-0

**6.934 Industrial Practice at the Raytheon Company**

Year: G (S) 0-9-0

Work at one of the Raytheon Laboratories (Newton, Burlington, Wayland, Sudbury, Bedford). Assignments involving circuit analysis and design as applied to communication and control systems; or research and development activity in the fields of solid-state physics; electro- and ferromagnetics; acoustics, and microwave electronics.

*J. A. Tucker*

**6.939 Industrial Project at the Raytheon Company**

Year: U (2) 0-12-0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only.

*J. A. Tucker*

**6.941-6.943 Industrial Practice at the Bell Telephone Laboratories, Inc.**

Year: U (1, 2, S) 0-9-0

**6.944 Industrial Practice at the Bell Telephone Laboratories, Inc.**

Year: G (S) 0-9-0

Work at a Bell Telephone Laboratory (Murray Hill, Holmdel, Whippany, New Jersey). Work in all areas of circuit development pertaining to communication systems. Solid-state physics, microwave propagation, transistor logic circuitry, digital comparators, ferro-electrics, switching systems, electronic instrumentation, push-button dial systems, and pulse transmission systems all available as projects in the development and application stages.

*J. A. Tucker*

**6.949 Industrial Project at the Bell Telephone Laboratories, Inc.**

Year: U (2) 0-12-0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only.

*J. A. Tucker*

**6.951-6.953 Industrial Practice at the General Radio Company**

Year: U (1, 2, S) 0-9-0

**6.954 Industrial Practice at the General Radio Company**

Year: G (S) 0-9-0

Work for the General Radio Company in West Concord. Assignments to manufacturing departments and development laboratories in manufacture of electronic instruments. Opportunity for laboratory assignments in fields of pulsing, counters, recorders, sound measurement, signal generators, bridges, laboratory standards, stroboscopy.

*J. A. Tucker*

**6.959 Industrial Project at the General Radio Company**

Year: U (2) 0-12-0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only.

*J. A. Tucker*

**6.971-6.973 Industrial Practice at the American Electric Power Service Corporation**

Year: U (1, 2, S) 0-9-0

**6.974 Industrial Practice at the American Electric Power Service Corporation**

Year: G (S) 0-9-0

Work at a plant of the American Electric Power Service Corporation (New York City). Work associated with the operation and planning of a large multistate power generation and distribution system. Challenging assignments in computer solutions (analog and digital) of power flow, stability, regulation, and economy loading in a large network. Microwave communication systems, electronic relaying, research in corona and extra-high voltages. Opportunities for outside experience during earlier terms.

*J. A. Tucker*

**6.979 Industrial Project at the American Electric Power Service Corporation**

Year: U (2) 0-12-0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only.

*J. A. Tucker*

**6.981-6.983 Research and Development at the Naval Ordnance Laboratory**

Year: U (1, 2, S) 0-9-0

**6.984 Research and Development at the Naval Ordnance Laboratory**

Year: G (S) 0-9-0

Work at the Naval Ordnance Laboratory in Silver Spring, Maryland. Assignments in physics and electrical engineering as applied to development of air and underwater ordnance of U. S. Navy. Studies of earth's magnetic field, solid-state physics, ballistics, supersonic and hypersonic aerodynamics, microwave circuitry, and entire range of transient measurements. Application of symbolic logic to the development of special purpose data processing equipment. Students offered one-half junior and senior tuition and full graduate tuition in exchange for eighteen months civilian employment with a branch of the Department of Defense following graduation. Acceptance optional.

*J. A. Tucker*

**6.989 Industrial Project at the Naval Ordnance Laboratory**

Year: U (2) 0-12-0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only.

*J. A. Tucker*

**6.991-6.993 Research and Development at the Air Force Cambridge Research Laboratories**

Year: U (1, 2, S) 0-9-0

**6.994 Research and Development at the Air Force Cambridge Research Laboratories**

Year: G (S) 0-9-0

The Electronics Research Directorate of the Air Force Cambridge Research Laboratories conducts fundamental research in those physical and allied sciences likely to enhance Air Force capability in electronic and electromagnetic technology. Assignments available in areas of computer principles and techniques (including related mathematical sciences, data processing and simulation); solid-state electronics, nucleonics, and physical electronics (to discover, create, or improve electronics materials); electromagnetic radiation and

microwave physics (leading to improved antenna systems); recognition and detection techniques including data processing (for collection of data on objects and phenomena above surface of earth); studies of terrestrial and extraterrestrial emission and propagation of electromagnetic waves (in order to obtain fundamental knowledge required for design of electronic equipment in terrestrial, aeronautical, and astronomical environments); communications systems and techniques (in terrestrial and extraterrestrial environments).

*J. A. Tucker*

**6.999 Industrial Project at the Air Force Cambridge Research Laboratories**

*Year:* U (2) 0-12-0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only.

*J. A. Tucker*

## 7.

### Biology

**7.00 Perspectives in Life Science**

*Prereq.:* —  
*Year:* U (2) 2-0-4

Lectures and readings presenting a general view of the broad area covered by the life sciences; emphasis on fundamental problems and current research from the molecular level to the place of man in the world of living organisms; summary of current work under way by general biologists, biochemists, biophysicists, microbiologists, and investigators in many other sciences. Treatment of subjects such as the origin of life; the chemistry of living things; the transfer of genetic information; growth and development; cellular, organismal, and environmental control mechanisms; and modern methods and techniques used in the life sciences. Planned for students electing the life sciences as a major field or as a survey for students planning to major in other fields.

*B. S. Gould*

**7.01 General Biology**

*Prereq.:* —  
*Year:* U (1) 4-0-8

Introduction to biology — lectures and demonstrations. Part 1: Molecular biology using examples from work done with bacteria and viruses; introduction to synthesis of small molecules and macromolecules to enzymes and various aspects of cellular control systems, biochemical energetics, and genetics. Part 2: Evolution of more complicated processes in simple multicellular organisms; evolution and classification of plants and animals. Part 3: Higher organism physiology; interactions of organisms with their unfriendly environment. Emphasis on detectors and effectors which enable the organism to respond to both predictable and non-predictable changes in environment.

*Luria, Gross*

**7.011 Introduction to Experimental Biology**

*Prereq.:* 7.01  
*Year:* U (2) 1-8-3

Basic techniques used in biochemistry, microbiology, and cell biology.

*B. S. Gould*

**7.02T Experiments in Biology**

*Prereq.:* 7.01  
*Year:* U (1) 1-8-3

Laboratory project to acquaint students interested in biology, but not following Course VII, with current problems of biological research. Student to carry out one of several projects offered for approximately first two-thirds of term, with last third used for discussion of results.

*J. E. Brown*

**7.03 Genetics**

*Prereq.:* 7.21T  
*Year:* U (2) 3-0-9

Continuity and variation in the multiplication of living organisms. Mutation and selection as a mechanism for biological change. Principles of formal genetics. Physical and chemical basis of heredity. Structure and function of the hereditary material. Molecular basis for mutation, genetic function and recombination in micro-organisms.

*Baglioni, Fox*

**7.031 Experimental Genetics and Microbiology**

*Prereq.:* 7.011, 7.21T  
*Year:* U (2) 2-16-6

Laboratory project in microbiology and genetics. (Alternate years.)

*Botstein*

**7.04T Developmental Biology**

*Prereq.:* 7.02T, 7.05T  
*Year:* U (1) 3-0-6

Mechanics and principles of development of selected invertebrate and vertebrate organisms. Biochemical and structural differentiation of cells, tissues, and organs. Review of experiments on metabolism, growth, movements, and interactions of cells and other components of developing systems.

*Bell*

**7.041T Experimental Cell Biology**

*Prereq.:* 7.011  
*Year:* U (1) 2-16-6

Laboratory investigation dealing with animal cells. (Alternate years.)

*Baltimore, Burge*

**7.05T General Biochemistry**

*Prereq.:* 5.41T  
*Year:* U (1) 4-0-8

Contributions of biochemistry toward an understanding of the structure and functioning of organisms, tissues and cells. Chemistry and functions of constituents of cells and tissues and the chemical and physical-chemical basis for the structures of nucleic acids, proteins, and carbohydrates. General metabolism of carbohydrates, fats, and nitrogen-containing materials such as amino acids, proteins, and related compounds.

*G. M. Brown, RajBhandary*

**7.051T Experimental Biochemistry**

*Prereq.:* 7.011, 7.05T  
*Year:* U (2) 2-16-6

Laboratory project in biochemistry. (Alternate years. Not offered 1969-70.)

*Robbins*

**7.06 General and Cell Physiology**

*Prereq.:* 5.60, 7.01, 7.05T  
*Year:* U (2) 3-0-9

Physical and chemical basis for molecular structure and relationship between structure and function in living systems. General principles of cell maintenance, transport, irritability, contraction, and cellular interaction. Relation of form and function. Mechanisms by which the animal interrelates with its internal and external environment.

*Penman, Gross*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## BIOLOGY

### 7.061T *Experimental Physiology*

Prereq.: 7.011

Year: U (1)

2-16-6

Laboratory project in neurophysiology. (Alternate years. Not offered 1969-70.)

J. E. Brown

### 7.06 *Introduction to Biophysics*

Prereq.: 7.00 or 7.01; 8.02

Year: U (2)

2-0-4

Application of the analytical methods of the physical sciences to biology. Emphasis on the molecular aspects of the control systems governing the growth, development and functioning of living organisms.

D. F. Waugh

### 7.21T *General Microbiology*

Prereq.: 7.01, 7.05T

Year: U (1)

3-0-9

Properties of unicellular organisms, especially bacteria; composition, metabolic activities, and structural organization. Micro-organisms as model systems for the study of cellular growth and its physiological basis. Variation, heredity, and the organization of the genetic system in bacteria. Comparative discussion of cellular organization in bacteria, in other microbes, and in multicellular organisms.

Luria

### 7.23T *Microbial Physiology (A)*

Prereq.: 7.21T

Year: G (2)

3-0-9

Principal chemical processes responsible for the function and growth of microbial cells. Genetic and environmental control of cellular functions. Chemical activities of micro-organisms in a framework of comparative physiology and biochemistry.

Magasanik

### 7.24 *Topics in Bacteriology (A)*

Prereq.: 7.23T, 7.86

Year: G (1)

2-0-6

Recent developments in bacteriology: genetic, regulatory and macromolecular processes.

Staff

### 7.25 *Topics in Virology (A)*

Prereq.: 7.21T, 7.86

Year: G (2)

2-0-6

Biological and molecular properties of bacteriophages and animal viruses.

Staff

### 7.31 *Biology Seminar (A)*

Prereq.: 7.05T

Year: G (1)

2-0-4

Areas of biology that may have been deficient in students' undergraduate preparation. The relation between the molecular and classical aspects of cellular physiology, genetics, and microscopic anatomy. Training of students in oral presentations and in the leading of group discussions.

Ingram, C. E. Holt

### 7.32 *Biology Seminar (A)*

Prereq.: 7.05T or 7.71T

Year: G (2)

2-0-4

Continuation of 7.31.

### 7.36 *Advanced Neurophysiology (A)*

Prereq.: 7.06

Year: G (1)

2-0-4

A series of lectures, with student participation, on some aspects of the nervous system. Foundation for work on the structure and function of the nervous system.

Staff

### 7.50 *Physical Chemistry of Macromolecules (A)*

Prereq.: 5.60, 7.05T

Year: G (2)

2-0-4

Emphasis on macromolecules of biological origin, particularly proteins and nucleic acids. Discussion of physical techniques (such as diffusion, ultracentrifugation, osmotic pressure, light scattering, electrophoresis, viscosity, spectrophotometry, optical rotatory dispersion) with

respect to theory and contemporary developments in two major areas: (1) molecular size, shape and solvation and (2) internal structure, surface structure, intermolecular forces and specific and non-specific molecular interaction.

D. F. Waugh

### 7.51 *Organ and System Physiology*

Prereq.: —

Year: U (1)

3-0-6

Study of the mechanisms of cell-cell interaction and the physiology of organ systems, starting with a study of detectors of the state of the internal and external environment and continuing to examine chemical and mechanical effectors. Lectures on comparative functional anatomy, experimental methods, the sensory analysis of events, the generation of action patterns, and the normal and pathological behavior of whole systems.

Lettvin

### 7.68 *Advanced Biochemistry Laboratory (A)*

Prereq.: 7.05T

Year: G (1)

1-8-3

A project laboratory with emphasis on experimental design and analysis in biochemistry. Projects based on procedures used in the study of structures and functions of carbohydrates, lipids, proteins and nucleic acids. Experiments dealing with problems in enzymology, oxidative phosphorylation, and nucleic acid metabolism.

K. B. Taylor

### 7.70 *Seminar in Protein and Nucleic Acid Structure (A)*

Prereq.: 7.05T

Year: G (1)

2-0-4

Preparation and discussion of students' papers on topics in protein and nucleic acid chemistry. Emphasis on chemical evidence for the structure of these substances and on relationships between structure, function, and genetic control in selected instances.

Ingram

### 7.71T *Biophysical Chemistry (A)*

Prereq.: 7.05T

Year: G (1)

2-0-4

Mechanism of enzyme action; steady-state enzyme kinetics and enzyme mechanisms and models; dynamics of enzyme catalysis from the viewpoint of fast reaction kinetics; regulation of enzyme activity and allosteric phenomena. Conformational analysis of polypeptides and proteins and relationship of conformation to biological activity; conformational energy estimates; folding of proteins, cooperative transitions in polypeptides and proteins; experimental approaches to the study of polypeptide and protein configurations, properties, and reactions. Physical chemistry of nucleic acids; conformational equilibria and configurations of synthetic polynucleotides and naturally occurring nucleic acids. Special topics.

Schimmel

### 7.72 *Advanced Biochemistry (A)*

Prereq.: 7.05T

Year: G (2)

4-0-8

Energy metabolism, the biochemistry of photosynthesis and photophosphorylation and the intermediary metabolism of carbohydrates. Discussion of electron transfer reactions and lipid metabolism from the point of view of the function of biological membranes. Major metabolic pathways involved in the synthesis and degradation of amino acids, purines, pyrimidines, porphyrins, and coenzymes with emphasis in the mechanisms of individual enzymatic reactions and problems of physiological control. Consideration of the synthesis of proteins and nucleic acids from the points of view of the enzymology of the relevant reactions, the relation of RNA metabolism to protein synthesis, and the structure and function of the ribosome.

Buchanan, G. M. Brown, Lodish

**7.73 Seminar in Immunology (A)**  
 Prereq.: 7.05T  
 Year: G (2) 2-0-4  
 Several lectures introducing basic concepts in immunology followed by student preparation of papers on topics of current research interest: antigens and immunogenicity, structure and heterogeneity of immunoglobulins, structural basis for antibody activity, ontogeny and phylogeny of the immune response, cellular and molecular events in antibody synthesis, tolerance, theories of antibody formation. *Steiner*

**7.74J Seminar in Biochemistry (A)**  
 (Same subject as 5.981J)  
 Prereq.: —  
 Year: G (1, 2) 1-0-2  
 Presentation by graduate students of critical reviews of recent publications in chemistry and biochemistry with application to selected biochemical problems. Discussions by staff and students. *Biochemistry and Chemistry Staff*

**7.85 Optical Methods in Biophysics (A)**  
 Prereq.: 8.03  
 Year: G (1) 2-2-4  
 Principles and biological applications of emission and absorption spectroscopy in the ultraviolet, visible, and X-ray regions; microscopy in general; electron microscopy; X-ray diffraction; related instrumentation. (Not offered 1969-70.) *Hall*

**7.86 Molecular Genetics (A)**  
 Prereq.: 7.21T  
 Year: G (2) 3-0-9  
 Review of recent experimental and theoretical developments in molecular genetics. Emphasis on the genetic, isotopic, and radiation experiments which yield information on the replication of nucleic acid, the mechanism of genetic recombination, and the translation of genetic information into molecular structure. *Fox, Signer*

**7.93 Selected Topics in Biology (A)**  
 Prereq.: —  
 Year: G (1 or 2) Arr.  
 Class work in various fields of biology not covered by the regular subjects of instruction. *Staff*

**7.941 Research Problems (A)**  
 Prereq.: —  
 Year: G (1) Arr.

**7.942 Research Problems (A)**  
 Prereq.: —  
 Year: G (2) Arr.  
 Directed research in a field of biological science, but not contributory to graduate thesis. *Staff*

**7.95 Electron Microscopy (A)**  
 Prereq.: 7.85 or 8.03  
 Year: G (2) 2-0-4  
 Principles of electron optics, the electron microscope, interaction of electrons with matter, methods in electron microscopy, applications of electron microscopy. (Not offered 1969-70.) *Hall*

**7.96 Electron Microscopy Laboratory (A)**  
 Prereq.: 7.95  
 Year: G (2) 0-2-1  
 Properties of electron lenses, use of the electron microscope, preparation of specimens, techniques in electron microscopy, selected experiments. (Not offered 1969-70.) *Hall*

**7.99 Molecular Configuration in Biological Systems Seminar (A)**  
 Prereq.: 7.05T or 7.72  
 Year: G (2) 2-0-4

The properties conferred on biochemical substances by assumption of specific physical configurations. Optical methods (emphasizing X-ray diffraction) for determining configuration in macromolecular systems. Special emphasis on molecular structure of crystalline proteins and nucleic acids. *Rich*

## 8. Physics

### GENERAL UNDERGRADUATE SUBJECTS

**8.01 Physics I**  
 Prereq.: —  
 Year: U (1, 2) 5-0-7

Particles: electrons, atoms and molecules, ions and nuclei; randomness; photon and wave properties of light; macroscopic particles. Newtonian mechanics: motions and forces; frames of reference; momentum and energy; conservation principles; conservative forces and linear oscillations; central forces; orbits; angular momentum and rotating bodies. Although Mathematics 18.01 is not a stated prerequisite for Physics 8.01, a majority of those students of previous years who received honor grades had already had a background subject in differential and integral calculus. *Staff*

**8.011 Physics I-A**  
 Prereq.: —  
 Year: U (1) 5-0-7

Newtonian mechanics: motion and forces; frames of reference; momentum and energy; conservation principles; simple harmonic motion; orbital motion, angular momentum, rotating bodies. Electricity and magnetism: electrostatics, currents, electromagnetism, motion of particles under electrical and magnetic forces. Concurrent registration in 18.01 recommended. 8.011 may be followed by either 8.021 or 8.02. *Hulsizer*

**8.02 Physics II**  
 Prereq.: 8.01 or 8.011; 18.01  
 Year: U (1, 2) 5-0-7

Relativity: deviations from Newtonian dynamics; Lorentz-Einstein transformations; relativistic dynamics. Electromagnetism: electrostatics and field concepts; electric currents and magnetic fields; induction laws; field energies; Maxwell's equations; circuit electricity; electromagnetism and relativity. *Staff*

**8.021 Physics II-A**  
 Prereq.: 8.01 or 8.011; 18.01  
 Year: U (2) 5-0-7

Electromagnetism; electromagnetic induction, alternating current, Maxwell's equations, electromagnetic waves. Light and optics, special relativity, quanta, atoms, molecules, nuclei, solids, heat, kinetic theory. The combination of 8.011 and 8.021 especially suited for those students who desire only one year of physics. 8.021 may be followed by 8.03 without too much difficulty. *Hulsizer*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## PHYSICS

### 8.03 *Physics III*

Prereq.: 8.02 or 8.021; 18.02

Year: U (1, 2)

5-0-7

Mechanical vibrations and waves; periodic motions and their superposition; free vibrations; forced vibrations and resonance; coupled oscillations and normal modes; vibrations of continuous systems; progressive waves; reflection, refraction and diffraction (with Huygens' principle.) Electromagnetic waves and optics: plane wave solutions of Maxwell's equations; polarization; transparent media and refractive index; boundary conditions at conductors and dielectrics; cavity resonance and wave guides; fields of accelerated charges; examples of wave and ray optics.

Staff

### 8.04 *Principles of Quantum Physics*

Prereq.: 8.03

Year: U (1, 2)

5-0-7

Evidence of quantized energy states and quanta. Bohr theory; optical and X-ray spectra. Wave properties of particles and the time-independent Schrödinger equation for one dimension. Interpretation of wave properties in terms of probability amplitudes. Polarization states and state vectors; superposition. Amplitudes for position and momentum; wave packets and the uncertainty principle. Time-dependent probability amplitudes. Superposed energy states; lifetimes and the uncertainty principle. Moving wave-packets, and scattering in one dimension. Barrier penetration problems and probability currents. Angular momentum.

Staff

### 8.05 *Physics of Atoms and Molecules*

Prereq.: 8.04

Year: U (1, 2)

4-0-8

Experimental basis of quantum physics, with examples mainly from atomic, molecular and radiation dynamics. Hydrogen-like atoms; spin orbit splitting; Zeeman and Stark effects. Emission and absorption of radiation: microwave, infrared, optical and X-ray spectra. Selection rules and the Correspondence principle. — Many electron atoms. The Pauli exclusion principle; the periodic system of elements. — Diatomic molecules. Rotational and vibrational spectra. Symmetry effects, para- and ortho hydrogen. Qualitative theory of molecular binding, and the structure of solids.

Staff

### 8.06 *Theoretical Physics I*

Prereq.: 8.04

Year: U (2)

4-0-8

Basic concepts of mechanics: Inertial frames of reference; space, time, mass, force. Types of forces. Equations of motion. Conservation laws for closed systems. Non-inertial frames of reference. — Planetary motion. Harmonic oscillator. Macroscopic objects: Constraints; Hamilton's principle and Lagrange's equations. Rigid body dynamics. Coupled oscillators, Green's functions. Normal modes; continuum limit: elastic strings, solids; fields. Canonical variables, Hamilton's equations, Poisson bracket equations of motion. Principle of least action; Hamilton-Jacobi equation. Survey of electrodynamics: Basic phenomena and systems of units. Maxwell's equations; simple applications: oscillating circuits, coaxial cables. Moving frames of reference, the Lorentz group. Energy momentum four-vectors, field tensors and relativistic equations of motion.

Staff

### 8.07 *Theoretical Physics II*

Prereq.: 8.06

Year: U (1)

4-0-8

Electromagnetic waves: plane waves, polarization. Huygens' principle, Kirchhoff approximation, diffraction. Energy, momentum, angular momentum of wave packets. Spherical waves; wave guides. — Inhomogeneous wave equations. Green's function solution, Cau-

ality. Periodic charge-current distributions,  $v/c \ll 1$  limit. Lienard-Wiechert potentials. Synchrotron radiation. Facts of quantum physics. Qualitative quantum mechanics. Classical limit; measurements and interpretation of  $\Psi$ . Systems with discrete spectra: harmonic oscillator, time-dependent solutions, classical limit. Angular momentum; scalar and vector operators. Diatomic molecules. The continuum: scattering of wave packets; scattering amplitude and cross sections. Quantum theory of radiation: photons, operators for E and B fields, classical limit. Emission, absorption and scattering of radiation; selection rules.

Ingard

### 8.08 *Theoretical Physics III*

Prereq.: 8.07

Year: U (2)

4-0-8

Quantum systems of identical particles. Pauli principle. Occupation number representation of Boson- and Fermion-states. Kinetic Theory: Phase space, Liouville theorem, Boltzmann equation. H-theorem. Ideal gas: work, heat, entropy. Transport phenomena. Thermodynamics: state variables, equations of state. First Law. Second Law; entropy maximum principle, reversible and irreversible processes. Thermodynamic temperature. Ideal gas and photon gas. Thermodynamic potentials, Maxwell relations. Simple and composite systems, phase transitions and chemical equilibrium. Statistical mechanics: ensembles and entropy. Canonical ensemble, partition function in classical and quantum mechanics. Bose and Fermi gas, Boltzmann limit. Specific heats, electric and magnetic susceptibilities. Fluctuations, noise, and Nyquist theorem.

Ingard

## UNDERGRADUATE LABORATORY AND SPECIAL PROJECT SUBJECTS

### 8.11 *Physics Project Laboratory I*

Prereq.: —

Year: U (1)

1-6-5

### 8.12 *Physics Project Laboratory II*

Prereq.: —

Year: U (2)

1-6-5

Laboratory work with close faculty guidance but emphasizing independent work and a professional approach. Study of various physical systems and interpretation of observed effects; construction of high-vacuum apparatus to study electrons, ions, and atoms; growing of single crystals and study of some of their properties.

Staff

### 8.13 *Experimental Atomic Physics I*

Prereq.: 8.04

Year: U (1)

0-6-6

Laboratory experiments including both those fundamental to the development of modern physics and those which illustrate modern experimental techniques. Experiments ranging from measurement of the electron charge by Millikan's oil drop method to the use of scintillation counters to detect coincident  $\gamma$ -rays from positron annihilation. Other experiments including the Hall effect, thermionic emission and the  $T^4$  dependence of radiated energy, the Faraday effect, and the Franck-Hertz experiment. Machine shop and vacuum techniques included as part of the experiments. In final weeks of term, experiments of the student's own choice. (Limited primarily to students in Course VIII.)

W. H. Moore

### 8.14 *Experimental Atomic Physics II*

Prereq.: 8.13

Year: U (2)

0-6-6

Continuation of 8.13 with emphasis on extending experimental experience to more sophisticated techniques and utilizing knowledge from 8.05. Experiments including X-ray and optical absorption, the Zeeman effect, optical pumping, nuclear magnetic resonance, Compton scattering, and Mössbauer scattering.

W. H. Moore

**8.15 Experimental Physics**

Prereq.: 8.14

Year: U (1)

2-0-2

Introduction to experimental research techniques by (1) lectures given by various members of the staff, and (2) individual presentation of research projects to whole group. Designed to bridge gap between elementary laboratory and research in modern physics. *Staff*

**8.18 Special Problems in Undergraduate Physics**

Prereq.: —

Year: U (1, 2)

Arr.

Opportunity for undergraduates to engage in experimental or theoretical research under the supervision of a staff member. *A. G. Hill*

**8.19 Readings in Physics**

Prereq.: —

Year: U (1 or 2)

Arr.

Supervised reading and library work. Choice of material and allotment of time according to individual needs. For students finding it desirable to do work not provided for in the regular subjects. Specific approval of Department Head required in each case. *A. G. Hill*

## UNDERGRADUATE ELECTIVE SUBJECTS

**8.211 Introduction to Quantum Physics**

Prereq.: 8.03

Year: U (1, S)

4-0-8

Study of the experimental foundations of quantum physics and the quantum theoretical interpretation of atomic phenomena. *Staff*

**8.222 Group Theoretical Methods in Physics**

Prereq.: 8.05

Year: U (2)

3-0-9

Introduction to the theory of groups and group representations, physical applications. Finite groups: point and permutation groups. Continuous groups: rotation and Lorentz groups. Infinitesimal transformations. Angular momentum. Atomic structure and the vector model of the atom. Atoms and molecules in external fields. Evaluation of matrix elements. Wave functions of electrons in crystals. Electron spin. Dirac equation. Topics from high-energy physics, molecular structure and spectra, or nuclear physics. *Kolenkow*

**8.231 Introduction to Solid-State Physics**

Prereq.: 8.05, 18.05

Year: U (1)

3-0-9

Introduction to properties of solids, including structure and external symmetry properties of crystals; X-ray diffraction and microscopic crystal structure, binding energy in solids, elastic properties of continuous media; elastic waves in discrete lattices, temperature dependence of the physical properties of solids. Magnetic properties of solids, free electron theory of metals. *Staff*

**8.232 Topics in Quantum Theory of Matter**

Prereq.: 8.05

Year: U (2)

3-0-9

Elementary quantum mechanics applied to the study of real problems, largely from the field of solid-state physics. Review of exactly soluble problems. Approximation methods applied to many-electron atoms (Hartree-Fock), molecular binding, lattice structure of solids. Electronic states in solids: metals, semiconductors and insulators. Superconductivity: electron pairing, Meissner effect, flux quantization and Josephson junctions. Origin and nature of magnetism: ferro-magnets at low temperature; qualitative discussion of critical points. *Litster*

**8.241 Electron Physics**

Prereq.: 8.04

Year: U (1)

4-0-8

Electron ballistics, mass spectroscopy; high-energy accelerators; space charge theory; Fermi-Dirac statistics, thermionic emission, Schottky effect, high field and secondary emission, photoelectric effect in metals; conductors, insulators, and semiconductors. *Harvey*

**8.242 Quantum Electronics**

Prereq.: 8.04

Year: U (2)

3-0-9

Fundamental processes in lasers and masers. Classical dipole radiation; susceptibility, and bulk properties of matter. Interaction of a quantum-mechanical two-level system with electromagnetic radiation. Laser oscillators. Excitation mechanisms in gaseous and solid-state lasers. Raman effect and non-linear optics. Laboratory demonstrations. Familiarity with Maxwell's equations and the Schroedinger equation a requirement. *Javan*

**8.251 Physics of Noise and Fluctuations**

Prereq.: 8.05

Year: U (1)

3-0-9

Mathematical description of random processes: joint probability distributions, correlation functions and power spectra. Fluctuations in discrete systems: shot noise, photon counting. Fluctuations about thermal equilibrium: space-time correlations of fluctuations of density, pressure, entropy, etc., and their relation to transport coefficients and dissipation constants. Discussion of modern experimental techniques for the study of thermal fluctuations. Quantum effects. Information theory. Fluctuations in living systems. *Greytak*

**8.261 Electrical Discharges in Gases**

Prereq.: 8.05

Year: U (1)

3-0-9

Study of the fundamental processes of plasma physics, experimental determination of the basic cross sections, the calculation of electron and ion mobility and diffusion coefficients, the Townsend avalanche and breakdown, ambipolar diffusion and the positive column, statistics of energy gained by free electrons and its transfer to the excitation and ionization of atoms, the passage of radiation through an excited gas, space charge sheaths, probe theory and plasma diodes, time lags in breakdown, and the formation of a spark. *Staff*

**8.272 Introduction to Nuclear Physics**

Prereq.: 8.05 or 8.211

Year: U (2)

4-0-8

Elementary discussion of various topics of nuclear physics with description of selected experiments and discussion of results in light of current theories: two-nucleon systems, radioactive decay, nuclear reactions, and nuclear structure. *Staff*

**8.291J Planetary Physics and Chemistry I**

(Same subject as 5.121J and 12.131J)

Prereq.: 8.02, 18.02

Year: U (1)

3-0-9

**8.292J Planetary Physics and Chemistry II**

(Same subject as 5.122J and 12.132J)

Prereq.: 8.02, 18.02

Year: U (2)

3-0-9

Study of the planetary system: evolution, composition, present configuration, dynamics, interiors, surfaces, atmospheres, and magnetospheres of the planets and, where appropriate, similar aspects of the satellites, asteroids, and comets. Stress on use of space-probes

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## PHYSICS

and modern ground-based optical, radio and radar techniques for diverse planetary observations and the interpretations. First term: a general description of the solar system and its origin and a comprehensive discussion of the outer planets. Second term: solar system dynamics, the interplanetary medium, and the interiors, surfaces, and atmospheres of the inner planets.

*I. I. Shapiro, J. S. Lewis*

### GRADUATE SUBJECTS

#### General Interest and Mathematical Physics

- 8.311 Electromagnetic Theory I (A)**  
*Prereq.:* 8.04, 18.05  
*Year:* G (1) 4-0-8
- 8.312 Electromagnetic Theory II (A)**  
*Prereq.:* 8.311  
*Year:* G (2) 4-0-8
- Maxwell's equations; static approximation; scalar potential, multipole expansion; boundary value problems; polarization; stress tensor. Vector potential; fields and forces of steady currents; magnetization. Induction and displacement current; conservation laws, energy-momentum tensor. Waves, polarization, and coherence. Reflection, refraction, and scattering of waves; Green's functions and causality; Huygens' principle, geometrical optics. Multipole radiation, radiation damping, "Bremsstrahlung." Special relativity. Covariant form of field equations and equations of motion. Potentials and gauge invariance. Classical electron theory. Vacuum field equations and equations of motion of electron. Lienard-Wiechert potentials. Self-energy and radiation damping. Derivation of macroscopic field equations; normal and anomalous dispersion. *Staff*
- 8.321 Quantum Theory I (A)**  
*Prereq.:* 8.07  
*Year:* G (1) 4-0-8
- Dynamics of particles and electromagnetic field in canonical form. Poisson brackets. Action and angle variables. Correspondence principle. Heisenberg matrices. Canonical commutation relations. Transformations of matrix representations and eigenvalue problems. Quantum states and superposition principle. Probabilistic interpretation. Uncertainty relations. Non-stationary states; equations of motion. Heisenberg and Schroedinger picture; transitions; the classical limit. Central field problems; angular momentum; elementary scattering theory. *Staff*
- 8.322 Quantum Theory II (A)**  
*Prereq.:* 8.321  
*Year:* G (2) 4-0-8
- Perturbation theory of stationary states. Symmetry and selection rules; rotations and tensor operators. Perturbation theory of non-stationary states. Adiabatic processes. Transition rates. Application to emission, absorption, and scattering of radiation and elastic and inelastic collisions. Systems of identical particles; method of "second quantization"; Hartree-Fock equations. General theory of scattering and reactions. T-matrix, variational, and other approximation methods. Unitarity conditions and S-matrix. *Staff*
- 8.323 Quantum Theory III (A)**  
*Prereq.:* 8.322  
*Year:* G (1) 4-0-8
- Relativistic kinematics; covariant equations of motion; dynamics of spin 0 particles; general concepts of relativistic quantum theory. Relativistic spin theory and Dirac equation. External field problems, scattering, polarization. Neutrinos and photons. Discussion of symmetry operations and symmetry properties of systems; CTP theorem. Quantum-, meso-, and electrodynamics. S matrix and Feynman rules. Chew-Low equation and elements of dispersion theory. *Staff*

- 8.331 Analytical Mechanics (A)**  
*Prereq.:* 8.03, 18.05  
*Year:* G (1) 4-0-8
- Hamilton's equations, variational principles, transformation theory, Hamilton-Jacobi equation. Poisson and Lagrange brackets, invariants, conservation theorems, and symmetry. Lagrangian and Hamiltonian formulations for fields. Relativistic mechanics. *Staff*

- 8.333 Statistical Mechanics I (A)**  
*Prereq.:* 8.321  
*Year:* G (1) 4-0-8
- Principles of thermodynamics: First and Second Law. Thermodynamic potentials. Conditions for equilibrium. Phase transitions and other applications. Third Law. Classical kinetic theory of gases: method of collisions. Boltzmann H-Theorem. Maxwell-Boltzmann distribution. Transport phenomena. Hydrodynamics. Chapman-Enskog Method. Classical statistical mechanics: the microcanonical, canonical and grand canonical ensemble. Equivalence of ensembles. Relationship with thermodynamics. *Staff*

- 8.334 Statistical Mechanics II (A)**  
*Prereq.:* 8.333  
*Year:* G (2) 4-0-8
- Quantum statistical mechanics: ensembles and density matrix. Ideal gases and selected elementary applications. Bose-Einstein condensation; imperfect gases. Introduction to the theory of Fermi liquids. Selected topics from the quantum mechanical many-body problem; non-equilibrium statistical mechanics. *Scully*

- 8.341 Methods of Theoretical Physics I (A)**  
*Prereq.:* 8.06, 8.311  
*Year:* G (1) 4-0-8
- Review of fundamental partial differential and integral equations of physics. Complex variables, boundary values of analytic functions. Separation of variables. Ordinary differential equations in complex domain boundary conditions. Variational principles. Eigenfunctions, abstract vector space, Green's functions. Integral equations. Wiener-Hopf and Muskhelishvili methods. (*Alternate years.*) *Feshbach*

- 8.342 Methods of Theoretical Physics II (A)**  
*Prereq.:* 8.341  
*Year:* G (2) 4-0-8
- Continuation of 8.341. Approximate methods; variational and perturbation methods applied to discrete spectra. Approximate methods for continuous spectra. Long wavelength and high-energy approximations. Scattering formalism for scalar equations. S-matrix theory. Analyticity of solutions in complex energy plane. Dispersion relations, causality, Mandelstam representation. Extension of scattering formalism to vector and tensor equations. Application to problems in electrostatics, hydrodynamics, acoustics, diffusion, electromagnetic waves, quantum mechanics. Perturbation theory for many-body problems. (*Alternate years.*) *Feshbach*

- 8.351 Physical Applications of Group Theory I (A)**  
*Prereq.:* 8.321  
*Year:* G (1) 3-0-9

- 8.352 Physical Applications of Group Theory II (A)**  
*Prereq.:* 8.351  
*Year:* G (2) 3-0-9
- Theory of groups and their representations. Discussions of point, rotation, space, Lorentz and Lie Groups. Applications to various branches of physics. (*Alternate years. Not offered 1969-70.*) *Staff*

- 8.391, 3.392 Special Problems in Theoretical Physics (A)**  
 Prereq.: —  
 Year: G (1, 2) Arr.  
 Reading, consultation, and original investigation on a problem in theoretical physics. Staff
- 8.399 Special Problems in Physics (A)**  
 Prereq.: —  
 Year: G (1, 2) Arr.  
 For graduate assistants in the Department of Physics where assigned research or teaching duties are approved for academic credit by the Department. Staff
- Physics of Atoms, Radiation, Solids, Liquids and Plasma
- 8.411 Advanced Atomic Physics (A)**  
 Prereq.: 8.321  
 Year: G (1) 3-0-9  
 Theory of spectroscopy, including atomic and solid-state spectroscopy in optical and microwave regions. Angular momentum through the use of the Racah formalism. One-electron and many-electron atoms. Atoms in crystal lattices; the Stark and Zeeman effects; the effects of strain on crystal spectra. Experimental methods and results. (Alternate years. Not offered 1969-70.) Koster
- 8.421 Introduction to Optical, Microwave, and Radiofrequency Physics (A)**  
 Prereq.: 8.321  
 Year: G (1) 3-0-9  
 Theory of radio frequency, microwave, and optical methods for determining magnetic and electric moments of nuclei and the charge and spin distributions of atoms. Topics include motion of spins in d-c and oscillating magnetic fields, electron-nuclear interactions, molecular beam methods, nuclear magnetic resonance, fluctuation phenomena and relaxation, masers, emission and absorption of light, optical pumping, and a brief introduction to lasers. (Alternate years. Not offered 1969-70.) Kleppner
- 8.431 Physics of Quantum Electronics (A)**  
 Prereq.: 8.321  
 Year: G (1) 3-0-9  
 Interaction of electromagnetic radiation with matter. Stimulated emission and scattering of radiation. Semi-classical theory of the optical maser; non-linear optics; photon echo, etc. Quantum theory of radiation, theory of optical coherence and the quantum description of laser behavior. Scully
- 8.442 Statistical Optics and Spectroscopy (A)**  
 Prereq.: 8.05, 8.08  
 Year: G (2) 3-0-9  
 Discussion of light as a statistical process and description of its spectrum by the modern concept of correlation functions. Interaction of light with photodetectors, modern techniques of spectral analysis: photon counting, self-beating, heterodyne beating. Brown-Twiss experiment. Principles of interference and spatial coherence. Applications to Fabry-Perot interferometers and Fourier transform spectroscopy. Theory of diffraction, and grating spectrometers. Spectrum of light scattered by thermal fluctuations in transparent media. Benedek
- 8.481, 8.482 Selected Topics in Physics of Atoms and Radiation (A)**  
 Prereq.: 8.321  
 Year: G (1, 2) 3-0-9  
 Presentation of subjects of current interest with topic varying from year to year. Staff
- 8.491, 8.492 Special Problems in Physics of Atoms and Radiation (A)**  
 Prereq.: —  
 Year: G (1, 2) Arr.  
 Advanced problems in atomic, optical, microwave and radiofrequency physics, with assigned reading and consultation. Staff
- 8.511 Theory of Solids I (A)**  
 Prereq.: 8.231 or 8.232; 18.05  
 Year: G(1) 4-0-8  
 Theory of phonons and lattice vibrations; X-ray and neutron scattering; band theory of solids. Electron theory of metals and Fermi-Dirac statistics. Boltzmann transport theory with applications to the flow of heat and electricity in metals and semiconductors. Staff
- 8.512 Theory of Solids II (A)**  
 Prereq.: 8.511  
 Year: G (2) 3-0-9  
 Formalism of many-body theory, applied to problems of solid-state physics. Theory of superconductivity and of superfluids. Theory of magnetism. Optical and magneto-optic properties of solids. Theory of semiconductors. Staff
- 8.541 Neutron Diffraction (A)**  
 Prereq.: 3.12 or 8.551  
 Year: G (2) 3-1-8  
 Neutron properties, sources, and apparatus. Absorption and scattering of neutrons by isolated atoms. Transmission through and scattering by assemblages of atoms. Diffraction by single crystal and polycrystalline specimens. Crystallographic and magnetic structure analyses. Long wave-length methods and applications. Refractive index characteristics. Neutron polarization. Inelastic scattering. Laboratory experiments offered. (Alternate years. Not offered 1969-70.) Shull
- 8.551 X-rays and Crystal Physics**  
 Prereq.: 8.05, 18.06  
 Year: G (1) 3-0-9  
 X-ray apparatus, production of X-rays, absorption, scattering, refraction, X-ray spectra. Theory and application of the diffraction of X-rays in matter to the determination of the structure of crystals, and the atomic and molecular arrangement in liquids and amorphous solids. General review of the structure of matter as determined by X-ray diffraction analysis. Warren
- 8.552 X-ray Diffraction (A)**  
 Prereq.: 8.551  
 Year: G (2) 3-0-9  
 Selected advanced topics in the application of X-ray diffraction to problems of solid-state physics. The elastic spectrum of crystals from the temperature diffuse scattering of X-rays. Measurement of long-range and short-range order parameters in binary alloys. Measurement of randomness in structures and cold work distortion in metals by X-ray diffraction. Fourier analysis of imperfect crystals. Discussion of extinction effects in perfect crystals. Warren
- 8.581, 8.582 Selected Topics in the Theory of Solids (A)**  
 Prereq.: 8.512  
 Year: G (1, 2) 3-0-9  
 Topics in solid-state theory varying from year to year. Staff
- (A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## PHYSICS

- 8.591, 8.592 Special Problems in Solid-State Physics (A)**  
*Prereq.:* —  
*Year:* G (1 or 2) *Arr.*  
 Advanced problems in the physics of the solid state, with assigned reading and consultation. *Staff*
- 
- 8.611 Introduction to Physics of Fluids and Plasmas (A)**  
*Prereq.:* 8.08 3-0-9  
*Year:* G (1) *Staff*  
 Properties of liquids, gases, and plasmas. Interaction forces. Equations of motion, particle vs. continuum description. Linear theory of waves and oscillations. Coupling between mechanical and electromagnetic waves. Energy loss mechanisms. Thermal relaxation effects. Landau damping. Non-linear effects. Interaction of waves. Shock waves. Instabilities. Classification of instabilities in liquids, gases, and plasmas. Introduction to the theory of turbulence.
- 8.621J Plasma Kinetic Theory (A)**  
 (Same subject as 22.68J)  
*Prereq.:* 8.611 or 8.622 3-0-9  
*Year:* G (1) *Staff*  
 Content varying from year to year. Typical subjects: the linearized Vlasov equation, Fokker-Planck and diffusion approximations for the average distribution function, autocorrelation functions, resonant and non-resonant diffusion, free energy, energy and momentum conservation, resonant wave coupling, non-linear Landau damping, strong turbulence theories. Selected applications to enhanced diffusion, stochastic acceleration, turbulent resistivity, shock waves, radio emission. *Dupree*
- 8.622 Wave Propagation in Plasmas (A)**  
*Prereq.:* 8.08; 8.261 or 8.611 3-0-9  
*Year:* G (2) *Allis*  
 Moment equations for a plasma. Waves in a cold plasma in a magnetic field with a close look at cyclotron waves, whistlers, Alfvén waves, etc. Beam-plasma interaction. Linearized Boltzmann treatment. Landau damping and Bernstein modes. Non-linear waves. (*Alternate years.*)
- 8.632 Interactions of Plasmas with Electromagnetic Waves (A)**  
*Prereq.:* 8.08 3-0-9  
*Year:* G (2) *Brown*  
 Propagation of transverse electromagnetic and longitudinal waves in infinite and bounded plasmas. Special emphasis on experimental methods and the interpretation of results insofar as these provide information about the physical behavior of the plasma medium. Discussion of the following topics: optical, laser, infrared and microwave interferometry; resonant cavity techniques; laser and microwave scattering from density fluctuations; bremsstrahlung, cyclotron and Cerenkov emission and absorption; longitudinal electron plasma and ion-acoustic waves in isotropic and magneto-active plasmas; beam-plasma interactions and instabilities.
- 8.681, 8.682 Selected Topics in Fluid and Plasma Physics (A)**  
*Prereq.:* 8.611 3-0-9  
*Year:* G (1, 2) *Staff*  
 Presentation of subjects of current interest, with topic varying from year to year.
- 8.691, 8.692 Special Problems in Fluid and Plasma Physics (A)**  
*Prereq.:* — 3-0-9  
*Year:* G (1 or 2) *Arr.*  
 Advanced problems in fluid or plasma physics with assigned reading and consultation. *Staff*

## Nuclear and Particle Physics

- 8.711 Nuclear Physics I (A)**  
*Prereq.:* 8.05, 8.06 3-0-9  
*Year:* G (1) *Staff*  
 Advanced experimental nuclear physics including description of properties of nuclei, and correlating experimental results with current theory and nuclear models. Shell models, collective models of vibrational and rotational states, and nuclear spectroscopy. The deuteron, np and pp scattering and nucleon-nucleon interaction. Elastic and inelastic scattering of protons, neutrons,  $\alpha$ -particles; stripping, pick-up and other strong interaction probes. Resonance reactions, analog and doorway states. Photonuclear reactions, dipole resonance and sum rules.
- 8.712 Nuclear Physics II (A)**  
*Prereq.:* 8.711 3-0-9  
*Year:* G (2) *Staff*  
 Electromagnetic and  $\beta$ -decay transitions as probes of nuclear structure; Mössbauer effect; nuclear properties from spectroscopy of electronic and  $\mu$ -mesic atoms. High-energy probes of nuclear structure: electron, proton and pion scattering, photodisintegration, Compton scattering and coherent  $\pi^0$ -production. Distribution of charge, matter, magnetization. Nuclear momentum distributions in nuclei from (p, 2p) and (e, e'p) studies. Nucleon-nucleon correlations, ( $\gamma$ , np) and ( $\pi$ , 2N) reactions.
- 8.721 Nuclear Physics for Engineers I (A)**  
*Prereq.:* 8.05 or 8.211 3-0-9  
*Year:* G (1) *Staff*  
 Nuclear phenomena, for advanced students not majoring in physics. Stationary states of nuclei: nuclear charge, radius, mass, moments, parity, and statistics. Barrier transmission; radioactive transitions; alpha, beta, and gamma decay. Binding energy, nuclear forces, and nuclear models.
- 8.722 Nuclear Physics for Engineers II (A)**  
*Prereq.:* 8.721 3-0-9  
*Year:* G (2) *Staff*  
 Continuation of 8.721. Nuclear dynamics: energetics and cross sections for nuclear reactions, scattering, and fission. Passage of charged particles through matter: ionization, scattering, and radiative losses. Interaction of neutrons and gamma rays with matter.
- 8.724 Statistical Fluctuations in Physical Processes (A)**  
*Prereq.:* 8.05 2-0-4  
*Year:* G (2) *R. D. Evans*  
 Application of statistical theory of fluctuations and errors to experimental physics. Theoretical frequency distributions: binomial, normal, Poisson, interval, and composite distributions. Statistical characterization of data, and tests of significance. Applications of Poisson statistics to the response of nuclear detection instruments, including scaling circuits and counting rate meters. Appraisal of random processes by inefficient statistics using non-parametric tests.
- 8.751 Theory of Nuclear Structure I (A)**  
*Prereq.:* 8.322 3-0-9  
*Year:* G (1) *Staff*  
 Review of the current theories of the structure of atomic nuclei. Nature of internuclear forces as determined by two-body phenomena. The three-body problem. The nuclear many-body problem: Hartree-Fock approximation; Bruecker-Bethe Goldstone many-body theory, and its application to nuclear matter and finite nuclei. The nuclear shell model. (*Alternate years. Not offered 1969-70.*)

**8.752 Theory of Nuclear Structure II (A)**

Prereq.: 8.751

Year: G (2) 3-0-9

Continuation of 8.751. Nuclear spectroscopy: collective and single particle excitations; the random phase approximation. Electromagnetic interaction, sum rules. Theory of nuclear reactions: resonance reactions and the Breit-Wigner formula; doorway and analog states. Theory of the optical potential. Interaction of nuclei with elementary particles. (Alternate years. Not offered 1969-70.) Staff

**8.781, 8.782 Selected Topics in Nuclear Theory (A)**

Prereq.: 8.751

Year: G (1 or 2) 3-0-9

Presentation of subjects of current interest in nuclear structure and reaction theory. Intended to be given once a year by Department members and (or) visiting professors. Staff

**8.791, 8.792 Special Problems in Nuclear Physics (A)**

Prereq.: —

Year: G (1 or 2) Arr.

Research and reading with consultation in the general area of experimental or theoretical nuclear physics. Staff

**8.811 Particle Physics I (A)**

Prereq.: 8.05, 8.321

Year: G (1) 3-0-9

Phenomenological approach to particles and their interactions. Classification, symmetry principles, conservation laws. Yukawa approach to mesons. Relativistic kinematics, elementary S-matrix theory, conservation of angular momentum, isotopic spin, etc. Characteristics of strong, electromagnetic, and weak interactions. Particle properties and their interpretation. B. T. Feld

**8.812 Particle Physics II (A)**

Prereq.: 8.811

Year: G (2) 3-0-9

Continuation in depth of 8.811 with particular emphasis on conservation laws, symmetries and their consequences. SU(3) and SU(6). Weak interactions and strong symmetries. B. T. Feld

**8.822 Theoretical Particle Physics (A)**

Prereq.: 8.323

Year: G (2) 3-0-9

Presentation of the basic techniques used in theoretical particle physics: static models; dispersion relations and the Mandelstam representation; helicity formalism. Complex angular momentum. Symmetries: current algebras and sum rules. Gerstein

**8.871, 8.872 Topics in Relativistic Quantum Theory (A)**

Prereq.: 8.323

Year: G (1 or 2) 3-0-9

Precise material to be covered to differ from year to year according to interest of the instructor. Typical subjects: quantum field theory, S-matrix theory, single and double dispersion relations, Regge-poles, approximate symmetries, and weak interactions. Staff

**8.881, 8.882 Selected Topics in Particle Physics (A)**

Prereq.: 8.811

Year: G (1, 2) 3-0-9

Topics in particle physics, varying from year to year. B. T. Feld

**8.891, 8.892 Special Problems in Particle Physics (A)**

Prereq.: —

Year: G (1, 2)

Arr.

Research and reading with consultation in the general area of experimental or theoretical particle physics. Experimental work which may involve use of off-campus facilities such as the Cambridge Electron Accelerator, Brookhaven National Laboratory, Stanford Linear Accelerator Center, or cosmic ray stations. Staff

**Space- and Astro-physics****8.911 Charged Particles in Space (A)**

Prereq.: 8.07

Year: G (1) 3-0-9

Outline of properties of space beyond earth's atmosphere. Motion of charged particles in magnetic fields: Störmer's theory, Alfvén's approximation, adiabatic invariants. Geomagnetic effects on cosmic rays. Radiation belts. Collision cross sections and diffusion coefficients pertinent to physics of space. Physical quantities that characterize plasma; macroscopic versus microscopic description. Boltzmann equations for fully ionized gases; moments of Boltzmann equations; the generalized "Ohm's Law"; magnetohydrodynamic approximation. Elements of shock theory for dilute plasmas. Vasylunas

**8.921 Physics of the Stars (A)**

Prereq.: 8.05, 8.08

Year: G (1) 3-0-9

Observable stellar characteristics and a survey of star types. Interpretation of the observations as suggested by theoretical studies of stellar structure and evolution. An examination of physical processes in the stellar interior: matter and radiation under stellar interior conditions; nuclear transformations and modes of energy generation appropriate to quasi-static stages of evolution; photon absorption cross-sections and modes of energy transfer. Simple models describing gravitationally contracting, main sequence, and white dwarf stages. Stellar atmospheres and the determination of surface chemical composition. Final reexamination of the observations in the light of processes discussed. Iben

**8.922 Stellar Evolution (A)**

Prereq.: 8.921

Year: G (2) 3-0-9

Star formation, protostars, red giants, variable stars, planetary nebulae, novae, supernovae, pulsars, X-ray sources, nucleosynthesis, massive stars, stellar winds, white dwarfs, neutron stars, gravitational collapse. W. K. Rose

**8.932 Physics of the Galaxy (A)**

Prereq.: 8.911 or 8.921

Year: G (2) 3-0-9

Stellar content of the galaxy; kinematical results and dynamical theory. Gas content: gravitational and optical methods; optical polarization and dust. Galactic radio astronomy: spectroscopy of H, OH; the continuum, thermal and non-thermal. Particles and radiation: the halo problem; cosmic rays; electrons and their history. The magnetic field. Relationships to external galaxies. Burke

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## PSYCHOLOGY

### 8.942 *Cosmology* (A)

Prereq.: —  
Year: G (2) 3-0-9

Cosmic ages, the Hubble law and Olbers paradoxes. Thermal backgrounds in space. The cosmological principle and its consequences; Newtonian cosmology and types of "universes"; survey of relativistic cosmology; horizons. Overview of evolution in cosmology: radiation, and element synthesis; physical models of the "early stages." Radio sources and their statistics; quasars. Variability of physical laws. (Consent of instructor required. Alternate years). Morrison, Weinberg

### 8.951J *Fundamentals of Radio Astronomy* (A)

(Same subject as 6.625J)  
Prereq.: 6.624 or 8.05 or 8.211  
Year: G (2) 3-0-9

Emission and absorption of radio energy in stellar and planetary atmospheres, gaseous nebulae, and the interstellar medium. Detailed development of emission mechanisms, including free-free transitions, spectral line radiation from H, OH, and other atoms and molecules, synchrotron radiation using classical relativistic electrodynamics. Theory and results of radio observations of the moon, planets, sun, discrete galactic sources, galactic background radiation, extra-galactic sources. Impact of radio astronomy on galactic structure, physics of the interstellar medium, origin of cosmic rays, cosmology. Radio astronomical observations and experiments from space vehicles. (No prior knowledge of astronomy or astrophysics required. Students who wish to do thesis work in this area are advised to take 6.624 as well as 8.951J.) Barrett, Staelin

### 8.953J *Dynamical Astronomy* (A)

(Same subject as 12.613J and 16.441J)  
Prereq.: 8.03, 18.05  
Year: G (1) 3-0-9

Astronomical background, central orbits, potential theory, the two-body problem, orbital elements and coordinate systems, orbit determination, three- and n-body problems, perturbation theory and techniques of computation, observations and statistical theory of data analysis. Applications to the motion of planets, natural and artificial satellites. I. I. Shapiro, Counselman, Wrigley

### 8.954J *Dynamical Problems of the Solar System* (A)

(Same subject as 12.614J and 16.442J)  
Prereq.: 8.953J  
Year: G (2) 3-0-9

Introduction to current research in solar systems dynamics, tidal friction, spin and orbital resonances, evolution of the earth-moon system, and tests of gravitational theories. I. I. Shapiro, Counselman, Wrigley

### 8.962 *Relativity* (A)

Prereq.: 8.312  
Year: G (2) 3-0-9

Review of special relativity: Lorentz transformations, relativistic mechanics, and electromagnetism. The equivalence principle. Linear gravitational theories. General covariance. Elements of tensor analysis. The gravitational field equations and some special solutions. Gravitational waves, Mach's principle, and cosmological models. Staff

### 8.981, 8.982 *Selected Topics in Astrophysics* (A)

Prereq.: —  
Year: G (1 or 2) 3-0-9

Topics of current interest, varying from year to year. Staff

### 8.991, 8.992 *Special Problems in Astrophysics* (A)

Prereq.: —  
Year: G (1 or 2) Arr.

Advanced problems in astrophysics with assigned reading and consultation. (Admission by permission of instructor only.) Staff

## 9. Psychology

### 9.00T *Introductory Psychology*

Prereq.: —  
Year: U (1, 2) 3-0-6

Survey of selected facts, principles, and theories in psychology. Historical origins, biological foundations, comparative and developmental studies, motivation, perception, learning, personality, and social processes. Teuber

### 9.001 *Proseminar in Psychology* (A)

Prereq.: 9.35T, 9.40T, 9.70T  
Year: G (1) 6-0-15

Intensive survey of psychology on the graduate level, covering historical origins, biological foundations, learning, and higher processes, perception, child development, personality, and social interaction. Lectures, group discussions, and guided reading. (Restricted to graduate students in psychology.) Staff

### 9.01T *Physiological Psychology I*

Prereq.: 9.00T  
Year: U (1) 4-0-6

Explanations of behavior in neurological terms. General structure and physiology of central nervous system. Reflexes and motor systems; sensory systems: anatomy, electrophysiology, ablation studies. Limbic system: exploring the bases of motivation, emotion, and visceral regulation. "Higher functions" and cerebral cortex. Introduction to neural processes in learning. Schneider

### 9.011 *Seminar in Psychophysiology of Memory* (A)

Prereq.: 9.001 or 9.01T or 9.40T  
Year: G (1) 3-0-6

Discussion of physiological, biochemical and structural aspects of the mnemonic process. Mechanisms of information handling in biological systems with particular emphasis upon habituation, conditioning, and similar phenomena in animals. Consideration of models and theories concerning the biological basis of memory. (Not offered 1969-70.) Chorover

### 9.012 *Seminar in Physiological Psychology* (A)

Prereq.: 9.001  
Year: G (2) 3-0-6

Advanced treatment of topics in physiological psychology. (Primarily for graduate students specializing in this field.) Staff

### 9.013 *Outline of Mammalian Neuroanatomy* (A)

Prereq.: 9.001  
Year: G (2) 3-0-6

An elementary survey of mammalian neuroanatomy based largely on the primate brain. Emphasis more on over-all organization of the central nervous system than on cellular detail. Nauta

**9.014 Practicum in Physiological Psychology I (A)**

Prereq.: 9.001 or 9.01T or 9.013  
Year: G (1) 2-4-3

Introduction to experimental techniques in psychophysiological research. Biophysical principles; control and measurement of electrophysiological and behavioral variables; care and treatment of laboratory animals; psychopharmacology, surgical and stereotaxic production of cortical and subcortical brain lesions, electrical and chemical brain stimulation techniques, recording and averaging of neuroelectrical activity. (Limited enrollment. Permission of instructor required.) Chorover

**9.015 Practicum in Physiological Psychology II (A)**

Prereq.: 9.001 or 9.01T or 9.013 or 9.014  
Year: G (2) 2-4-3

Elementary neurohistology: fixation, blocking, embedding, cutting and staining techniques; interpreting and displaying the results. Special projects according to student interests. (Limited enrollment. Permission of instructor required.) Schneider

**9.02T Physiological Psychology II**

Prereq.: 9.01T  
Year: U (2) 3-0-6

Seminar dealing with selected topics of special interest to students and instructor. Student projects and reports. Staff

**9.021 Brain and Behavior (A)**

Prereq.: 9.001  
Year: G (2) 3-0-6

Methods and results in neuropsychology — the correlation of neural structure with neural function (behavior). Analysis of cerebral structure in rodent, carnivore, and primate by methods drawn from macro- and micro-anatomy, by electrical stimulation and recording, and by chemical means. Analysis of function (behavior) proceeds by comparing effects of cerebral stimulation (or destruction) in the experimental animal, with corresponding effects of injury or disease in man. Teuber

**9.022 Light and Electron Microscope Techniques in Neurobiology (A)**

Prereq.: —  
Year: G (1) 2-6-2

Fixation and embedding of tissue for light and electron microscopy. Preparation of ultrathin sections. Fundamentals of light and electron microscopy techniques and their applications to the study of interneuronal connections. The ultrastructure of the nervous system. (Enrollment limited to five students. Permission of instructor required.) Greenlaw, Heimer, Karten

**9.03T Neural Mechanisms of Learning and Motivation**

Prereq.: 9.01T  
Year: U (2) 3-0-6

Consideration of the evidence for physiological mechanisms of learning and of motivated behavior (e.g. eating, drinking, sleep, maternal and reproductive behavior) derived from neuropsychological, neurophysiological and neurochemical experiments. Reports, lectures and discussion. (Not offered 1969-70.) Chorover

**9.30T Comparative Psychology**

Prereq.: 9.00T  
Year: U (1) 3-0-6

Review of basic concepts and methods in the study of behavior in animals ranging from amoeba to primate. Instinctive response patterns and their specific sensory releasers. Problems of maturation and learning in the analysis of these phenomena. Survey of parallels in the evolution of sensory-neural systems and the emergence of various behavior patterns. (Not offered 1969-70.) Hein

**9.301 Seminar in Comparative Psychology (A)**

Prereq.: 9.001 or 9.01T or 9.30T  
Year: G (2) 3-0-6

Topics for reports and discussion drawn from the following: evolution of sensory and motor systems, learning in invertebrates, animal navigation, animal communication, problems in interaction of genetic, maturational and experiential factors in the development of behavior, ethological theory, problems in the comparison of intellectual abilities within and between phyla, and similar topics. (Not offered 1969-70.) Hein

**9.341 Seminar in Sensorimotor Processes (A)**

Prereq.: 9.001; or 9.01T and 9.35T  
Year: G (1) 3-0-6

Discussion of the systems which control spatially oriented movements of man and other vertebrates. Data from studies of spatial behavior, its modification by rearrangement, and its early development. Consideration of relevant neurology and neurophysiology as constraints on modeling these systems. Other topics: the relevance of sensorimotor systems to spatial perception, the dissociation of pattern analyzing from orienting behavior, and invertebrate systems of coordination. Held, Hein

**9.35T Psychology of Perception**

Prereq.: 9.00T  
Year: U (2) 3-0-6

Critical and historical survey of phenomena revealed in study of the senses and the problems they raise for the development of theories of perception. Information drawn from anatomy, neurophysiology, psychophysics, and other relevant disciplines. Held, Richards

**9.351 Seminar on Sensation and Perception (A)**

Prereq.: 9.001 or 9.35T  
Year: G (2) 3-0-6

Reading, discussion, and criticism of current theory and experiments bearing on topics selected according to interests of participants. Topics may include perception of form, motion, and space; sensorimotor interaction; relevant neural processes; theoretical models, comparisons among species; and developmental approaches. Held, Richards

**9.355 Visual Processes (A)**

Prereq.: 6.37T or 9.001 or 9.35T  
Year: G (1) 3-0-6

Fundamental visual processes, seen as major advances in the evolution of visual systems. Integration of these processes in the human visual system. Depending upon interest of participants, topics to be emphasized: image formation, contrast, spatial-temporal interactions, adaptation phenomena, color, binocular vision, receptive fields and physiological correlates of form and movement perception. Visual mechanisms elucidated by psychophysical and neurophysiological evidence from primitive and complex visual systems. (Not offered 1969-70.) Richards

**9.361T Electrophysiology of the Visual System (A)**

Prereq.: 9.001  
Year: G (1) 3-0-6

Survey of the electrophysiology of the mammalian visual system. Special attention given to the relationship between electrophysiological and psychophysical data. Schiller

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## PSYCHOLOGY

- 9.37 Color Science and Color Vision**  
*Prereq.:* 9.35T  
*Year:* U (1) 3-0-6  
 Measurement and specification of color; colorimetry; color scales and color tolerances; chromatic adaptation; human color vision and its anomalies; theories of color vision. *Richards*
- 9.40T Learning**  
*Prereq.:* 9.00T  
*Year:* U (1) 3-0-6  
 Theories and experimental findings on learning and memory in both humans and animals. Short-term and long-term memory for verbal and non-verbal materials, classical and instrumental conditioning, extinction, habituation, motivation and learning, discrimination learning, mathematical theories of learning and memory. *Staff*
- 9.40I Seminar in Learning (A)**  
*Prereq.:* 9.001 or 9.40T  
*Year:* G (2) 3-0-6  
 Reading, discussion and criticism of selected topics. Emphasis on one or more of the following themes in a particular term: conditioning and instrumental learning, multiple response learning, problem solving and concept formation, verbal learning, memory, systematic formulations of learning phenomena, mathematical learning theories, neural mechanisms of learning. *Chorover*
- 9.45T Problem Solving**  
*Prereq.:* 9.00T  
*Year:* U (2) 3-0-6  
 Theories, methods, and findings in human problem solving. Analysis of some heuristic problem solving methods applied to problems taken from mathematics, logic, games, puzzles, concept attainment, and practical situations. Use of these methods by humans. Learning of new methods. Transfer of methods from one problem to another. Language and problem solving. Development of problem solving ability in children. (*Not offered 1969-70.*) *Staff*
- 9.49I Seminar in Mathematical Psychology (A)**  
*Prereq.:* 18.02  
*Year:* G (1) 3-0-6  
 Reading, discussion, and criticism of selected topics. Goals of the seminar: (a) discussion of methods for mathematical formulation of psychological principles, (b) sharing of intuitive knowledge of areas of mathematics considered relevant to psychology, and (c) understanding, developing and evaluating mathematical theories of particular phenomena in perception, learning, memory, decision, and action. (*Not offered 1969-70.*) *Staff*
- 9.50 Research in Psychology**  
*Prereq.:* 9.00T and one other subject in psychology  
*Year:* U (1, 2, S) *Arr.*  
 Laboratory research in the areas of perception, learning and memory. Each student to carry out an original study in the area of interest to him. Survey of problems specific to research topics, design and conduct of experiments, written presentation of results. *Schiller*
- 9.59T Psychology of Language and Communication**  
*Prereq.:* 9.00T or 23.751T  
*Year:* U (1) 3-0-6  
 Study of psychology of language processes in light of recent advances in structural linguistics; extensive critique of learning-theoretic accounts of verbal behavior; examination of problems of language acquisition and speech perception. Methodological implications of psycholinguistic experiments and theory will be stressed. *Garrett*
- 9.59I Seminar in Psychology of Language and Communication (A)**  
*Prereq.:* 9.001  
*Year:* G (1) 3-0-6  
 Reading, discussion, and criticism of selected topics. Emphasis on one or more of the following themes in a particular term: theories of language, speech perception, communication in sub-human species, aphasia, language acquisition, language and thought, interaction between grammatical structure and verbal performance. *Garrett*
- 9.595J Philosophical Psychology (A)**  
 (Same subject as 21.676J)  
*Prereq.:* —  
*Year:* G (2) 3-0-9  
 Place of psychology in the sciences. Nature of psychological explanation. Materialism and behaviorism. Problems concerning simulation of human behavior. *Fodor*
- 9.60T Personality Structure and Development**  
*Prereq.:* 9.00T  
*Year:* U (1) 3-0-6  
 Detailed study of basic personality phenomena and concepts, experimental and non-experimental methods and research findings. Phenomena discussed include: personality traits; the interrelations between motivation and memory, imagery, and thinking; anxiety, conflict, and defense; personality and beliefs; developmental changes in personality, especially in motives, modes of adaptation and morality. *Schiller*
- 9.65I Cognitive Processes (A)**  
*Prereq.:* —  
*Year:* G (2) 3-0-6  
 Issues in the formation and exploitation of cognitive structures. Special attention to 'motor' theories of concepts, associationism, and the impact of recent psycholinguistic studies on general problems about thought and perception. (*Permission of instructor required for undergraduate students.*) *Fodor, Garrett*
- 9.70T Social Psychology**  
*Prereq.:* 9.00T  
*Year:* U (2) 3-0-6  
 Examination of the basic processes by which people interact, perceive and make judgments of others, influence each other, and develop social beliefs and values, in the context of small and large groups and societies. *Potter*
- 9.80T Behavior in Groups**  
*Prereq.:* 9.00T  
*Year:* U (2) 3-0-6  
 Psychological study of the behavior of individuals in group situations. Field studies and laboratory research, with emphasis on the latter. (*Not offered 1969-70.*) *Staff*
- 9.85I Seminar in Social Development of Children (A)**  
*Prereq.:* —  
*Year:* G (2) 3-0-6  
 Description and comparison of children's social behavior at different stages of development. Selected topics concerned with moral development, communication and interaction, imitation and compliance, and group formation. (*Permission of the instructor required. Not offered 1969-70.*) *Staff*
- 9.88T Seminar in the Origins of Behavior**  
*Prereq.:* 9.00T  
*Year:* U (2) 3-0-6  
 Interaction of innate and experiential factors in the neonatal development of learning capacities, perception, cognition, social behavior, and motor patterns. Implications of evolution, genetics, embryology, and early experience for the ontogeny of behavior. *Hein*

**9.89T Developmental Psychology**

Prereq.: 9.00T  
Year: U (2) 3-0-6

Survey of major issues, problems, and theories of ontogenetic development. Developmental aspects of sensorimotor coordination, perception, learning and personality.  
Schiller

**9.89I Seminar in Developmental Psychology (A)**

Prereq.: 9.001  
Year: G (2) 3-0-6

Advanced treatment of topics in developmental psychology. (Not offered 1969-70.)  
Hein

**9.92T Advanced Psychology Seminar**

Prereq.: 9.00T and any two subjects in psychology  
Year: U (2) 3-0-6

Critical survey of contemporary problems in experimental psychology.  
Staff

**9.92I Research in Psychology (A)**

Prereq.: 9.001  
Year: G (1) Arr.

**9.922 Research in Psychology (A)**

Prereq.: 9.001  
Year: G (2) Arr.

**9.923 Research in Psychology (A)**

Prereq.: 9.001  
Year: G (S) Arr.

Guided research under the sponsorship of individual members of the faculty. Ordinarily restricted to candidates for the doctor's degree in psychology.  
Staff

**10.****Chemical Engineering****10.12 Staged Cascades in Chemical Processing**

Prereq.: —  
Year: U (1) 3-3-6

Cascade theory of staged separations processes such as solvent extraction, distillation, absorption, and gaseous diffusion. Numerical iteration techniques and computer methods. Concepts of reflux. Algebraic solutions for linear systems. Graphical methods of analysis. Computer techniques for multicomponent distillation. Coupled cascade systems. Design and optimization of such systems.  
Brian

**10.13 Chemical Engineering Thermodynamics**

Prereq.: 5.60  
Year: U (2) 4-0-8

Engineering applications of thermodynamics. Concepts of equilibrium and reversibility. Properties of pure materials and of mixtures. The entropy, free energy, and availability functions and their use in the analysis of chemical reactors, power cycles, refrigeration cycles, and separation processes. Chemical equilibrium in homogeneous and heterogeneous systems.  
Bodman

**10.15 Thesis Reports**

Prereq.: —  
Year: U (1, 2) Arr.

Work done in conjunction with the S.B. thesis. Written and oral reports on literature survey and experimental work. Normally consists of three units in the fall term plus one unit in the spring term.  
Cottrell

**10.18 Industrial Chemistry**

Prereq.: 5.60; 10.301  
Year: U (2) 3-0-6

Study of processes for making industrial chemicals as systems. Exploration of those factors which determine the flowsheet and apparatus required for carrying out the reactions and associated operations. Extensive problem work on the influence of stoichiometry, energy requirements, equilibria, kinetics and the transfer processes on over-all design and operation.  
Meissner

**10.21 Structures and Properties of Matter**

Prereq.: 5.41T, 5.62  
Year: U (1) 3-0-6

Atomic and molecular interactions and their importance in determining physical and chemical properties of matter. Bulk and interfacial properties of pure and mixed gases and solids, including synthetic and natural polymeric substances. Techniques for characterizing molecular structure and for predicting properties of matter.  
Baddour

**10.21I Structures and Properties of Matter (A)**

Prereq.: 5.41T, 5.62  
Year: G (1) 3-0-6

Graduate equivalent of 10.21.  
Baddour

**10.24 Chemical Engineering Instrumentation Laboratory**

Prereq.: 5.60  
Year: U (1, 2) 1-3-1

Combination of lectures, demonstrations, and laboratory exercises outlining principles and range of applicability of a number of instrumental methods currently important in chemical engineering. Opportunities to work with specific instruments in association with research workers. Emphasis on gas chromatography, infrared spectroscopy, and potentiometric measurements. Study of some of the following topics: flame photometry, ultra-violet and visible spectrophotometry, hot-wire anemometry, viscometry, microscopy, transient temperature measurements, pyrometry, pH measurements, and radiation counting techniques.

**10.25 Industrial Chemistry (A)**

Prereq.: 5.41T, 5.62  
Year: G (1) 3-0-6

Study of the factors determining the flow sheets, equipment design and interrelations in plants for producing industrial chemicals. Many examples drawn from the inorganic and organic industries both quantitatively and qualitatively.  
Meissner

**10.26T Chemical Engineering Laboratory**

Prereq.: 5.41T, 10.13, 10.301  
Year: U (1) 0-10-0

Laboratory projects in the areas of applied chemical research and unit operations. Emphasis on the applications of engineering concepts and fundamentals to the solution of practical and research problems. Training in planning research projects, execution of experimental work, and articulation (both oral and written) of the research plan and results in the areas of applied chemical technology and engineering operations related to mass, momentum, and heat transfer.  
Fleming

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## CHEMICAL ENGINEERING

### 10.28 Industrial Chemical Synthesis (A)

Prereq.: 5.41T, 5.62

Year: G (1)

2-0-4

Study of the reactions and the large-scale processes for making selected petrochemicals, with particular reference to ethylene, acetylene, propylene, butadiene, and their derivatives. Exploration of current practice, including the state of the patent art. *Meissner*

### 10.301 Modes of Heat and Mass Transfer

Prereq.: 10.13

Year: U (1)

4-0-6

Diffusive transport of heat or mass in stationary media; additivity of resistances concept and transient analysis. Radiative transport of energy. Convective transport. Chemical engineering design of heat and mass exchangers. *K. A. Smith*

### 10.302 Fluid Mechanics and Transport Processes

Prereq.: 10.301

Year: U (2)

4-0-6

Introduction to fluid mechanics. Dynamics of fluids in motion; laminar and turbulent flow; Bernoulli's equation; friction in conduits, boundary layer theory; Navier-Stokes equations. Convective transport analysis. The analogies, boundary layers, condensation, natural convection. *K. A. Smith*

### 10.311 Continuum Mechanics

Prereq.: 10.301

Year: U (2)

4-0-6

A sound foundation for extensive work. Kinematics of continua; forces and stresses in continua; fluid statics; flow of an ideal fluid; rheology of real fluids; simple laminar flows. *K. A. Smith*

### 10.312 Transport Phenomena

Prereq.: 10.311

Year: U (1)

4-0-6

Convective heat and mass transfer. Boundary layer flows, turbulence, the analogies, flow past bluff bodies, condensation, natural convection. *K. A. Smith*

### 10.33 Analytical Treatment of Chemical Engineering Processes (A)

Prereq.: 10.301, 18.034

Year: G (2)

3-0-6

Mathematical techniques for handling rate problems such as diffusion, heat transfer, and chemical reactions basic to most chemical engineering operations. Formulation of problems corresponding to specific physical situations in terms of ordinary differential, partial differential, and finite-difference equations. Solution of these equations by appropriate analytical and numerical methods. *L. B. Evans*

### 10.34 Numerical Solution of Problems in Chemical Engineering (A)

Prereq.: 10.33

Year: G (2)

2-2-4

Advanced seminar in the numerical analysis associated with the solution of ordinary and especially partial differential equations by numerical methods. Lectures and problem assignments on the analysis of the stability and convergence of finite-difference methods of solving differential equations. Lectures and student seminar reports to cover recent advances and new techniques in the field. Each student to program and solve on a digital computer at least one problem from such fields as chemical reactor simulation, heat transfer, diffusion, and fluid mechanics, with the focus upon the relative effectiveness of various finite-difference methods of solving a particular type of problem. Some training in FORTRAN coding. (Limited to ten students. Permission of instructor required.) *Brian*

### 10.35 Dynamics and Control of Chemical Engineering Processes (A)

Prereq.: 10.301, 18.034

Year: G (1)

3-0-6

Description of the dynamic behavior of processes and equipment by ordinary and partial differential equations. Use of linearized approximations. Introduction to feedback control concepts. Solution of systems of equations by classical methods and by use of Laplace transforms. Optimal control theory. Use of analog and digital simulation techniques. Design and analysis of conventional and computer control systems. *L. B. Evans*

### 10.361 Process Design

Prereq.: 10.301

Year: U (1)

3-0-6

Presentation and discussion of real process design problems, with case studies in chemical processing and petrochemicals. Emphasis on conception and invention of processes, as well as analysis and economic balances, to specify optimum design and operating conditions. Discussion of a variety of cases throughout the term. *Bodman*

### 10.362 Process Design

Prereq.: 10.301

Year: U (2)

3-0-6

Same as 10.361, but with new case studies. May be taken by students who have credit for 10.361. *G. C. Williams*

### 10.37 Chemical Kinetics and Reactor Design

Prereq.: 5.60, 10.301

Year: U (1)

3-0-6

Fundamentals of chemical kinetics. Analysis of batch, plug flow, and continuous stirred tank reactors for single, multiple and series-type reactions. Introduction to concepts of residence time distribution and chain reactions. Consideration of some real reactors and typical reactor design problems. *Satterfield, Deibert*

### 10.38 Analysis and Simulation of Chemical Processing Systems (A)

Prereq.: 10.301, 18.034

Year: G (2)

2-2-4

Introduction to techniques for computer-aided analysis of chemical processing systems. Development of mathematical models to describe dynamic and steady-state process behavior. Representation of the structure of complex, interconnected chemical processes with arbitrary recycle streams. Numerical methods for solving resulting systems of non-linear differential and algebraic equations. Analog computation. Use of one or more special digital simulation languages. Application of various mathematical optimization techniques. Survey of recent developments in comprehensive problem-oriented computing systems to assist in chemical process design. Training in computer programming in special class sessions. *L. B. Evans*

## ENGINEERING OPERATIONS

### 10.40 Chemical Engineering Thermodynamics (A)

Prereq.: 10.13

Year: G (1, 2)

3-0-9

Basic postulates of classical thermodynamics. Application to transient open and closed systems. Criteria of stability and equilibria in homogeneous and complex heterogeneous systems including the effect of external force fields and chemical reaction. Thermodynamic properties of pure materials and mixtures with some discussion of estimation and correlating techniques. Applications emphasized through extensive problem work relating to practical cases. *Modell, Reid*

**10.41 Distillation (A)**

Prereq.: 10.13

Year: G (1)

3-0-6

General principles of staged contacting with major emphasis on the distillation of binary and multicomponent mixtures. Vapor-liquid equilibria of high-pressure and non-ideal multicomponent systems. Cascade configurations. Graphical, analytical and computer techniques for binary and multicomponents systems. Tridiagonal matrix solutions for complex columns. Vapor-liquid contacting theory from transport fundamentals. *Virk*

**10.47 Ion Exchange (A)**

Prereq.: 5.60, 10.301

Year: G (2)

2-0-4

Preparation and properties of synthetic organic exchangers. Industrial applications of the general ion exchange process; equilibrium and rate studies for fixed and moving beds; ion exchange chromatography. *Baddour*

**10.50 Heat and Mass Transfer (A)**

Prereq.: 10.302

Year: G (1)

3-0-6

Fundamentals of diffusive and convective transport of heat and mass. Analytical and numerical solutions to steady-state and transient diffusion problems. Superposition techniques. Forced convection of heat and mass in laminar flow. Turbulent diffusion. Mass, heat, and momentum transfer from a phase boundary to a turbulent fluid. Simultaneous heat and mass transfer. *Bodman*

**10.52 Mechanics of Fluids (A)**

Prereq.: 10.302

Year: G (1)

3-0-6

Content varying from year to year with subject material drawn from topics such as boundary layer theory, turbulence, rheology, hydrodynamic stability, compressible flow, and continuum mechanics. *Hales*

**10.53 Chemical Engineering Design (A)**

Prereq.: 10.301

Year: G (1, 2)

3-0-6

Same as 10.361 but with the case study level appropriate for graduate students. *Bodman*

**10.54 Advanced Topics in Mass Transfer (A)**

Prereq.: 10.50

Year: G (2)

3-0-6

Advanced treatment of molecular and eddy diffusion and mass transfer between phases. Theories of mass transfer with simultaneous chemical reactions. Process design cases involving gas absorption. *Sherwood*

**10.55 Advanced Topics in Heat Transfer (A)**

Prereq.: 10.50

Year: G (2)

3-0-6

Advanced treatment of selected problems in heat transfer of current concern to the chemical engineer. Choice of problems in conduction, simultaneous heat transfer and chemical reaction, condensation, natural convection, and radiation. Emphasis on analytical methods such as superposition, perturbation, asymptotic methods, and integral equations. *Sarofim*

**10.56 Chemical Engineering in Medicine (A)**

Prereq.: 5.62, 10.301

Year: G (2)

2-0-4

Seminar with oral presentations by members on topics of current interest involving broad applications of chemical engineering to medical problems. Visits to local hospitals and discussions with physicians, surgeons, and life scientists on problems of mutual interest. *Merrill*

**10.59 Properties of Gases and Liquids (A)**

Prereq.: 5.62, 5.63

Year: G (2)

3-0-6

Intermolecular forces including dipole, multipole, induced dipole, and London-type forces. Application of intermolecular force theories to the problems of predicting equilibrium and transport properties of gases and liquids. Modern theories of liquid structure are reviewed. *Reid*

**APPLIED CHEMISTRY****10.602 Catalysis (A)**

Prereq.: 5.62 or 10.37

Year: G (1)

3-0-6

Relationships of activity and selectivity to physical and chemical properties of a solid catalyst. Components and preparation of catalysts. Physical adsorption, chemisorption. Physical characterization of catalysts; surface area, pore size distribution. Examination of catalyst structures and surfaces by modern instrumental methods. Kinetic models and correlation of rate data. Electronic factors in catalysis; geometrical factors; concept of the unstable intermediate. Acid catalysts and molecular sieve catalysts. Multifunctional catalysis. Homogeneous catalysis by organometallic compounds. Case studies of several industrial catalysts and associated catalytic processes. *Satterfield, Modell*

**10.61 Physics and Chemistry of Surfaces (A)**

Prereq.: 5.62

Year: G (1)

3-0-6

Thermodynamic, kinetic, and chemical factors underlying surface and interfacial phenomena. Intermolecular forces, orientation at interfaces and the origins of surface tension. Capillarity and the effects of surface curvature on bulk phase properties. Thermodynamics of adsorption at interfaces; the Gibbs adsorption isotherm. Electrical phenomena at interfaces: origins of surface potential, structure of the diffuse double layer, electrokinetic phenomena. Surface-active agents, contact angles, spreading, and wetting phenomena. Properties of colloidal electrolytes, micelles, solubilization phenomena, monolayers. Correlation of these fundamentals of surface and interfacial phenomena with important industrial applications as: emulsions, foams, flotation, detergency, adhesion, and lubrication. Survey of some important surface phenomena in biological systems. *A. S. Hoffman*

**10.62 Electrochemistry (A)**

Prereq.: 5.62

Year: G (2)

3-0-6

Application of principles of thermodynamics, surface chemistry, mass transport, catalysis, and reaction kinetics to the operational characteristics of electrochemical systems. Outline of methods of experimental electrochemical investigations. Discussions of current electrochemical practice including selected industrial electrolytic processes, primary and secondary batteries, and fuel cells. *Deibert*

**10.631 Surface and Colloid Chemistry**

Prereq.: 5.60

Year: U (2)

2-0-4

Consideration of selected phenomena and processes relevant to chemical engineering characterized by large interfacial area relative to phase volume. Surface chemistry and physics: interfacial tension and pressure, contact angle, capillarity, wetting, surface active agents and monolayers. Colloid particles: electrical double layer theory, preparative methods, flocculation, and sedimentation. Control of rate processes at a phase interface, including nucleation and crystallization. *A. S. Hoffman*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

CHEMICAL ENGINEERING

## 10.64 Structure and Properties of Polymers (A)

Prereq.: 5.42, 5.60

Year: G (2)

3-0-6

Relationship of molecular structure and composition of organic high polymers to their bulk physical properties. Kinetic theory of rubber elasticity, glass transition behavior, viscoelastic theory, melt rheology, crystallinity in polymers. Effects of orientation, crosslinking, plasticization, copolymerization and presence of fillers on the properties of plastics, elastomers, fibers, films, and foams. Physical properties including mechanical (dynamic and transient), electrical, optical, gas transport properties.

A. S. Hoffman

## 10.648 Synthesis and Properties of Polymeric Materials

Prereq.: 5.41T; 5.62

Year: U (1)

2-0-4

Principles of the synthesis, dilute solution properties and bulk properties of macromolecules are covered. The chemistry of polymerization mechanisms; conformational statistics of long chains, solution thermodynamics, viscosity of polymer solutions, rubber elasticity, viscoelasticity of bulk solid and molten polymers, glass transitions and crystalline structure of single crystals, bulk undrawn and drawn polymeric materials. A. S. Hoffman

## 10.65 Applied Chemical Kinetics (A)

Prereq.: 10.37

Year: G (2)

3-0-6

Application of chemical kinetics to development and improvement of industrial processes. Basic concepts of homogeneous and heterogeneous reactions and of chain reactions. Non-ideal reactor analysis, including residence time distributions, concepts of mixedness and segregation, dispersion and  $j$  CSTR models. Mass and energy transfer limitations in heterogeneous reaction systems. Choice and design of reactors for heterogeneous reactions including fluidized beds, slurry-type reactors and trickle beds. Emphasis on interpretation and correlation of experimental data and application to kinetic and reactor design problems. Satterfield

## 10.66 Surface Science and Engineering (A)

Prereq.: 5.62

Year: G (2)

3-0-6

Molecular constitution of interfaces, origin of surface tension; relation to intermolecular forces. Capillarity and surface thermodynamics; monolayer formation, properties, and degree of ordering. Description of supra-ordered microstructures and their formative processes: flocculation, nucleation and crystal growth, coacervation and gelation. Sorption in — and transport through — such structures: Langmuir, BET, Polanyi, Zimm-Lundberg treatments; elementary consideration of membrane transport phenomena and flow in microporous media.

## 10.68 Physical Chemistry of Polymers (A)

Prereq.: 5.42, 5.62

Year: G (1)

3-0-6

Principal emphasis on linear, random-coiling, non-electrolytic polymers. Conformation properties of the isolated random-coiling macromolecule, including the radius of gyration, segment density distribution, effective diameter in the computation of excluded volume and entropy elasticity. The definition of the dilute polymer solution based on volume fraction of "free" solvent external to random coils. The statistical thermodynamics of polymer solutions, derived (following Flory) for the dilute and for the concentrated solution. Applications to osmotic phenomena and to phase equilibria

including fractionation. Thermodynamic and conformational properties deduced from light scattering of polymer solutions. Extension of thermodynamic analysis to the theory of the intrinsic viscosity of polymer solutions. Special topics include: (a) non-Newtonian viscosity of polymer solutions (including gradient dependence of intrinsic viscosity); (b) response of dilute polymer solutions in turbulent flows (including the Tom's effect); (c) thermodynamic and hydrodynamic properties of certain biological polymers, including the hyaluronates.

Merrill

## 10.69 Polymerization Processes (A)

Prereq.: 5.42, 5.62

Year: G (2)

3-0-6

Synthesis of polymers with emphasis on interrelationships of reaction kinetics, chemical equilibria, fluid mechanics, heat transfer, and mass transfer. Specific topics include condensation polymerization; classical free radical polymerization in solution and in bulk; high-pressure radical polymerization of ethylene; emulsion polymerization and bead polymerization; cationic polymerization of isobutylene; anionic polymerization; Ziegler-Natta and related heterogeneous, stereoregulating polymerizations, various processes for generating cross-linked polymers or elastomers ("vulcanization" of elastomers, epoxy resin reactions, isocyanate-urethane reactions, maleic polyester-styrene reactions), and processes for chemical conversion of side groups on previously synthesized polymers (acetylation of cellulose, deacetylation of polyvinyl acetate, sulfonation or quaternization of polystyrene).

Merrill

## 10.70 Principles of Combustion (A)

Prereq.: —

Year: G (1)

3-0-6

Application of the principles of chemical kinetics (including chain reactions) and of mixing and diffusion to combustion processes. Problems on rate processes in the combustion of gaseous, liquid, and solid fuels. Principles of model analysis. Thermodynamics of high-temperature processes, with applications to chemical processing and to high-output power plants such as turbines, rockets, ramjets.

Hottel

## 10.72 Seminar in Air Pollution Control (A)

Prereq.: 10.302 or 10.312

Year: G (2)

2-0-4

Review of combustion sources of pollution and of criteria and legislation for maximum allowable emission rates. Methods for reduction of SO<sub>2</sub>, particulate, and NO<sub>x</sub> formation by modifications of the combustion process. Absorption systems for SO<sub>2</sub> and NO<sub>x</sub> removal. Methods for reduction of particulate emission. Stack dispersion. Survey of above topics by faculty and guest lecturers. Term projects for detailed studies of promising new techniques of pollution control.

Sarofim

## 10.74 Radiative Transfer (A)

Prereq.: 10.301

Year: G (2)

3-0-6

Heat transmission in high-temperature operations and interaction of radiative and other transport mechanisms. Radiation geometry; matrix algebra in application to radiative transfer in enclosures; zoning method as alternative to integral equation; use of machine computation. Thermal radiating characteristics of surfaces, gases, and particle clouds. Radiation methods of temperature measurement. Synthesis of analytical and empirical approach to produce approximations of engineering utility. Quantitative design of several furnaces and high-temperature systems.

Sarofim, Hottel

- SCHOOL OF CHEMICAL ENGINEERING PRACTICE**
- 10.82 School of Chemical Engineering Practice — Bound Brook Station (A)**  
*Prereq.:* —  
*Year:* G (1 or 2) 0-12-0  
 Conducted in the main plant of the Organic Chemicals Division of American Cyanamid Company at Bound Brook, New Jersey. Highly diversified operations, including process development and production of dyes, synthetic pharmaceuticals, organic pigments, rubber chemicals, intermediates, textile chemicals, plastics, resins, and related products.
- 10.83 School of Chemical Engineering Practice — Bound Brook Station (A)**  
*Prereq.:* 10.82  
*Year:* G (1 or 2) 0-12-0  
 Continuation of 10.82.
- 10.84 School of Chemical Engineering Practice — Bound Brook Station (A)**  
*Prereq.:* 10.83  
*Year:* G (1 or 2) 0-12-0  
 Continuation of 10.83.
- 10.85 School of Chemical Engineering Practice — Bound Brook Station (A)**  
*Prereq.:* 10.84  
*Year:* G (1 or 2) 0-12-0  
 Continuation of 10.84.
- 10.86 School of Chemical Engineering Practice — Oak Ridge Station (A)**  
*Prereq.:* —  
*Year:* G (1 or 2) 0-12-0  
 Conducted at the Oak Ridge, Tennessee, Station located at the Oak Ridge National Laboratory of the Atomic Energy Commission, operated by Union Carbide Company, Nuclear Division. Work under direction of Institute faculty residing at Oak Ridge with emphasis on the application of engineering principles to the solution of research and development problems arising from the programs of the Oak Ridge National Laboratory. *Application should be made three to four months in advance to allow ample time for routine entry procedures.* —
- 10.87 School of Chemical Engineering Practice — Oak Ridge Station (A)**  
*Prereq.:* 10.86  
*Year:* G (1 or 2) 0-12-0  
 Continuation of 10.86.
- 10.88 School of Chemical Engineering Practice — Oak Ridge Station (A)**  
*Prereq.:* 10.87  
*Year:* G (1 or 2) 0-12-0  
 Continuation of 10.87.
- 10.89 School of Chemical Engineering Practice — Oak Ridge Station (A)**  
*Prereq.:* 10.88  
*Year:* G (1 or 2) 0-12-0  
 Continuation of 10.88.

**GENERAL**

- 10.90 Experimental Research Problem (A)**  
*Prereq.:* —  
*Year:* G (1, 2) Arr.  
 For special and graduate students who wish to carry out some minor investigation in a particular field. Subject and hours to fit individual requirements. *G. C. Williams*
- 10.91 Experimental Research Problem**  
*Prereq.:* —  
*Year:* U (1, 2) Arr.  
 For undergraduate students who wish to carry out a special investigation in a particular field. Topic and hours to fit individual requirements. *Meissner*

- 10.93 Teaching Experience in Chemical Engineering (A)**  
*Prereq.:* —  
*Year:* G (1, 2) 2-0-4  
 For qualified graduate students interested in teaching as a career. Tutorial or classroom teaching under the supervision of a faculty member. Students selected by interview. Total enrollment limited by availability of suitable teaching assignments. *G. C. Williams*
- 10.991 Seminar in Chemical Engineering (A)**  
*Prereq.:* —  
*Year:* G (1) 2-0-4
- 10.992 Seminar in Chemical Engineering (A)**  
*Prereq.:* —  
*Year:* G (2) 2-0-4  
 For students working on doctoral theses. *Gilliland*

## 11. Urban Studies and Planning

- 11.001 Representation**  
*Prereq.:* —  
*Year:* U (1) 1-3-2  
 Use of graphic techniques to record or control the environment and to express ideas: freehand drawing, elementary drafting, three-dimensional models, surveying and mapping, diagrams, graphic presentation. The common principles underlying these techniques and their use as tools in analysis. For entering planning students without background in design fields. *Staff*
- 11.01 Community Planning Design**  
*Prereq.:* 11.001, 11.11  
*Year:* U (1) Arr.  
 Problems in planning of the physical environment. The functional, social, aesthetic, and economic consequences of physical arrangement at the city scale, in the light of fundamental human objectives. Workshop problems in real situations, but under generous limits of time-scale and capability. *Staff*
- 11.02 City and Regional Planning (A)**  
*Prereq.:* 11.01  
*Year:* G (2) Arr.  
 Practical application of city and regional planning theory to towns, cities, and regions, including problems of replanning, redevelopment, and urban renewal in existing communities. Individual problems, supplemented by group projects worked out in collaboration. Work in field, library, and studio leading to written, oral, and graphic presentations. *Staff*
- 11.03 Problems in City Planning (A)**  
*Prereq.:* 11.02  
*Year:* G (2) Arr.  
 Advanced problems in city planning, including pioneering studies and studies in specialized areas. *Staff*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## URBAN STUDIES AND PLANNING

- 11.05 Collaborative Design (A)**  
*Prereq.:* 11.02  
*Year:* G (1) Arr.  
 Project work on design problems which will benefit from collaboration between architects and city planners or between these groups and other disciplines. Staff
- 11.06 Problems in Urban Design (A)**  
*Prereq.:* 11.02, 11.05  
*Year:* G (2) Arr.  
 Advanced problems in planning for the visual form of the environment at the scale of cities or regions. Staff
- 11.08 Problems in Regional Planning (A)**  
*Prereq.:* 11.45  
*Year:* G (1) Arr.  
 Advanced problems in spatial planning and programming development at the regional scale: resource regions, depressed areas, and intermetropolitan zones in the United States. (*Not offered 1969-70.*) Staff
- 11.10 Introduction to City and Regional Planning**  
*Prereq.:* —  
*Year:* U (1) 3-0-5  
 Objectives and scope of comprehensive physical planning as applied to urban and rural areas. Basic concepts and theories of planning. Examples of comprehensive plans for cities and regions. (*Restricted to Course XI students.*) Staff
- 11.11 Components of the Urban Environment**  
*Prereq.:* —  
*Year:* U (1) 3-0-6  
 Physical nature and characteristics of the urban environment and its component parts. Land uses for residences, commerce, industry, institutions, etc. Circulation elements: streets, expressways, transit, parking. Physical structure and relationship of parts of city and regional development. J. T. Howard
- 11.12 City Planning Techniques**  
*Prereq.:* 11.11  
*Year:* G (2) 3-0-6  
 Survey, analysis, and design methods and practices in comprehensive planning: population and economic development, land use, circulation, other components of the city or metropolitan general plan; relationship of planning to implementation techniques, zoning, urban renewal, etc. J. T. Howard
- 11.15 Site Planning**  
*Prereq.:* —  
*Year:* U (2) 1-2-5  
 Arrangement of structures on the land: building grouping, land use and circulation planning, site engineering, landscaping. Lectures and brief exercises in design and field analysis. (*Limited enrollment.*) —
- 11.19 Models and the Metropolis**  
*Prereq.:* 11.60  
*Year:* U (1) 2-0-6  
 Examination, in detail, of current tries at reducing the metropolis to simple systematics through mathematical models describing spatial patterns — e.g., of population, of economic activity, or of circulation flows. Fleisher
- 11.20 Models and the Metropolis (A)**  
*Prereq.:* 11.60  
*Year:* G (1) 2-0-6  
 Same as 11.19, but with a level of study appropriate for graduate students. Fleisher
- 11.21 The Urban Transportation Problem (A)**  
*Prereq.:* 11.11, 11.60  
*Year:* G (2) 2-0-6  
 Seminar on the conditions of transportation in American and foreign cities; nature of the urban transportation problem as it is now and what it may become; its relevance to the form and structure of the city. Critical scrutiny of current research with particular emphasis on methods, old and new. Fleisher
- 11.22 Transportation and Urban Form (A)**  
*Prereq.:* 11.11, 11.60  
*Year:* G (1) Arr.  
 Seminar on the relations between transportation in the city and its form, structure, and quality; alternate designs for metropolitan transportation systems and the possibilities of innovation in organization and technology. Fleisher
- 11.25 Housing Problems**  
*Prereq.:* 11.11 or 11.60 or 14.01T  
*Year:* U (2) Arr.  
 The meaning and scope of housing problems. The market and social system for producing housing; evaluation of economic, social, design, administrative, and political problems. The broadening perspective of housing policy in the United States and other countries. Extensive readings and a paper required. Keys
- 11.31 Urban Landscape (A)**  
*Prereq.:* 4.121 or 11.11  
*Year:* G (2) 2-0-4  
 The city and its components as aesthetic elements. Role of plan organization, spatial relations, symbol, silhouette, scale, view, movement, light, color, sound, detail, etc. Presentation through field observation, group projects, and seminar discussion. Lynch
- 11.32 City Design (A)**  
*Prereq.:* 11.31  
*Year:* G (1) 2-0-6  
 Seminar on principles and techniques for the comprehensive design of the city environment, with special attention to its perceptual form; the relation between city form and community objectives; the visual plan as part of the total planning process. (*Limited enrollment.*) Lynch
- 11.33 Advanced City Design (A)**  
*Prereq.:* 11.31  
*Year:* G (1) 2-0-6  
 Criteria and methods for the design of the city environment, focusing on sensory qualities, communication, elements, systems, change and design for various population groups. Techniques of notation and simulation, methods of implementation and control. Case studies and design exercises. (*Not offered 1969-70.*) —
- 11.34 Psychology of the Environment**  
*Prereq.:* —  
*Year:* G (1) Arr.  
 Applications to environmental design of theories, experimental methods, and findings in psychology. Discussion of the following topics, both from the viewpoint of current psychology and in reference to environmental design: perception, attention, memory, learning, thinking, interpersonal attitudes and behavior, needs and values. (*Open to advanced undergraduates and to graduate students.*) M. C. Potter
- 11.35 Psychological Functions of Environmental Form (A)**  
*Prereq.:* 11.34  
*Year:* G (2) 2-0-6  
 Advanced analysis of topics of special interest to individual students, emphasizing experimental approaches. Organization and character of the environment as

significant variables in the psychological processes basic to effective human functioning. Attention to various scales of environment, from a single room to an urbanized region, but focusing on the implications for city design.  
*Carr, M. C. Potter*

**11.45 Metropolitan and Regional Planning in Developing Countries (A)**

*Prereq.:* 11.60

*Year:* G (1)

*Arr.*

Problems of cities and regions in developing countries in relation to economic and social development policy. Extended readings and workshop problems. *Rodwin*

**11.46 Urban Settlement, Squatters, and Social Change (A)**

*Prereq.:* 11.25; 11.50 or 11.60

*Year:* G (1)

*Arr.*

Lectures and seminars on the urban accommodations of the low-income sectors in urbanizing countries and the formation of squatter settlements. Examination of the principal social, economic and physical determinants of housing and settlement forms and development procedures in the context of a transitional economy. *J. Turner*

**11.50 Urban Social Structure and Process**

*Prereq.:* —

*Year:* U (1)

2-0-6

The city as a social system, including social subsystems, from the perspective of continuity of social structure across generations. Study of the conflict relations among various segments of the urban population — race, religion, and so on — for their implications; examination of segregation and its effects. The problems of child-raising in a modern city — the family and the educational system viewed from this perspective. The impact of social and technological change upon urban social systems. The physical and environmental characteristics of a city as outputs of social systems as well as constraints upon behavior.

**11.55 Urban Planning and Social Policy (A)**

*Prereq.:* 11.01, 11.50

*Year:* G (1)

*Arr.*

Interdisciplinary approaches to planning for urban problems, drawing on methods of (a) city and regional planning, and (b) social planning. Definition of urban problems as seen in the framework of each discipline, and identification of promising areas for collaborative planning. Focus on developing and evaluating techniques for dealing with selected problems in housing and relocation planning, antipoverty programs, and model cities planning. (*Offered jointly with Florence Heller Graduate School for Advanced Studies in Social Welfare, Brandeis University.*) *Frieden*

**11.56 Urban Social Policy Seminar (A)**

*Prereq.:* 11.01, 11.50

*Year:* G (2)

*Arr.*

Development of planning methods for dealing with selected areas of urban social policy; exploration of current social issues as they relate to city and regional planning, such as race and housing, relocation, antipoverty programs, and health and welfare services. Focus, varying from year to year, initially on health services and facilities. (*Offered jointly with Florence Heller Graduate School for Advanced Studies in Social Welfare, Brandeis University.*) *Frieden*

**11.57 Planning and Poverty (A)**

*Prereq.:* 11.50

*Year:* G (1)

2-0-6

The culture of poverty, its social and economic manifestations; programs for the amelioration of the poverty

problem; interactions among programs for social, economic, and environmental change; case studies and readings. *Peattie*

**11.575 Social Aspects of Development (A)**

*Prereq.:* 11.25; 11.50 or 11.57

*Year:* G (2)

2-0-6

Seminar discussion of the social and cultural aspects of economic development: urbanization, changing systems of social stratification, urban family structure, and the concept of a "culture of poverty." Treatment of the themes so as to show a sense of the social and cultural transformations implied by economic development and how "social problems" may be thought about in terms of their technical, economic, and institutional parameters. *Peattie*

**11.58J Seminar on Urban Development Policy (A)**

(Same subject as 17.812J)

*Prereq.:* 11.01, 11.50

*Year:* G (2)

*Arr.*

Interdisciplinary seminar on the politics of urban planning. Analysis of selected policy issues, ranging from transportation, urban renewal, and model cities to housing and central city-suburban relations. Consideration through research, field work, and case studies, of public action for guiding urban development, including intergovernmental relations and national urban policy. *Frieden, Altschuler*

**11.591 Deliberate Social Change in the Cities I (A)**

*Prereq.:* 11.11 or 11.25 or 11.57

*Year:* G (1)

*Arr.*

Study of theories and strategies of social and institutional change in urban settings, case studies in the formation of community corporations, urban development corporations, the advocate planning role, the neighborhood health center as a means to social change, low-income housing. Examination of relationships between social and technological change. Work toward a theory of deliberate social change, taking account of the stance and role of the change agent, the institutional forms involved, and the special areas of concern. *Schon*

**11.592 Deliberate Social Change in the Cities II (A)**

*Prereq.:* 11.11 or 11.25 or 11.57

*Year:* G (2)

*Arr.*

Seminar for students engaged in social-change projects, focused on problems encountered in carrying out these projects, on strategies of social change, and on aspects of theory of social change emerging from ongoing projects. *Schon*

**11.60 City Structure and Economic Development**

*Prereq.:* —

*Year:* U (1)

2-0-6

Economic, social, and technological factors which affect the functions and physical environment of the city and region; analytical techniques for evaluating urban, intrametropolitan, and interregional characteristics; an evaluation of the issues posed by national policy for urban and regional development.

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## URBAN STUDIES AND PLANNING

### 11.62 *Urban Development Patterns and Economic Growth (A)*

Prereq.: 11.60  
Year: G (2) 2-0-6

Designed for the urban planner and urban economist: background on our U. S. urban economy, the characteristics and significance of the postwar growth, the perspectives and potential in the next generation, and the expanding role of urban infrastructure in the optimization of resource use for the economy as a whole. Extensive readings, preparation of a quantitative analytical paper covering some phase of urban growth analysis and projection. (Not offered 1969-70.) Ganz

### 11.65 *Real Estate Economics*

Prereq.: 14.01T  
Year: U (1) 2-0-6

Social, political, industrial and economic factors affecting the location, construction, financing and marketing of real estate and buildings — with emphasis on the relationships between the interests of the planner, the architect and the developer-investor. Weisberg

### 11.66J *Urban Economics: Positive Analysis I (A)*

(Same subject as 14.572J)  
Prereq.: 14.03T or 14.04  
Year: G (2) 3-0-6

Economic analysis of urban areas in their regional setting, organized around the sources, characteristics, and implications of spatial concentration of economic activities. Consideration of both market and governmental forces. Location theory; spatial competition; general equilibrium models of interregional economic activity with emphasis on input-output and linear programming models; interregional transmission of economic fluctuations; metropolitan growth and development. Explicit attention to spatial factors affecting the demand for transportation services.

Urban Studies and Planning Staff, J. R. Harris

### 11.67J *Urban Economics: Positive Analysis II (A)*

(Same subject as 14.573J)  
Prereq.: 11.66J or 14.572J  
Year: G (1) 3-0-6

Continuation of 11.66J. The land use market and the spatial structure of the metropolitan community. Models of the metropolis. The housing market; demand and supply, growth, aging and urban renewal. The economics of race in the metropolitan area, the Model Cities Program. The urban transportation system and its problems. In each of these topics, emphasis on the resource allocation process, its efficiency, and sources of suboptimality. Rothenberg

### 11.68J *Urban Economics: Positive and Normative Analysis III (A)*

(Same subject as 14.574J)  
Prereq.: 11.67J or 14.573J  
Year: G (2) 3-0-6

Continuation of 11.67J. The nature and problems of government decision making in metropolitan areas. Urban-suburban relations: market and governmental interactions. Optimal and suboptimal government. Welfare economics and the normative theory of local public policy. Applied normative analysis: criteria for public expenditures; cost-benefit analysis. Examination of public policy issues in current urban problems: poverty, race, the spatial form of the city, optimal land use patterns, growth and renewal. Rothenberg

### 11.70 *Law of Land Use (A)*

Prereq.: 11.12  
Year: G (2) 2-0-6

The basis in constitutional, common, and statute law and decisions of regulation or taking of private property to accomplish public purposes; the balance between

public and private interests; zoning, urban renewal, and other plan implementation devices; study of leading court cases. Michelman

### 11.75 *Metropolitan Planning Administration (A)*

Prereq.: 11.12  
Year: G (2) 2-0-4

Methods and practices of planning and implementation; organization of planning agencies, relationships to government and private operations; techniques of administration. (Not offered 1969-70.)

### 11.80 *Theory of the Planning Process (A)*

Prereq.: 11.12  
Year: G (2) Arr.

Current theories and research in planning, planning organization and action, and the relationship of physical planning to the general theory and process of planning. Required papers and other exercises. (Registration limited.) Rodwin

### 11.81 *Theory of City Form (A)*

Prereq.: 11.12  
Year: G (2) 2-0-6

Seminar on the analysis of the functioning, effects, and implications of the general form of the urban physical environment. Effect of this form on basic human objectives. (Limited enrollment.)

### 11.85 *Seminar on Urban American History (A)*

Prereq.: 11.11, 11.50 or 11.60  
Year: G (2) 2-0-6

Readings and discussions about the emergence of the modern American metropolis and the transformation of selected institutions from roughly 1900 to the present. Consideration of the following topics, among others: the professionalization of the police, the bureaucratization of the schools, and the disintegration of mass transit. Choice of institutions to be studied upon consultation with the students and varying from term to term. (Limited enrollment; admission by consent of instructor.) Fogelson

### 11.90 *Methods of Research in City Planning*

Prereq.: 11.11  
Year: U (2) 2-0-6

Lectures and seminars on the treatment, organization, and validity of some data used by city planners; the use and limitations of some linear and non-linear analyses of activities in the city; urban models and simulations. Staff

### 11.905 *Practicum in Survey Research Methods*

Prereq.: —  
Year: G (1) Arr.

### 11.906 *Practicum in Survey Research Methods*

Prereq.: 11.905  
Year: G (2) Arr.

Interdisciplinary seminar with practical work and field experience, in conjunction with the Boston Survey Research Program of the M.I.T.-Harvard Joint Center for Urban Studies. Survey theory, methodology, and measurement and practice, for students seeking a thorough understanding of social survey research processes through intensive involvement in a major field undertaking. Axelrod

### 11.911 *Introduction to Information Processing*

Prereq.: —  
Year: G (1) 2-0-4

Basic principles of digital computers and programming languages. Practice in writing programs in algebraic and problem-oriented languages. Introduction to describing planners' problems as computational processes and programming a digital computer to solve them. Intended for students with no previous contact with computers. McMains

**11.912 Computer Systems Seminar (A)**

Prereq.: 11.20, 11.911

Year: G (2)

Arr.

Advanced discussion of existing computer systems and current research on new systems that help the planner to communicate with the machine. Discussion of the computer realization of mathematical models. Opportunity for the student to do individual research in the area of planning models or planner-machine communication.

Fleisher, McMains

**11.92 City Planning Research (A)**

Prereq.: —

Year: G (1, 2)

Arr.

Selected topics in city planning. Supervised study, with conferences, readings, and reports. No lectures. Staff

**11.93 Regional Planning Research (A)**

Prereq.: —

Year: G (1, 2)

Arr.

Selected topics in regional planning. Supervised study with conferences, readings, and reports. No lectures. Staff

**11.95 Preparation for Thesis (A)**

Prereq.: —

Year: G (1, 2)

Arr.

Selection of thesis subject, definition of method of approach, and preparation of preliminary thesis outline. Independent study, supplemented by frequent individual conferences with staff members. (Restricted to doctoral candidates.) Staff

**12.02 Geology II**

Prereq.: 12.01T

Year: U (2)

3-4-5

Further survey of the elements of geology: marine topography and sediments; development of landforms by moving water, wind, and ice; production, transportation, and deposition of sedimentary materials; sedimentary rocks; evolution of the earth and its atmosphere and ocean; geological development of the continents; isotopic and biologic methods of dating rocks. Laboratory work on fossils, sedimentary processes, and sedimentary rocks; laboratory case study of the development of the northern Appalachian mountain system. Three or four weekend days of field work. Naylor

**12.03 Geology III**

Prereq.: 12.02

Year: U (1)

3-4-5

Survey of rock structures and mechanics of rock deformation. Elementary concepts of plastic flow and fracture of materials with discussion of observed strains in all types of rocks in relation to mineral deposits, intrusion and metamorphism. Introduction to the geology of North America and survey of the important tectonic elements in other continental and oceanic areas. Laboratory work in map interpretation; five Saturdays of field work on mapping local structures. Brace

**12.04 Geology IV**

Prereq.: 12.01T

Year: U (2)

3-4-5

Evolution of plants and animals. Principles and methods of stratigraphy. Rock weathering, production of sedimentary materials. Sediment erosion, transportation, and deposition. Survey of modern depositional environments. Petrology of major sedimentary rock types: classification, composition, primary textures and structures. Lithification and diagenesis. Geologic occurrence of metallic and non-metallic mineral deposits. Laboratory work on fossils, sediments, sedimentary rocks and processes. Two weekend days of field trips to examine local sediments and sedimentary rocks. Southard

**12.051 Crystallography**

Prereq.: —

Year: U (1)

2-2-4

Introduction to the nature of crystalline matter. Patterns of atoms in crystals and how they are investigated. Crystal symmetry; point groups, crystal forms, space groups. Use of X-ray diffraction in the study of crystals. The rotating-crystal, Weissenberg, and precession methods. Modern methods of determining the arrangements of atoms in the cell, Fourier synthesis, the Patterson function, and refinement. Buerger, *Elementary Crystallography*; Buerger, *Contemporary Crystallography*. (Alternate years.) Buerger

**12.052 Theoretical Mineralogy**

Prereq.: 12.051

Year: U (2)

2-0-4

Introduction to the theory of the structure of crystals, and application of crystal structure concepts to crystallography and mineralogy, including elementary crystal chemistry, structures of the silicates, polymorphism and transformations, disordered structures, solid solution and segregate phase formation, crystal growth and habit, crystal imperfection and lineage structure, and plastic deformation of crystals. (Alternate years.) Buerger

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

**12.****Earth and Planetary Sciences****UNDERGRADUATE SUBJECTS****12.002 The Earth and the Planets**

Prereq.: —

Year: U (2)

2-0-4

Selected topics in the physics and chemistry of the earth and solar system. Dynamics of orbits, properties of the atmosphere surface, and interior of the planets including the earth. Interplanetary medium, planetary magnetic fields, solar wind, and interactions. General lecture and a specialized recitation meeting each week. Recitation as workshop for in-depth study in one of these areas: orbits, interiors, surfaces and atmospheres. Toksöz, Simmons

**12.01T Geology I**

Prereq.: 5.01, 8.02

Year: U (1)

3-4-5

Introduction to the elements of geology: structure of the crust and mantle; composition and evolution of the common crystalline rocks; mineralogy with emphasis on rock-forming silicates; construction and interpretation of geologic maps: structure of typical continental and oceanic areas. Laboratory work on rocks and minerals, geologic maps, and microscopic and X-ray methods. Three full days of field work. Wones

# Descriptions

EARTH AND PLANETARY SCIENCES

## 12.061 Petrology I

Prereq.: 12.01T

Year: U (1)

3-6-3

Principles and practice of optical crystallography by means of the immersion method of mineral identification. Application of X-ray powder diffraction to the rock-forming minerals. Introduction to the phase equilibria of silicate melts. Heinrich, *Microscopic Identification of Minerals*; Bloss, *Introduction to Optical Crystallography*; Turner and Verhoogen, *Igneous and Metamorphic Petrology*. Fairbairn, Wones

## 12.062 Petrology II

Prereq.: 12.061

Year: U (2)

2-6-4

Distribution, association, and origin of igneous and metamorphic rocks. Laboratory study of igneous and metamorphic rock-forming minerals with petrographic microscope. Turner and Verhoogen, *Igneous and Metamorphic Petrology*; Kerr, *Optical Mineralogy*; Williams, Turner and Gilbert, *Petrography*; Heinrich, *Microscopic Identification of Minerals*. Fairbairn

## 12.066 Analysis of Geological Materials

Prereq.: 12.01T

Year: U (2)

2-0-2

Introduction to instrumental techniques for the analysis of geologic materials. Topics on applications of X-ray spectrometry, X-ray diffraction, neutron activation analysis, atomic absorption spectrophotometry, mass spectrometry, optical emission spectrometry, electron-probe microanalysis, and chromatography. One of these techniques in detail and the others in outline form. (Enrollment limited to 12 students; admission only by permission of the instructor.) F. A. Frey

## 12.07 Paleontology

Prereq.: 12.02

Year: U (2)

3-6-3

Study of the plant and animal life of the earth through comparison of fossils and living organisms. Emphasis on use of the fossil record as a basis for paleogeographic and paleo-ecological reconstructions and stratigraphic interpretations. Lectures, laboratory work, and seashore field trips. Shrock and Twenhofel, *Principles of Invertebrate Paleontology*. (Alternate years.) Shrock

## 12.091-12.094 Special Problems

Prereq.: —

Year: U (1, 2)

Arr.

For students desiring reading or special laboratory or field work on geological or geophysical problems in sedimentology, petroleum geology, economic geology, paleontology, exploration geophysics, space physics, and other fields. Staff

## 12.111 Astronomy I

Prereq.: —

Year: U (1)

2-0-4

Introduction to the methods and principles of modern astronomy. Topics: astronomical coordinate systems, time, and theoretical principles of celestial navigation; solar system astronomy, including the earth as a planet, its motions; the moon, planets and satellites; meteors and comets, meteoritics; time scale of the solar system, and a review of theories of its origin; observable properties of the stars and stellar classification. At least one trip to an observatory for students. Some attention to instrumentation used in modern astrophysics. 12.113 recommended as a supplement for students seriously interested in observational astronomy. Motz and Duveen, *Essentials of Astronomy*. Pinson

## 12.112 Astronomy II

Prereq.: —

Year: U (2)

2-0-4

Topics: atmospheres of the sun and stars; stellar radii and masses; stellar interiors; binary systems; intrinsic variable stars; peculiar stars; stellar motions; nebulae and stellar clusters; the interstellar medium; stellar evolution; galaxies and models of the universe and the cosmic time scale; quasistellar objects; review of theories of origin of the universe. Some attention to instrumentation used in modern astrophysics. Motz and Duveen, *Essentials of Astronomy*. Pinson

## 12.113 Workshop in Astronomy

Prereq.: 12.111

Year: U (1, 2)

0-8-0

Workshop in observational astronomy conducted every Friday night at Whitin Observatory, Wellesley College. Instruction in operating the telescopes, taking celestial photographs, using a spectrohelioscope; exercises using variable star data, and exercises with stellar spectra. Pinson

## 12.131J Planetary Physics and Chemistry I

(Same subject as 5.121J and 8.291J)

Prereq.: 8.02, 18.02

Year: U (1)

3-0-9

## 12.132J Planetary Physics and Chemistry II

(Same subject as 5.122J and 8.292J)

Prereq.: 8.02, 18.02

Year: U (2)

3-0-9

Study of the planetary system: evolution, composition, present configuration, dynamics, interiors, surfaces, atmospheres, and magnetospheres of the planets and, where appropriate, similar aspects of the satellites, asteroids, and comets. Stress on use of space-probes and modern ground-based optical, radio and radar techniques for diverse planetary observations and the interpretations. First term: a general description of the solar system and its origin and a comprehensive discussion of the outer planets. Second term: solar system dynamics, the interplanetary medium, and the interiors, surfaces, and atmospheres of the inner planets. I. I. Shapiro, J. S. Lewis

## 12.21 Physical Oceanography

Prereq.: 8.02, 18.034

Year: U (1)

3-0-9

Introduction to the physical processes and properties of the oceans; their structure, circulations, and relationships to the atmosphere and solid earth. Similar to 19.83. (Not offered 1969-70.) Wunsch

## GRADUATE SUBJECTS

### Geology and Geophysics

## 12.301-12.304 Seminar in Geology and Geochemistry (A)

Prereq.: —

Year: G (1 or 2)

Arr.

Problems of current interest in geology and geochemistry. Subject matter varying from term to term.

Staff (12.301, 12.303);  
Naylor (12.302, 12.304)

## 12.32 Sedimentology and Sediment Movement (A)

Prereq.: 12.04

Year: G (1)

3-0-9

Aspects of turbulent flow mechanics relevant to sediment movement. Modes and mechanics of sediment erosion, transportation, and deposition. Nature and origin of terrigenous sedimentary material. Survey of modern depositional environments. Primary structures and textures in recent and ancient sediments. Southard

- 12.325 Sedimentology Seminar (A)**  
 Prereq.: 12.32  
 Year: G (1 or 2) 2-0-4  
 Discussion of current research and problems in sedimentology, sedimentary petrology, and sediment transport mechanics. Content varying from term to term.  
 Southard
- 12.329 Research in Sedimentology or Sedimentary Petrology (A)**  
 Prereq.: —  
 Year: G (1 or 2) Arr.  
 Supervised research on a problem in sedimentology or sedimentary petrology. Staff
- 12.339 Stratigraphic Research (A)**  
 Prereq.: —  
 Year: G (1 or 2) Arr.  
 Supervised research on a stratigraphic problem. Shrock
- 12.34 Special Topics in Petrology (A)**  
 Prereq.: —  
 Year: G (1 or 2) Arr.  
 Supervised studies in the field of petrology. Fairbairn
- 12.35T Mechanical Behavior of Crystalline Material (A)**  
 Prereq.: 8.03, 18.034  
 Year: G (2) 3-0-9  
 Review of symmetry and bonding in crystals. Introduction to cartesian tensors. Review of certain tensor and non-tensor properties of perfect crystals, including elastic, thermal and optical properties, cleavage and fracture, twin and translation gliding and surface properties. Introduction to dislocations and other defects, particularly in rock-forming minerals. Derivation of behavior of aggregates from single crystal behavior with application to rocks under geologic conditions. Nye, *Physical Properties of Crystals*. Brace
- 12.355 Seminar in Structural Geology (A)**  
 Prereq.: 12.35T  
 Year: G (1 or 2) 2-0-4  
 Discussion of current research or advanced topics in tectonics, rock mechanics or experimental structural geology. Brace
- 12.359 Structural Research (A)**  
 Prereq.: —  
 Year: G (1 or 2) Arr.  
 Supervised research on a structural problem. Brace
- 12.38 Special Topics in Experimental Petrology (A)**  
 Prereq.: —  
 Year: G (1 or 2) Arr.  
 Supervised studies in experimental petrology or geochemistry. Wones
- 12.381 Experimental Petrology (A)**  
 Prereq.: 5.60, 12.062  
 Year: G (1) 3-0-9  
 Application of homogeneous and heterogeneous equilibria to rock forming systems. Methods of experimental petrology, and application to the development of igneous rocks. Field trips. (*Alternate years. Not offered 1959-70.*)  
 Wones
- 12.382 Rock Forming Minerals (A)**  
 Prereq.: 5.60, 12.062  
 Year: G (2) 4-4-4  
 Application of mineralogy to petrology. Review of the mineralogy of the rock-forming oxides and silicates. Use of mineral equilibria in placing constraints on petrological processes. Laboratory work in determinative mineralogy using X-ray and optical techniques. Emphasis on igneous and metamorphic rocks. Three field trips required.  
 Wones
- 12.40 Chemistry of the Earth (A)**  
 Prereq.: 5.60, 18.034  
 Year: G (2) 3-0-6  
 Principles of physical geochemistry. Planetary origin and differentiation. Solid and melt phase equilibria, trace element partitioning and generation of magma types. Development of the crust, atmosphere and oceans. Major chemical and geological distributions. Denbigh, *Chemical Equilibrium*. Hurley
- 12.411 Isotope Geology (A)**  
 Prereq.: 8.04, 12.01T  
 Year: G (1) 3-0-6  
 Applications of the variations in the relative abundance of radiogenic and stable isotopes to geologic problems. Topics including geochronology, studies of petrogenesis and the source of ore mineralizations, geologic processes that can be traced by stable isotope fractionations, techniques, and instrument design. (*Alternate years.*) Hurley
- 12.418 Research in Isotope Geology (A)**  
 Prereq.: —  
 Year: G (1 or 2) Arr.  
 Supervised research on a problem in isotope geology. Hurley
- 12.45 Geochemistry (A)**  
 Prereq.: 5.60  
 Year: G (1) 3-0-6  
 Study of the distribution of the elements. Application of modern chemical theory to the location of elements in geologic systems, thorough discussion of the existing data of geochemistry, and application of geochemical data to general geologic problems. F. A. Frey
- 12.453 Marine Geochemistry (A)**  
 Prereq.: —  
 Year: G (1) 3-0-6  
 Study of the biological, chemical, and geological parameters in marine sediments in the ocean. Emphasis on the interactions of the aforementioned forces in the sea and sediments and the individual geochemical end products they yield. (*Restricted to students with undergraduate major in chemistry, biology or geology.*) Degens (Woods Hole Staff)
- 12.458 Geochemical Research (A)**  
 Prereq.: —  
 Year: G (1 or 2) Arr.  
 Supervised research on a problem in geochemistry. Staff
- 12.465 Meteoritics Seminar (A)**  
 Prereq.: —  
 Year: G (1 or 2) Arr.  
 Discussion of current research and advanced topics in meteoritics, including tektite study, with special emphasis on problems of genesis. (*Alternate years.*) Pinson
- 12.468 Research in Meteoritics and Geochemistry (A)**  
 Prereq.: —  
 Year: G (1 or 2) Arr.  
 Supervised research, especially of an analytical nature. Pinson

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

EARTH AND PLANETARY SCIENCES

## Geophysics and Planetary Physics

- 12.501 Physics of the Earth (A)**  
Prereq.: 8.03, 18.034  
Year: G (1) 3-0-6  
Survey of the earth's interior, thermal regime, composition, structure, elastic and inelastic properties, equation of state as revealed by physical measurements on the surface and on laboratory samples. Reviews results of heat flow, seismology, earth gravity and magnetism, high-pressure geophysics and regional geophysics.  
Simmons, Press
- 12.502 Interpretation Methods in Regional Geophysics (A)**  
Prereq.: —  
Year: G (2) 3-0-6  
Review of methods of data acquisition and analysis in applied and regional geophysics. Appropriate for geologists and geophysicists interested in the solution of geological problems by geophysical field methods. Grant and West, *Interpretation Theory in Applied Geophysics*. Biehler
- 12.51T Geoelectricity and Geomagnetism (A)**  
Prereq.: 8.03, 18.06  
Year: G (2) 3-0-9  
Survey of the electric, magnetic and electromagnetic properties and processes in the earth's environment. The plasma environment of the earth's magnetosphere and ionosphere and electromagnetic wave and particle phenomena occurring therein. Electric properties of the earth's interior. Magnetohydrodynamic origin of the magnetic fields of the earth and other astronomical bodies.  
Madden
- 12.52iT Elements of Seismology (A)**  
Prereq.: 18.05  
Year: G (1) 3-0-9  
A basic subject in seismology and the utilization of seismic waves for the study of the earth's interior. Introduction of techniques necessary for understanding of elastic wave propagation in layered media, and dispersion. Seismic ray theory and the interpretation of travel times. Surface wave dispersion and free oscillations of the earth. Seismicity, magnitude, energy. Structure of the earth's interior.  
Toköz
- 12.522 Advanced Seismology (A)**  
Prereq.: 12.521T, 18.27  
Year: G (2) 3-0-9  
Advanced methods of theoretical seismology; the general properties of seismic waveforms; separate discussions on sources and media; head waves, normal modes, leaky modes, and exact synthetic seismograms in layered media; seismic scattering due to lateral heterogeneity of the earth; near-field and far-field of seismic radiation from elastic dislocations; determination of earthquake source parameters.  
Aki
- 12.531 Analytic Methods in Applied Geophysics I (A)**  
Prereq.: 18.15  
Year: G (1) 3-0-6
- 12.532 Analytic Methods in Applied Geophysics II (A)**  
Prereq.: 18.15  
Year: G (2) 3-0-6  
Advanced topics in the analysis and interpretation of geophysical phenomena, including such problems as multilayered media, two-dimensional inhomogeneities, inverse-boundary-value problems, and use of time series analysis in the treatment of current geophysical problems. (Alternate years.)  
Madden
- 12.581-12.588 Seminar in Geophysics (A)**  
Prereq.: —  
Year: G (1 or 2) Arr.  
Problems of current interest in geophysics; subject matter varying from term to term. Staff (12.581, 12.582); Aki, Toköz (12.583); Madden (12.584); Press, Simmons (12.585); Biehler (12.586); Staff (12.587); I. I. Shapiro (12.588)
- 12.591-12.599 Special Problems in Geophysics (A)**  
Prereq.: —  
Year: G (1 or 2) Arr.  
For graduate students desiring to perform special investigations, special laboratory work, or special field work in geophysics. Staff (12.591, 12.592); Aki, Toköz (12.593); Madden (12.594); Press, Simmons (12.595); Biehler (12.596); Staff (12.597); I. I. Shapiro (12.598); McCord (12.599)
- 12.613J Dynamical Astronomy (A)**  
(Same subject as 8.953J and 16.441J)  
Prereq.: 8.03, 18.05  
Year: G (1) 3-0-9  
Astronomical background, central orbits, potential theory, the two-body problem, orbital elements and coordinate systems, orbit determination, three- and n-body problems, perturbation theory and techniques of computation, observation and statistical theory of data analysis. Applications to the motion of planets, natural and artificial satellites. Counselman, I. I. Shapiro, Wrigley
- 12.614J Dynamical Problems of the Solar System (A)**  
(Same subject as 8.954J and 16.442J)  
Prereq.: 12.613J  
Year: G (2) 3-0-9  
Introduction to current research in solar systems dynamics, tidal friction, spin and orbital resonances, evolution of the earth-moon system, and tests of gravitational theories.  
Counselman, I. I. Shapiro, Wrigley
- 12.621 Methods of Planetary Astronomy (A)**  
Prereq.: —  
Year: G (1) 3-2-7  
Instrumentation and techniques used to observe solar system bodies at visible, infrared and radio wavelengths using ground-based telescopes. Optical and radio telescopes, detectors, photometers, spectrometers and data processing systems. Delay-Doppler mapping, interferometry, optical and infrared photometry, and other special topics. Special observational problems undertaken by the student. (Consent of instructor required. Alternate years. Not offered 1969-70.) McCord, I. I. Shapiro
- 12.623 Planetary Surfaces (A)**  
Prereq.: —  
Year: G (1) 3-0-9  
Observational evidence pertaining to the surface geology and geophysics of the moon, Mars, Mercury, and the Galilean satellites; also brief consideration of the probable surface conditions on other planets. Discussion of both earth-based and spacecraft-borne experiments. Interpretation of available data in terms of the structure of the surface and the condition and composition of the surface material of these bodies. (Consent of instructor required. Alternate years.)  
McCord, McGetchin
- 12.631J Planetary Atmospheres (A)**  
(Same subject as 5.125J)  
Prereq.: —  
Year: G (1) 3-0-6  
Discussion in light of recent spectroscopic and space-probe data of compositions, structures, and origins of the atmospheres of the planets. Thermodynamics of atmospheric structure, cloud precipitation, and mineral buffers of pressures of reactive gases. Photolysis; escape rates,

mineralogy of surface rocks. Chemical behavior of a solar-composition atmosphere; the solar nebula, the interiors of the major planets. Models for the origin and development of planetary atmospheres. (*Permission of instructor required. Alternate years. Not offered 1969-70.*)  
*J. S. Lewis*

**12.636J Current Research in Meteoritics (A)**  
 (Same subject as 5.129J)

*Prereq.:* —  
*Year:* G (2) *Arr.*  
 Discussion of current research and special problems in meteoritics. Composition and structure of important classes of meteorites; meteorite dating methods and their results; thermodynamics of meteoritic minerals. Isotopic chemistry of meteoritic material. Evidence concerning the origin of meteorite classes and proposed genetic relationships. Conditions in the solar nebular. (*Alternate years.*)  
*J. S. Lewis*

**12.691-12.699 Special Problems in Planetary Physics (A)**

*Prereq.:* —  
*Year:* G (1 or 2) *Arr.*  
 For graduate students desiring to perform special investigations, special laboratory work, or special field work in planetary physics. *Staff*

**Oceanography**

**12.71 Marine Acoustics (A)**

*Prereq.:* 18.06  
*Year:* G (2) 3-0-6  
 Marine propagation media, boundary conditions, modern measurement techniques, ray and mode analysis, normal mode theory, stochastic models. Tolstoy and Clay, *Ocean Acoustics*; Prokosky, *Waves in Layered Media*; Albers, *Underwater Acoustics, I and II.*  
*Hays (Woods Hole Staff)*

**12.73 Marine Geodesy (A)**

*Prereq.:* 12.21  
*Year:* G (1 or 2) 2-0-7  
 Concepts of classical and modern geodesy considered in relation to physical oceanographic problems; the definition of the geoid at sea by astro-geodetic, gravimetric and satellite techniques; the relief of the physical sea surface with reference to the geoid. (*Admission by permission of instructor only.*) *von Arx*

**12.81 Waves and Tides (A)**

*Prereq.:* 18.60  
*Year:* G (1) 3-0-9  
 Aspects of tide and wave motion in the sea and atmosphere. Derivation of the tide producing forces. Hydrostatic and non-hydrostatic approximations. Oceanic wave motions as examples of geophysical time series; stochastic surfaces, prediction, spectra and bi-spectra, filtering, etc. Content varying from year to year.  
*Wunsch*

**12.812 Physical Properties of Sea Water (A)**

*Prereq.:* 18.60  
*Year:* G (2) 3-0-6  
 Equation of state. Thermodynamic potentials. Colligative properties. Equilibria. Diffusion potentials. Energy transformations of a sea water system. (*Given at Woods Hole Oceanographic Institution.*)  
*Fofonoff (Woods Hole Staff)*

**12.815 Seminar in Physical Oceanography (A)**

*Prereq.:* 12.21  
*Year:* G (1, 2) 2-0-7  
 Reading and discussion of classical and contemporary books and papers having relevance to the marine aspects of earth science. Varying scope and content to meet the special needs and interests of the participants. *von Arx*

**12.829 Research in Chemical Oceanography (A)**

*Prereq.:* —  
*Year:* G (1 or 2) *Arr.*  
 Supervised research on a problem in chemical oceanography.

**12.891-12.899 Seminar in Oceanography (A)**

*Prereq.:* —  
*Year:* G (1 or 2) *Arr.*  
 Topics in marine geophysics, physical, dynamical and chemical oceanography. Content varying from term to term. *Staff*

**12.901-12.909 Special Problems in Oceanography (A)**

*Prereq.:* —  
*Year:* G (1 or 2) *Arr.*  
 For graduate students desiring to perform special investigations, special laboratory work or special field work in oceanography.  
*von Arx (12.901); — (12.902); Wunsch (12.903); Biehler, Press, Simmons (12.904); Staff (12.905-12.907); Woods Hole Oceanographic Institution Staff (12.908, 12.909)*

**12.91 Research in Physical Oceanography (A)**

*Prereq.:* —  
*Year:* G (1, 2) *Arr.*  
 For graduate students pursuing a special investigation of some physical aspect of the oceans. *Staff*

13.

**Naval Architecture and Marine Engineering**

**13.00 Introduction to Marine Hydrodynamics**

*Prereq.:* 1.05 or 2.201  
*Year:* U (1) 3-1-8  
 Hydrostatics; buoyancy and stability of waterborne vehicles in intact and partially waterborne conditions; dynamics and hydrodynamics applied to resistance and propulsion of ships; wave hydrodynamics; propellers and interaction effects between propeller and vehicle; equations of motion and stability indices for maneuvering of ships and submarines; definitive maneuvers; hydrodynamics of control surfaces; ship motions in regular and irregular seas. Laboratory exercises in ship model towing tank and variable pressure water tunnel. *Cummings*

**13.01 Applied Hydrostatics**

*Prereq.:* —  
*Year:* G (S) 1-7-2  
 Elementary principles of naval ship design and statics of naval architecture. Work in the project room on fairing of naval ship lines, calculations for and drawing of displacement and other curves, cross curves of stability, curves of statical stability and floodable length curves for a naval ship from preliminary design data. (*Primarily for students in Course XIII-A; others admitted with permission of instructor.*) *Reed*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

NAVAL ARCHITECTURE AND MARINE ENGINEERING

## 13.02T *Marine Hydrodynamics (A)*

*Prereq.:* 1.05 or 1.612 or 2.201; 13.00 or 13.01; 18.05

*Year:* G (1, 2) 3-1-8

Development of hydrodynamic principles and their application to marine vehicles. Dimensional analysis, similitude, and model testing. Solutions of the Navier-Stokes equations and boundary-layer approximations. Water waves, ship-generated waves, and motions in a seaway. Lifting surfaces, thin-wing theory, cavitation, and propeller theory. Maneuvering and control of vehicles in calm water.

*J. N. Newman*

## 13.03 *Advanced Hydromechanics of Ship Design (A)*

*Prereq.:* 13.00 or 13.02T; 18.05

*Year:* G (2) 3-0-6

Advanced work in the application of theoretical and experimental hydrodynamics to the solution of marine vehicle design problems in the area of resistance, powering, steering, motion response, and control. Advanced considerations of motion stability and control and the behavior of uncontrolled and controlled ships in waves and rough seas. Discussion of modern model testing and computational techniques, and recent research and progress in marine vehicle dynamics.

*Abkowitz*

## 13.04T *Two-Dimensional Hydrofoil Theory (A)*

*Prereq.:* 13.02T, 18.06

*Year:* G (1) 3-0-9

Thin hydrofoil theory: lifting and thickness problems, conformal mapping and singular integral equation techniques, treatment of leading edge non-uniformity by matched asymptotic expansions and by computer technique based on conformal mapping. Design of high speed subcavitating sections. Supercavitating hydrofoil theory. Free surface effects, planing problem. Unsteady subcavitating and supercavitating hydrofoil theory. Demonstration experiments in variable pressure water tunnel.

*Kerwin, Leehey*

## 13.05T *Three-Dimensional Hydrofoil Theory (A)*

*Prereq.:* 13.04T

*Year:* G (2) 3-0-9

Lifting line and lifting surface theory by matched asymptotic expansions and computer techniques based on singularity distributions. Topics in propeller theory, including propeller lifting-line and lifting-surface theory and applications to the design of homogeneous flow and wake adapted propellers. Selection of topics in three-dimensional theory from the following: free surface effects and planing, supercavitating hydrofoils and propellers, unsteady flow about hydrofoils and propellers, hydroelastic and vibration effects. Demonstration experiments in variable pressure water tunnel.

*Kerwin, Leehey*

## 13.07T *Free Surface Hydrodynamics (A)*

*Prereq.:* 18.06

*Year:* G (1) 3-0-6

Water wave phenomena pertinent to problems in naval architecture and ocean engineering. Generation, propagation, and diffraction of plane progressive waves. Exciting and restoring forces on floating and submerged bodies. Ship waves and wave resistance. Selected topics of interest in non-linear wave propagation and internal waves. (Some background in water waves assumed, equivalent to that covered in 13.02T.)

*J. N. Newman*

## 13.08 *Stability and Motion Control of Ocean Vehicles (A)*

*Prereq.:* 13.00 or 13.02T; 18.05

*Year:* G (1) 3-0-6

Development of the equations of motion in six degrees of freedom and the formulation of mathematical models for

ocean vehicle dynamics. Concepts of automatic control and the amplification of the model to include the effects of such controls and the various excitations and restraints resulting from an ocean environment or system arrangement. Discussion of the relationships between the mathematical model and physical reality. Solution of the equations for stability determination and for various important vehicle motion responses in a sea environment. Analysis and discussion, by the case study method, of the motion evaluation and reduction for a variety of types of ocean vehicles in their particular environment, such as hydrofoil boats, surface effect ships, buoys, towed and moored bodies, surface ships, drilling platforms, flipships, submersibles, submarines, and others.

*Abkowitz*

## 13.10T *Introduction to Structural Mechanics*

*Prereq.:* 2.01 or 2.015

*Year:* U (1) 3-0-6

Selected structural mechanics concepts applicable to marine structures: statically determinate structures, principle of superposition, Castigliano's theorems, Betti's law, Maxwell's law, introduction to statically indeterminate structures, force and displacement methods. Mohr's circles of stress and strain, failure theories. Buckling of columns, large deflection theory of columns. Stationary potential energy, Rayleigh Ritz method, beam-column. Stress concentration, curved bars, cylindrical and spherical shells. Plastic analysis of beams.

*Mansour*

## 13.11T *Theory of Plates and Shells (A)*

*Prereq.:* 2.01, 18.034

*Year:* G (1) 3-0-6

General theory of isotropic plates, circular and rectangular plates, influence of large deflections, orthotropic plates, stability of rectangular plates, thermal effects, discussion of applicability to the design of typical ship structures. General theory of isotropic shells. The behavior of typical shells encountered in ocean engineering structures, such as cylindrical, conical, and spherical shells. Curved tubes. Shell intersections of the types encountered in oil drilling platforms, etc. Buckling of shells.

*N. Jones*

## 13.12T *Marine Structures (A)*

*Prereq.:* 13.10T, 13.30

*Year:* G (2) 3-0-6

Two-dimensional stress analysis, hull primary response using stress function method, primary longitudinal and girth stresses, shear stresses and deflection. Torsion loading on ships, hull girder response to primary torsion. Oscillation loads and inertia forces. Linear shear lag theory, stress function method, effective breadth concept. Deck houses and superstructures effect on primary bending. Ship transverse strength and elastic analysis of frames using matrix methods. Effect of shear and axial forces. Basic concept of finite element method and application on marine structures. Statistics of risk and failure. (Background in ship loading conditions and resulting bending moments assumed.)

*Mansour*

## 13.13T *Plastic Analysis of Structures (A)*

*Prereq.:* 13.10T, 18.034

*Year:* G (2) 3-0-6

Elastic-plastic behavior of thick-walled cylinder. Yield criteria. Drucker's stability postulate, normality and convexity. Limit theorems. Static plastic collapse of beams, plates, shells, shell intersections, and other structures encountered frequently in ocean engineering and naval architecture. Discussion of relevant experimental work. Influence of finite deflections. Creep behavior. Minimum weight design. Shakedown theorem. General theorems for the dynamic behavior of rigid-plastic

structures. Theoretical and experimental behavior of beams, plates, and shells when subjected to dynamic loads of an intensity sufficient to cause plastic flow.  
*N. Jones*

**13.151J Welding Engineering (A)**

(Same subject as 3.36J)

Prereq.: 3.13 or 3.141

Year: G (1)

3-0-6

Detailed study of processing variables involved in joining materials by welding, brazing, and adhesive bonding. Synthesis of elementary physical phenomena such as transient heat flow, phase transformations, and dimensional changes into the complex over-all reactions associated with joining. Testing, inspection, and properties of finished joints. Laboratory demonstrations of arc; electron beam, resistance, and other electric welding processes.  
*Masubuchi*

**13.161J Properties of Metals**

(Same subject as 3.701J)

Prereq.: —

Year: G (2)

4-1-6

Properties of metals with reference to materials used in ship construction. Microstructure, processing, heat treatment, joining and corrosion resistance of non-ferrous and ferrous metals. (Primarily for selected officers of the U.S. Navy and Coast Guard.)  
*Masubuchi, Powell*

**13.20 Energy Conversion Systems and Components**

Prereq.: 2.01, 2.201, 2.403

Year: U (2)

4-0-8

Energy conversion devices and systems of types applicable to ships and ocean engineering vehicles, involving thermal, mechanical, hydraulic, and electrical machinery; interaction of coupled devices under steady-state and transient conditions; optimization principles.  
*Powell*

**13.21 Ship Propulsion (A)**

Prereq.: 2.403, 2.54

Year: G (1)

2-0-4

Critical examination of ship propulsion requirements and the machinery systems and components used to satisfy them. Design and analysis projects on a professional level. This subject together with 13.24 represents substantially the material covered in 13.22.  
*Powell, Reed*

**13.22 Naval Ship Propulsion (A)**

Prereq.: 2.402, 2.54

Year: G (1)

4-2-6

Critical examination of naval ship propulsion requirements for the design of systems and components. Selection of propulsion devices and system parameters to satisfy ship performance requirements or demonstrate feasibility. Optimization of propulsion system parameters on the basis of minimum weight or other constraints. Design and analysis projects and calculation specially selected to stimulate professional application of engineering fundamentals. (Primarily for students in Course XIII-A; others admitted with permission of instructor.)  
*Reed, Powell*

**13.23 Propulsion System Reliability and Control (A)**

Prereq.: 6.28 or 13.60 or 18.10 or 18.18

Year: G (2)

3-0-6

Application of statistical and operations research methods to complex system reliability. Classical constant component failure rate models, systems with component interaction, wear, environmental effects, resulting in time- and wear-dependent failure rates. Markov models, systems availability, preventative and corrective maintenance scheduling. Dynamics and control of marine power plants.  
*Frankel*

**13.24 Propulsion Hydrodynamics (A)**

Prereq.: 1.05 or 2.201; 13.00 or 13.02T

Year: G (1)

2-0-4

Propulsion devices, particularly marine propellers, similitude and related selection parameters, interaction between propulsion and vehicle, momentum and energy considerations, extremals and optimization, cavitation effects, and special aspects of marine propulsion devices, including unsteady and vibratory considerations. (Not for students taking 13.22.)  
*Powell*

**13.30 Ship Structural Analysis and Design**

Prereq.: 2.01, 13.00

Year: U (1)

3-3-6

General and local structural reactions of marine vehicles to their environment including consideration of materials, structural configurations, modes of failure, elastic and plastic instability, and elementary plate theory. Integration and optimization of primary longitudinal structure. Midship section design project.  
*J. H. Evans*

**13.32 Ocean Engineering Structures (A)**

Prereq.: 2.01

Year: G (1)

3-0-6

Seminar on the structural design of semi-submerged mobile drilling platforms, bottom supported towers, submarine vehicles, bottom habitations and stayed structures. Brief treatment of the evaluation of towing, mooring, wave, jacking and bottom suction loads needed for the structural design of these vehicles and platforms. Configuration optimization of pressure chamber structures, moorings, buoy systems and anchoring devices. Emphasis on selection of materials.  
*J. H. Evans*

**13.34 Ship Structural Design I (A)**

Prereq.: 13.12T

Year: G (1)

0-5-0

Determination of load distribution on the hull of surface ship types and development of optimized primary longitudinal structure.  
*J. H. Evans*

**13.36 Ocean Engineering Structural Design (A)**

Prereq.: 13.32

Year: G (2)

0-5-0

Development of a stayed antenna mast design and the optimum mooring trajectory to suit specific performance requirements. Manual analysis of a simple offshore platform space frame with computer solution verification. Design and analysis of stiffened cylindrical shells under external pressure.  
*J. H. Evans*

**13.39 Analysis of Techniques for Fabricating Structures (A)**

Prereq.: 13.151J

Year: G (2)

2-0-4

Analysis of problems related to the fabrication of structures, such as ships, aircrafts, rockets, pressure vessels, buildings, and ocean engineering structures by various joining processes including welding, riveting, and adhesive bonding. Discussion of such problem areas as fracture characteristics of welded structures; residual stress, distortion, and stress relieving; advanced welding metallurgy; and non-destructive testing of structural welds. Laboratory demonstrations of some tests.  
*Masubuchi*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

NAVAL ARCHITECTURE AND MARINE ENGINEERING

## 13.40T *Introductory Ship Design*

Prereq.: 13.00, 13.30

Year: U (2)

2-4-3

Engineering and economic principles involved in the selection of dimensions and coefficients of commercial ships; design of hull form, internal arrangements, mid-ship section, and estimation of performance criteria in a comprehensive design exercise. *Keil*

## 13.41 *Principles of Ship Design (A)*

Prereq.: 13.00 or 13.02T; 13.01; 13.12T or 13.30

Year: G (1)

2-4-5

Ship in context of a larger system; formal optimization procedures applied to ship design; assumption of subsystems sufficiency; mathematical model of ship design process; engineering, economic and military principles governing selection of dimensions and coefficients of commercial and combatant ships and submarines; design of hull form; principles governing internal subdivision for maximum survivability; influence of hull form and dimension selection on operability in rough seas. Design exercise in application of principles. (Not recommended for students who have taken 13.40T.) *Keil*

## 13.42 *Design of a Waterborne Vehicle (A)*

Prereq.: 13.41

Year: G (2)

Arr.

Determination of performance criteria for a waterborne vehicle or platform based on an arbitrary set of system mission requirements established by the student in consultation with instructor. Preparation of the preliminary design of the vehicle or the floating platform fulfilling the selected performance criteria. Participation by several students in a single project encouraged. *Horn, Reed*

## 13.43 *Naval Ship-System Design I (A)*

Prereq.: 13.02T

Year: G (S)

3-0-6

Principles involved in the design of selected hull, electrical, machinery and weapon systems for naval ships and their influence on the configuration and arrangement of ships. (Primarily for students in Course XIII-A; others admitted with permission of instructor.) *Horn*

## 13.44 *Naval Ship-System Design II (RA)*

Prereq.: 13.43

Year: G (1)

0-5-0

Analyses of problems involved in the design of naval ship systems and their incorporation in a ship. Preparation of drawings to reflect the results of these studies. (Restricted to selected officers of the U.S. Navy and Coast Guard.) *Horn, Reed*

## 13.45 *Principles of Naval Ship Design (RA)*

Prereq.: 13.43

Year: G (1)

3-0-6

Fundamental considerations in selecting and providing the military features of naval ships. (Restricted to selected officers of the U.S. Navy and Coast Guard.) *Horn*

## 13.46 *Conceptual Design of Naval Ships (RA)*

Prereq.: 13.41, 13.43, 13.45

Year: G (2)

0-9-3

Project-type studies, including preparation of necessary drawings and calculations to support formulation and preliminary design of naval ships. (Restricted to selected officers of the U.S. Navy and Coast Guard.) *Horn, Reed*

## 13.47J *Special Studies in Systems Engineering (A)*

(Same subject as 1.16J, 2.191J, 6.604J, 17.818J)

Prereq.: 13.20, 13.41, 13.60

Year: G (2)

2-4-6

Introduction to basic techniques employed in planning and design of complex systems. Detailed design of sub-

systems by individual student groups with emphasis upon use of parametric design principles in arriving at suitable tradeoffs between subsystems. Supplementing lectures covering general principles of the operational complex and subsystems by guest lecturers. The particular operational complex chosen for each term to be announced before start of the term. Students encouraged to discuss subject with staff prior to registration. (Previous projects: Group 1 — integrated urban transportation system. Group 2 — manned satellite inspection and retrieval system.) *Frankel, Baumann, Seifert, R. C. Wood*

## 13.50 *Computer Applications to Marine Problems*

Prereq.: 18.05

Year: G (2)

2-2-4

Steps required in the development of useable computer programs for the solution of engineering problems including problem definition, numerical analysis, program organization, FORTRAN IV programming, M.I.T. Information Processing Center operating procedures, development of program tests, debugging and program documentation. Assigned projects and lectures based on realistic problems in naval architecture and marine engineering selected to illustrate many of the advantages and difficulties encountered in computer applications. (Primarily for seniors and graduate students in naval architecture and marine engineering; others admitted by permission of the instructor.) *Kerwin, Cummings*

## 13.51 *Computer Systems for Naval Architecture and Marine Engineering (A)*

Prereq.: 1.151 or 2.101 or 3.73 or 6.00 or 13.50

Year: G (1)

2-0-4

Principles of computer systems and their application to ship design and construction. Role played by various types of equipment in a system; program definition and organization; principles of compilers, interpreters, monitor systems, and problem oriented languages. Translation of functional requirements, file design, data control and supporting systems in the context of naval architecture, considering broadly based applications in preliminary design, machinery, structures and fabrication, and construction management. Review of systems currently under development. *Romberg*

## 13.60 *Application of Operational Methods*

Prereq.: 18.034

Year: U (1)

4-0-8

Elementary probability theory and statistics. Linear, non-linear, and dynamic programming. Inventory control, game theory, and queuing. Flow graphs and elementary control theory. Methods of applications to transportation, distribution, and marine design problems. Shipping system analysis, including scheduling and flow procedures, decision strategies, and information search. *Frankel*

## 13.61 *Decision Processes in Ship Operation and Construction (A)*

Prereq.: 6.28 or 13.60 or 18.10; 13.00; 13.20; 13.30; 14.01T

Year: G (2)

3-0-6

Development of techniques which optimize decisions in the face of uncertainty on a long-term basis. Analysis of legal, financial, assurance, political, trade, labor, and administrative factors influencing the shipping venture. Routing and scheduling. Bayesian statistics and decision theory. Information flow and system response prediction. Critical path and networks. Integration of transportation systems. *Frankel*

## 13.62 *Shipping Economics (A)*

Prereq.: 13.00, 13.20, 13.40T

Year: G (2)

3-0-6

Economic aspects of ship operation and design, including

application of engineering economic principles to the evaluation of shipping enterprises as systems and their components. Principles of optimization and semi-analytical techniques applicable thereto. Students with a background in transportation engineering who lack prerequisites may apply to the instructor for admission.

Powell

**13.64 Hydrospace Vehicles**

Prereq.: —

Year: U (2)

2-0-4

Distinction between user performance criteria and engineering performance criteria that are common to all vehicle types. Development from basic principles of the concepts of buoyancy, hydrodynamic lift, hydrodynamic drag, propulsor thrust and scaling laws as applied to surface ships, submarines, dirigibles, airplanes, hydrofoil craft, planing craft and air-cushion vehicles. Comparison of the most significant performance criteria among these different vehicle types as well as evaluation of the effect of vehicle size, and speed and fluid density on these performance criteria. Impact of potential technological advances in power plants and structural materials on the performance criteria of these vehicles.

J. N. Newman

**13.65 Ship Production Analysis (A)**

Prereq.: 13.40T or 13.41; 13.60

Year: G (1)

2-0-4

Operations research; mathematical and econometric models of ship production. Production process design and control. Modern production techniques. Network and flow analysis.

Frankel

**13.70 Special Problems in Naval Architecture and Marine Engineering**

Prereq.: —

Year: U (1, 2)

Arr.

Special reading, study, design, and/or investigation under supervision of a specially qualified member of the faculty. Topics in naval architecture or marine engineering individually arranged to suit the interests of the student.

Powell

**13.701 A Survey of Ocean Engineering**

Prereq.: —

Year: U (2)

1-0-1

Series of lectures to acquaint undergraduate students in naval architecture, marine engineering, and ocean engineering with the many facets of the field. Exploration of relationships and interfaces with the various engineering and scientific disciplines. Use of current problems and research projects as for illustration. Each session conducted by a different faculty member, with concentration on that faculty member's area of interest.

Staff

**13.71 Special Problems in Naval Architecture and Marine Engineering (A)**

Prereq.: —

Year: G (1, 2)

Arr.

Special reading, study, design, and/or investigation under supervision of a specially qualified member of the faculty. Topics in naval architecture or marine engineering individually arranged to suit the interests of the student.

Powell

**13.72 Methods of Harmonic and Statistical Analysis (A)**

Prereq.: 18.06

Year: G (2)

3-0-9

Consideration of methods of dealing with random physical phenomena from the mathematical basis to appli-

cations in instrumentation. Topics: generalized harmonic analysis; random processes; correlation functions; power spectra; linear systems, with emphasis on systems with frequency dependent parameters; and applications to measurement and instrumentation.

Milgram

**13.80 Mechanical Vibration (A)**

Prereq.: 2.01, 2.02

Year: G (1)

3-0-6

Free and forced vibration of systems of a single degree of freedom; complex variable and vector representation; Fourier series; harmonic analysis by tabular and mechanical methods; systems of several degrees of freedom; torsional systems; balance of rotating machinery and reciprocating engines; elements of torsional vibration problems in reciprocating engines.

Den Hartog

**13.81 Acoustics and Structural Vibrations (A)**

Prereq.: 2.01, 18.034

Year: G (1)

3-0-6

Elements of sound radiation and vibrations of continuous elastic structures. Basic concepts of acoustics: elementary solutions of the wave equation; sound intensity and power; radiation impedance; near- and far-field. Elementary source configurations: monopoles, image sources; pulsating spheres, plane pistons. Dynamics of elastic structures: longitudinal and flexural waves; structure-borne noise; reflection by impedance discontinuities. Normal modes: columns, beams and plates; sprung masses; coupled structural elements. Vibration control; structural damping and vibration mounts isolating non-rigid machinery from non-rigid foundations. Normal-mode analysis of shock response in structures. Theory of scaled model tests.

Junger

**13.82 Acoustics and Shock Response of Marine Structures (A)**

Prereq.: 13.81, 18.06

Year: G (2)

3-0-6

Steady-state and transient interaction between vibrating elastic plates or shells and the ambient water. Sound radiation and scattering by plane and curved surfaces. Asymptotic far-field and short-wave length solutions of the wave equation. Acoustic transients. Advanced concepts of structural vibrations: effect of rotary inertia, shear, and curvature on vibrations of plates; asymptotic high-frequency formulation of shell response. Coupled acoustical and vibrational problem: vibration and sound radiation from submerged plates and shells. Normal modes of submerged structures. Elastic scatterers. Radiation by a source set in an elastic baffle. Interaction of a pressure step-wave and an elastic shell (linear theory); dynamic coupling between the shock-excited shell and sprung masses.

Junger

**13.83 Hydroacoustics (A)**

Prereq.: 13.81, 18.06

Year: G (2)

3-0-6

Topics in underwater acoustics important to modern naval architecture and marine engineering. Physics of water; mechanism of cavitation; cavitation noise. Radiation of sound by various types of sources. Transmission of sound in the ocean. Fundamentals of active and passive sonars. Vibrations in marine structures and machinery. Engineering applications to ship and submarine noise control.

Leehey

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## ECONOMICS

### 13.84J *Flow Noise (A)*

(Same subject as 2.065J)

Prereq.: 1.05 or 2.201 or 16.02; 2.061 or 6.571; 6.35 or 13.81

Year: G (2)

3-0-9

Lighthill's theory of aerodynamic sound. Source, dipole and quadrupole radiation. Sound radiated from subsonic and supersonic jets. Curle's theory of the influence of solid boundaries. Aeolian tone, edge tone, feedback and resonator effects. Turbulent boundary-layer noise: fluctuating wall pressure statistics, structural response and radiation, eddy Mach wavy radiation. Comparison of theory with experimental results. Laboratory demonstrations. *Leehey*

### 13.92J *Public Policy and Use of the Seas*

(Same subject as 17.443J)

Prereq.: —

Year: G (1)

3-0-6

Policies of the United States and other nations toward possession and use of the seas. Interfaces between technology and public policy. Laws and agreements relating to jurisdiction in the maritime frontier, use of Continental Shelf, navigation, exploitation of ocean resources, deep submergence, and pollution. Role of the U.N. and other agencies. New goals for national policy. *Padelford*

### 13.93 *Ocean Engineering Systems*

Prereq.: 13.21 or 13.41

Year: G (1)

3-0-6

Conception and design of systems for exploration or utilization of the oceans. Tradeoffs and related management of systems applications to non-military systems such as offshore resource recovery, oceanographic networks or the merchant marines. Selected military applications. *Craven*

### 13.94 *Ocean Engineering and International Affairs (A)*

Prereq.: 13.92J

Year: G (2)

3-0-6

Impact of advancing technology on ocean engineering systems. Resulting impact on international affairs. Discussion of selected examples from the broad spectrum of new or emerging non-military or military systems with the law of the sea, arms control, world trade, etc. *Craven*

## 14.

### Economics

#### GENERAL ECONOMICS AND THEORY

### 14.01T *Economic Principles I*

Prereq.: —

Year: U (1, 2)

3-0-6

Introduction to fundamental economic concepts and analysis, economic interdependence and the operation of a mixed economy, the determinants of the over-all levels of economic activity, fiscal and monetary policy and international trade and payments. Current economic problems. *Eckaus*

### 14.02T *Economic Principles II*

Prereq.: 14.01T

Year: U (1, 2)

3-0-6

Continuation of 14.01T. The composition and pricing of output of particular industries, supply and demand analysis and competition and monopoly. Current economic problems. *Adelman*

### 14.03T *Prices and Production*

Prereq.: 14.02T

Year: U (1)

3-0-6

Basic theory, partial and general, of the firm, household, production and markets, treated at the intermediate level. Emphasis on applications, such as cost-benefit analyses, price regulation, technical change, and income distribution. *R. W. Crandall*

### 14.04 *Intermediate Microeconomic Theory*

Prereq.: 14.02T

Year: U (1, 2)

4-0-8

Basic theory of consumer behavior, production, pricing, market structures in a partial equilibrium framework, general equilibrium, welfare, and capital. (Credit given only for either 14.03T or 14.04.) *Diamond, von Weizsäcker*

### 14.05T *Economic Fluctuations and Growth*

Prereq.: 14.02T

Year: U (2)

3-0-6

Theory of income determination, static and dynamic. Emphasis on applications to fiscal and monetary policy. *J. R. Harris*

### 14.06 *Intermediate Macroeconomic Theory*

Prereq.: 14.02T

Year: U (1, 2)

4-0-8

Theory of national income determination, static and dynamic; components of aggregate demand; national accounts. Theory of growth and inflation. (Credit given only for either 14.05T or 14.06.) *Eckaus, J. R. Harris*

### 14.09 *Reading Seminar in Economics*

Prereq.: 14.04, 14.06

Year: U (1, 2)

Arr.

Reading and discussion of particular topics in economics. Open to advanced undergraduate students by arrangement with individual staff member. *Staff*

### 14.101 *Mathematics for Economists*

Prereq.: —

Year: G (1)

3-0-6

Introduction to mathematical methods, with emphasis on topics useful in economics: differential calculus, maxima and minima, definite integral, Taylor's series, partial derivatives, homogeneous functions, implicit function theorem, and constrained maxima and minima. *Engle*

### 14.102 *Mathematics for Economists*

Prereq.: 14.101

Year: G (2)

3-0-6

Continuation of 14.101. Single equation linear difference and differential equations; vector spaces and matrices; system of linear difference and differential equations and latent roots; properties of non-negative square matrices; quadratic forms. *Fisher*

### 14.114 *Economics and Finance: Principles and Policies I*

Prereq.: —

Year: G (S)

4-0-9

Introductory discussion of the determination of national income and its fluctuations; the composition and pricing of output; financial institutions and the functioning of money and capital markets; fiscal and other stabilization policies; industrial economics, price policy and the relations of government and business; and international economics. (Restricted to Sloan Fellows.)

### 14.115 *Economics and Finance: Principles and Policies II*

Prereq.: 14.114

Year: G (1)

3-0-6

Continuation of 14.114. (Restricted to Sloan Fellows.) *Millikan, Rosenstein-Rodan, Kindleberger*

- 14.116 Economics and Finance: Principles and Policies III (A)**  
Prereq.: 14.115  
Year: G (2) 3-0-6  
Continuation of 14.115. (Restricted to Sloan Fellows.)  
Adelman
- 14.121 Economic Analysis I (A)**  
Prereq.: 14.04  
Year: G (1) 4-0-8
- 14.122 Economic Analysis II (A)**  
Prereq.: 14.121  
Year: G (2) 4-0-8  
General theory of equilibrium under competition and monopoly. Theory of consumer choice, of demand, of the firm, of production and distribution, of welfare economics.  
Bishop (14.121), Samuelson (14.122)
- 14.123 Advanced Economic Theory I (A)**  
Prereq.: 14.102, 14.122  
Year: G (1) 3-0-6  
Topics centered around modern general equilibrium theory and its extensions. Linear programming, the simplex and duality theorems, and relation to economic analysis. Leontief systems, non-negative square matrices, the Hawkins-Simon and other conditions. Existence, optimality, and stability of competitive equilibrium. The von Neumann model of production as extended; prices and outputs. The turnpike theorem and related topics.  
Solow
- 14.124 Advanced Economic Theory II (A)**  
Prereq.: 14.122  
Year: G (2) 3-0-6  
Special topics in economic theory, drawn from microeconomics and macroeconomics. Content varying from year to year; current emphasis on theory of capital and behavior under uncertainty.  
von Weizsäcker
- 14.125 Mathematical Price Theory (A)**  
Prereq.: 14.102, 14.122  
Year: G (1) 3-0-6  
Systematic mathematical treatment of topics in neo-classical price theory. Theory of the firm and household; general equilibrium; related topics.  
Fisher
- 14.132 Schools of Economic Thought (A)**  
Prereq.: 14.121  
Year: G (1) 3-0-6  
Economic ideas developed by different groups of economists in recent times.  
Samuelson
- 14.151 Mathematical Approach to Economics (A)**  
Prereq.: 14.122  
Year: G (2) 3-0-6  
The use of mathematical methods in all the fields of economics.  
Samuelson
- 14.191 Economics Seminar (A)**  
Prereq.: 14.121  
Year: G (1) 3-0-6
- 14.192 Economics Seminar (A)**  
Prereq.: 14.121  
Year: G (2) 3-0-6  
Special economic problems.
- 14.193 Seminar: Topics in Economics (A)**  
Prereq.: 14.121, 14.451  
Year: G (1) 3-0-6
- 14.194 Seminar: Topics in Economics (A)**  
Prereq.: 14.122, 14.452  
Year: G (2) 3-0-6  
Topics in economics of current interest.
- 14.195 Reading Seminar in Economics (A)**  
Prereq.: 14.121  
Year: G (1) Arr.

- 14.196 Reading Seminar in Economics (A)**  
Prereq.: 14.121  
Year: G (2) Arr.  
Reading and discussion of special topics in economics. Open to advanced graduate students by arrangement with individual members of the staff.  
Staff

## INDUSTRIAL ECONOMICS

- 14.20T Industrial Organization and Public Policy**  
Prereq.: 14.02T  
Year: U (2) 3-0-6  
Analysis of market structures in the U.S. economy. Measures of market concentration and monopoly power. Detailed study of the effectiveness of American antitrust policy and public utility regulation.  
R. W. Crandall
- 14.22T Economics of Particular Industries**  
Prereq.: 14.04  
Year: U (1) 3-0-6  
Analysis of key economic features of particular industries such as nature of production process, characteristics of demand for its output, financial problems, growth, stability, and location. Entire term ordinarily to be spent on two or three industries such as transportation, chemical, machinery, fuel and power, minerals, and retail.  
R. W. Crandall
- 14.23 Economics of Fuel and Power**  
Prereq.: 14.02T  
Year: G (2) 2-0-4  
Survey of the main trends in production, pricing, and investment costs of coal, electric power, crude oil, and refined oil products. Economics of nuclear power. Intended for students of either economics or engineering.  
Adelman
- 14.231 Seminar in the Economics of Eastern Hemisphere Petroleum (A)**  
Prereq.: 14.04  
Year: G (1) 2-0-6  
Joint seminar with Harvard, meeting at Center for Middle East Studies weekly. Basic production economics, market structure, price evolution, company-government relations, energy policy in Western Europe.  
Adelman
- 14.271 Problems in Industrial Economics (A)**  
Prereq.: 14.04  
Year: G (1) 3-0-6  
Small and large enterprises in the American economy; market structures; degrees of monopoly and competition; requisites of public policy.  
Adelman
- 14.272 Government Regulation of Industry (A)**  
Prereq.: 14.271  
Year: G (2) 3-0-6  
Follows 14.271. Development of anti-trust policy, generally and in specific cases. "Public utility" price fixing, government ownership as alternative.  
Adelman
- 14.282 Economics of Technology and Innovation (A)**  
Prereq.: 14.04  
Year: G (1) 3-0-6  
Analysis of the economic and engineering concepts of technology, alternative estimates of production and cost functions. Theories of adjustment to technological change and research and development with case studies of innovation processes. Technological adaptation in less developed areas. Economics of education and training. (Not offered 1969-70.)  
Eckaus
- (A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## ECONOMICS

- 14.291 Industrial Economics Seminar (A)**  
*Prereq.:* 14.271  
*Year:* G (1) 3-0-6
- 14.292 Industrial Economics Seminar (A)**  
*Prereq.:* 14.271  
*Year:* G (2) 3-0-6
- Readings, discussions, reports on such topics as industrial price policies, government regulation of industry, competitive practices, and similar problems in industrial economics.

## STATISTICS

- 14.31 Econometrics**  
*Prereq.:* 14.381  
*Year:* U (1) 3-0-6
- Introduction to basic econometric techniques with strong emphasis on applications. Problems in estimating such economic variables as consumption-income-price relationships, production functions, and in simulating economic models. *Kuh*
- 14.371 Statistical Theory**  
*Prereq.:* 18.02  
*Year:* U (1) 3-0-6
- Axiomatic probability, random variables, mathematical expectation, generating functions, probability distributions, convolution, correlation, regression, and elementary stochastic processes. *H. A. Freeman*
- 14.372 Statistical Theory (A)**  
*Prereq.:* 14.371  
*Year:* G (2) 3-0-6
- Sampling theory, statistical estimation, the Gauss-Markov theorem and least squares, testing statistical hypotheses, the general linear hypothesis. *H. A. Freeman*
- 14.373 Time-Dependent Probability (A)**  
*Prereq.:* 14.371 or 18.10  
*Year:* G (1) 3-0-6
- Markov chains and Markov processes, the relevant ergodic theorem, Kolmogorov equations, time series theory: spectral density functions, harmonic representation, autoregressive models. *H. A. Freeman*
- 14.374 Design and Analysis of Scientific Experiments (A)**  
*Prereq.:* 14.381  
*Year:* G (1) 3-0-6
- Application of statistical theory to the design and analysis of scientific experiments. Factorial and fractional factorial designs offering large number of factors for simultaneous study. Applications to experimentation in the physical, biological and social sciences, and to engineering. *H. A. Freeman*
- 14.381 Statistical Method**  
*Prereq.:* 14.101 or 18.02  
*Year:* U (2) 3-0-6
- Self-contained subject in statistics which also serves as a background for advanced study in econometrics. Elements of probability theory, sampling theory, statistical estimation, hypothesis testing, introduction to regression analysis. *Engle*
- 14.383 Econometric Theory (A)**  
*Prereq.:* 14.102; 14.372 or 14.381  
*Year:* G (1) 3-0-6
- Principal statistical problems in the analysis of economic phenomena, including identification, least-squares bias, and autocorrelation, with emphasis on newer estimation procedures. *Fisher*

- 14.384 Applied Econometrics (A)**  
*Prereq.:* 14.383  
*Year:* G (2) 3-0-6
- Econometric applications to supply and demand analysis and macroeconomic models. Emphasis on using structural econometric models for policy and forecasting. An empirically oriented term paper required. *Kuh*
- 14.386 Advanced Topics in Econometrics (A)**  
*Prereq.:* 14.383  
*Year:* G (2) 3-0-6
- Selected topics including specification error, non-linear estimation, simulation, aggregation, and the derivation of economic policy models. *Kuh, Fisher*
- 14.39T Economic Research Seminar**  
*Prereq.:* 14.04, 14.06, 14.381  
*Year:* U (1) 2-0-7
- Introduction to research procedures in economics in preparation for thesis. Students to prepare reports on research topics. *Staff*
- 14.393 Doctoral Dissertation Seminar (A)**  
*Prereq.:* 14.122, 14.452  
*Year:* G (1) 2-0-7
- 14.394 Doctoral Dissertation Seminar (A)**  
*Prereq.:* 14.122, 14.452  
*Year:* G (2) 2-0-7
- Seminar for students writing doctoral dissertation. Presentation by students and discussion of dissertation research in various stages of completion. *Staff*

## NATIONAL INCOME AND FINANCE

- 14.40T Monetary and Banking Policy**  
*Prereq.:* 14.06  
*Year:* U (2) 3-0-6
- Monetary factors affecting the level of national income and relationships of financial institutions to these factors. Financial organization of society; the money-banking system, credit institutions, capital markets, and international financial relations. *Foley*
- 14.41T Distribution of Income and Employment Opportunity**  
*Prereq.:* 14.02T  
*Year:* U (2) 3-0-6
- Analysis of public policies deriving from concerns about the equity of the distribution of income and employment opportunities in the United States. Particular attention to manpower training, public assistance, the "war on poverty," and the economic problems of Afro-Americans. *Piore*
- 14.43T Public Finance**  
*Prereq.:* 14.04, 14.06  
*Year:* U (1) 3-0-6
- Effects of government revenue and expenditure programs on the level and distribution of economic activity; inter-governmental fiscal problems; relationship of fiscal to other economic policies. *E. C. Brown*
- 14.451 Theory of Income and Employment (A)**  
*Prereq.:* 14.06  
*Year:* G (1) 4-0-8
- Examination of principal determinants of aggregate levels of income and employment. *Domar*
- 14.452 Economic Growth and Fluctuations (A)**  
*Prereq.:* 14.451  
*Year:* G (2) 4-0-8
- Application of theory of income and employment to analysis and measurement of changes in level of economic activity over time, and to study of inflation. *Solow*

**14.462 Monetary Economics I (A)**

Prereq.: 14.121, 14.451

Year: G (2) 3-0-6

Examination of sources and determinants of supply of money with special attention to roles of commercial banks, Federal Reserve System, and Treasury. Discussion of nature of demand for money. Role of monetary policy in determination of level of economic activity.

Modigliani

**14.463 Monetary Economics II (A)**

Prereq.: 14.122, 14.452

Year: G (1) 3-0-6

General equilibrium theory of money, interest, prices, and output; portfolio problems, cost of capital, and the effects of monetary phenomena on investment and accumulation of wealth with special reference to problems arising from uncertainty.

**14.471 Fiscal Economics I (A)**

Prereq.: 14.121, 14.451

Year: G (1) 3-0-6

**14.472 Fiscal Economics II (A)**

Prereq.: 14.121, 14.451

Year: G (2) 3-0-6

Examination, both theoretic and quantitative, of governmental fiscal institutions and behavior: the budget process, taxation, expenditure, pricing, and debt activities.

Diamond (14.471); E. C. Brown (14.472)

**14.474 Seminar in Fiscal and Monetary Policy (A)**

Prereq.: 14.462 or 14.471; 14.463 or 14.472

Year: G (2) 3-0-6

Analysis of economic effects of alternative governmental policies aimed towards stabilization and growth, economic development, and other social objectives. Various topics in these fields to be discussed from year to year. Seminar divided by field.

E. C. Brown, Modigliani, Thurow, Diamond, Foley

## INTERNATIONAL, INTERREGIONAL AND URBAN ECONOMICS

**14.51T Urban Economics**

Prereq.: 14.02T

Year: U (1) 3-0-6

Analysis of selected economic problems of urban areas in the United States. Metropolitan growth and suburbanization. Housing markets, segregation and urban renewal. Transportation systems. Ghetto economic development. Scale, finance and decentralization of public services. Development of methodological approaches through discussion of policy issues.

Grieson

**14.52T Economics of the Soviet Union**

Prereq.: 14.02T

Year: U (2) 3-0-6

Historical background. Russian agriculture and industry before the Communist revolution. Economic ideology of the Communist regime. General approach to industrialization. Allocation of resources. Agriculture and industry. Management and labor. Recent changes and discussions. Evaluation of the Soviet experiment. Lessons for underdeveloped countries. (14.53 is desirable preparation but not a prerequisite.)

Domar

**14.53T Comparative Economic Systems**

Prereq.: 14.02T

Year: U (1) 3-0-6

Analytical study of economic problems in different economic systems. The economic ideology of capitalism, utopian writings, Marxism and socialism. Comparison of several capitalist and socialist countries, including the United States, West Germany, Sweden and Yugoslavia. Role of the price system, investment decisions, economic growth, etc.

Domar

**14.54T International Trade**

Prereq.: 14.04, 14.06

Year: U (2) 3-0-6

Theory of international trade and finance, and application to current problems, such as exchange restrictions, economic development, and foreign aid.

Bhagwati

**14.572J Urban Economics: Positive Analysis I (A)**

(Same subject as 11.66J)

Prereq.: 14.03T or 14.04

Year: G (2) 3-0-6

Economic analysis of urban areas in their regional setting, organized around the sources, characteristics, and implications of spatial concentration of economic activities. Consideration of both market and governmental forces. Location theory; spatial competition; general equilibrium models of interregional economic activity with emphasis on input-output and linear programming models; interregional transmission of economic fluctuations; metropolitan growth and development. Explicit attention to spatial factors affecting the demand for transportation services.

J. R. Harris, Urban Studies and Planning Staff

**14.573J Urban Economics: Positive Analysis II (A)**

(Same subject as 11.67J)

Prereq.: 11.66J or 14.572J

Year: G (1) 3-0-6

Continuation of 14.572J. The land use market and the spatial structure of the metropolitan community. Models of the metropolis. The housing market: demand and supply, growth, aging and urban renewal. The economics of segregation in the metropolitan area. The Model Cities Program. The urban transportation system and its problems. In each of these topics, emphasis on the resource allocation process, its efficiency, and sources of suboptimality.

Rothenberg

**14.574J Urban Economics: Positive and Normative Analysis III (A)**

(Same subject as 11.68J)

Prereq.: 11.67J or 14.573J

Year: G (2) 3-0-6

Continuation of 14.573J. The nature and problems of government decision making in metropolitan areas. Urban-suburban relations: market and governmental interactions. Optimal and suboptimal government. Welfare economics and the normative theory of local public policy. Applied normative analysis: criteria for public expenditures; cost-benefit analysis. Examination of public policy issues in current urban problems: poverty, race, the spatial form of the city, optimal land use patterns, growth and renewal.

Rothenberg

**14.581 International Economics I (A)**

Prereq.: 14.04, 14.06

Year: G (1) 4-0-8

Theory of international trade and applications in commercial policy.

Bhagwati

**14.582 International Economics II (A)**

Prereq.: 14.581

Year: G (2) 4-0-8

Adjustment in international economic relations with attention to foreign exchange markets, balances of payments, and the international monetary system.

Kindleberger

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## ECONOMICS

**14.584 Seminar in International Economic Theory (A)**  
Prereq.: 14.582  
Year: G (2) 2-0-7  
Limited to second-year graduate students and beyond, including especially students preparing theses in international economics. Emphasis on theory, rather than empirical questions or policy issues, and on student contribution.  
*Bhagwati, Kindleberger*

**14.586 Interregional Economics (A)**  
Prereq.: 14.04  
Year: G (2) 3-0-6  
Problems of economic analysis as affected by the geographical separation of resources and markets; factors leading to interregional trade; the role of transportation with particular reference to national transportation policy; problems of industrial location and regional competition; interregional adjustment of diverse economic activities; regional economic planning in the context of national economic policy.  
*J. R. Harris*

### LABOR ECONOMICS AND INDUSTRIAL RELATIONS

**14.63T Labor Relations**  
Prereq.: —  
Year: U (1, 2) 3-0-6  
An introductory analysis, through an integrated social science approach, of the institutions which have developed in response to "human resource problems." The growth, structure, and objectives of management and organized labor groups, collective bargaining as part of a dynamic accommodation process between organizations that have economic, political, and social characteristics.  
*Piore, Annable*

**14.64T Labor Economics and Public Policy**  
Prereq.: 14.63T  
Year: U (1, 2) 3-0-6  
Particular applications of the analytical tools developed in prerequisite subjects to two aspects of the industrial relations scene: (1) the economics of collective bargaining, problems presented by wage determination at firm, industry, and economy levels; and (2) the development of public policy on the rights and obligations of employers, unions, and workers.  
*Mills*

**14.671J Labor Economics (A)**  
(Same subject as 15.671J)  
Prereq.: 14.64T or 15.312  
Year: G (1) 3-0-6  
Primary emphasis on the determination of wage levels and wage differentials through an analysis of labor supply and labor demand, as affected by economic as well as by institutional factors. The impact of unions on both wage and non-wage elements of collective bargaining in the light of the characteristics and objectives of particular unions. Other special topics growing out of recent research in labor economics.  
*Piore, C. A. Myers*

**14.672J Public Policy on Labor Relations (A)**  
(Same subject as 15.672J)  
Prereq.: 14.64T or 15.312  
Year: G (2) 3-0-6  
Major trends in labor legislation, the legality of union activities, protection of the right to organize and bargain collectively, regulation of wages and hours, governmental machinery for the adjustment of labor disputes, and social insurance. The broad economic and social questions raised by these trends. (Not offered 1969-70.)  
*Piore, D. V. Brown*

**14.674J Comparative Systems of Industrial Relations and Human Resource Development (A)**  
(Same subject as 15.674J)  
Prereq.: 14.64T or 15.312  
Year: G (2) 3-0-6

International and comparative analysis of industrial relations systems and systems of human resource development. Concentration on an examination of selected issues involving interest groups and the strategies of economic development, including discussion of the nature and functions of labor and management organization in different contexts; the role of the state in establishing procedures and in shaping the substance of industrial relations; the participation of interest groups in the formulation of economic and social policy; manpower and economic growth in the context of comparative systems of human resource development; external influences on national industrial relations systems and human resource development.  
*C. A. Myers*

**14.69T Labor Problems Seminar**  
Prereq.: 14.64T  
Year: U (1 or 2) 3-0-6  
Supplements the humanities combination in labor relations and labor economics. Selected labor problems chosen for their current interest or continuing significance. Development and application of problems and techniques of 14.63 and 14.64. (Section limited to 15 students. Not offered 1969-70.)

**14.691J Research Seminar in Industrial Relations (A)**  
(Same subject as 15.691J)  
Prereq.: 14.671J or 14.672J  
Year: G (1) 3-0-6  
Discussion of important areas for research in industrial relations, frameworks for research, research techniques, and methodological problems. Centered mainly on the thesis research of advanced graduate students.  
*C. A. Myers*

**14.692J Research Seminar in Industrial Relations (A)**  
(Same subject as 15.692J)  
Prereq.: 14.691J  
Year: G (2) 3-0-6  
Continuation of 14.691J.  
*C. A. Myers*

### ECONOMIC HISTORY

**14.71T Economic History**  
Prereq.: 14.02T  
Year: U (2) 3-0-6  
Survey of growth in the American and/or European economy in the nineteenth and twentieth centuries. Topics including the economic effects of governmental policies, the causes and effects of technical change, the role of specific institutions, the economic causes of political conflicts. Content varying from year to year, with emphasis usually on the United States.  
*Temin*

**14.731 American Economic History (A)**  
Prereq.: 14.121  
Year: G (2) 3-0-6  
Basic survey of the beginnings of American industrialization, emphasizing a quantitative approach and the period from 1760 to 1860. The nature of the colonial economy, economic problems of political independence, factors inducing the growth of industry (and specific industries), problems of antebellum agriculture and slavery.  
*Temin*

**14.732 European Economic History (A)**  
 Prereq.: 14.121  
 Year: G (2) 3-0-6  
 Selected topics in recent European economic history with special attention to problems associated with technical progress, productivity, and changes in economic and social structure. (Not offered 1969-70.)

**14.733 European Economic History (A)**  
 Prereq.: 14.121  
 Year: G (1) 3-0-6  
 Development of the European economy since 1750 and, especially since 1850, with emphasis on growth and slow-down, the transition from local to national and European-wide institutions, and extra-European relations.  
*Kindleberger*

**14.734 Problems in Economic History (A)**  
 Prereq.: 14.731 or 14.732  
 Year: G (2) 3-0-6  
 Analysis of problems of industrial society, concentrating on the century after 1860 and on the American experience. Subject matter varying from year to year on topics such as the effects of wars on welfare and growth, the nature of the long deflation of the late nineteenth century, the contrast in international relations before and after 1914, the depression of the 1930's. (Not offered 1969-70.)  
*Temin*

#### ECONOMIC DEVELOPMENT

**14.74T Economic Growth and Development**  
 Prereq.: 14.02T  
 Year: U (2) 3-0-6  
 Analytical treatment of the problems of economic growth and development combined with comparative studies of the growth of advanced and underdeveloped economies. Considerations of policy measures to promote economic development and growth.  
*Edel*

**14.771 Problems of Economic Development (A)**  
 Prereq.: 14.772  
 Year: G (1) 3-0-6  
 Applications of development theory. Studies of structure of less-developed economies, technological constraints, interaction of foreign trade and internal development, international financial problems.  
*Rosenstein-Rodan*

**14.772 Theory of Economic Development (A)**  
 Prereq.: 14.121, 14.451  
 Year: G (2) 3-0-6  
 Analysis of theories of economic development with attention to alternative patterns of resource scarcity, population growth, and models of growth. Econometric and programming models for planning. Investment criteria in less-developed countries.  
*Eckaus*

**14.773 Seminar in Economic Development (A)**  
 Prereq.: 14.772  
 Year: G (1) 3-0-6  
 Special problems in economic development such as international trade policy, monetary and fiscal issues, and problems of particular sectors with special attention to agriculture.  
*Bhagwati*

**14.774 Seminar in Economic Development (A)**  
 Prereq.: 14.772  
 Year: G (2) 3-0-6  
 Studies of current issues in the economic development of particular countries and regions which will normally include India and some other countries in Southeast Asia, countries in Latin America, Africa and the Middle East. (Not offered 1969-70.)  
*Millikan*

**14.782 Capitalism, Socialism and Growth (A)**  
 Prereq.: 14.121, 14.451  
 Year: G (2) 3-0-6  
 A comparative study of capitalist and socialist economies

mainly from the point of view of development and growth, and with major emphasis on the economy of the Soviet Union.  
*Domar*

**14.784 Elements of Economic Growth**  
 Prereq.: 17.721  
 Year: G (1) 3-0-6  
 Introduction to the economic theory of growth for students without graduate training in economics. Introduction to relevant technical economic concepts in income, employment, and production theory.  
*Hagen*

## 15. Management

**15.012 Economics for Management I**  
 Prereq.: —  
 Year: G (1) 3-0-6  
 Microeconomics for students of management. How the price-profit system works through operation of supply and demand. Market structures and market behavior in specific industries. Regulation of competition. (Restricted to Sloan School of Management graduate students; others admitted only with permission of instructor.)  
*MacAvoy*

**15.014 Economics for Management II**  
 Prereq.: 15.012  
 Year: G (2) 3-0-6  
 Macroeconomics for students of management. Study of the determination of national income and the level of economic activity; monetary economics and growth; prices and business cycles; stabilization policies, monetary and fiscal, and balance of payments problems. (Restricted to Sloan School of Management graduate students; others admitted only by permission of instructor.)  
*Thurrow*

**15.019 Seminar in Economics for Management (A)**  
 Prereq.: 15.014  
 Year: G (2) 3-0-6  
 Review of basic economic theories of the firm, the industry and the economy, with emphasis on those aspects useful for analyzing the American experience. Detailed discussion of case studies applying the theories, including industry studies of the pricing effects of market structure, economy-wide forecasts, and studies of the effects of government regulatory, monetary, and fiscal policies. (Restricted to doctoral candidates in the Sloan School of Management.)  
*MacAvoy*

**15.02 Industrial Statistics**  
 Prereq.: 18.034  
 Year: U (1, 2) 4-0-8  
 Introduction to statistical methods with application to engineering and administrative problems. Basic statistical distributions including binomial, hypergeometric, Poisson, exponential, normal, and Chi-square. Introduction to acceptance sampling, quality control, and the analysis of variance.  
*Durand*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## MANAGEMENT

### 15.032 Sampling of Finite Populations (A)

Prereq.: 15.02 or 15.092

Year: G (2) 3-0-6

This subject is designed specifically for students in advanced marketing and demand analysis. Cluster sampling; equal and unequal sized cluster; cluster sampling with and without subsampling; multistage sampling; combinations of cluster sampling and stratified sampling; disproportionate stratified sampling; two-phased and sequential sampling.

Durand

### 15.05 Introduction to Management

Prereq.: —

Year: U (2) 4-0-8

Introduction to what a business is, how it relates to the environment within which it operates, and how it operates; an over-all appreciation of the global problems of planning, making decisions, organizing, directing, operating and controlling a business.

Staff

### 15.06 Managerial Psychology

Prereq.: —

Year: U (1, 2) 3-0-6

Core subject for all students majoring in management. Survey of individual and social psychology and organization theory interpreted in the context of the managerial environment.

Allen

### 15.07 Managerial Economics

Prereq.: —

Year: U (1) 4-0-8

Introduction to fundamental concepts of the economics of the firm and of industry. The mechanisms of supply and demand. Operation of the price-profit system. Market structures and market behavior in specific industries. Analyses of economic problems of relevance to management.

MacAvoy

### 15.08 Managerial Environment

Prereq.: 15.05, 15.06, 15.07

Year: U (2) 4-0-8

The nature of the environment affecting the operation and growth of purposeful organizations. Social, political, and technological changes, and their impact on managerial problems and responsibilities. The multi-dimensional character of issues posed by environmental changes. Interaction of business, government, and non-profit organizations with technology and society at large.

Staff

### 15.091 Mathematics for Management I

Prereq.: —

Year: G (1) 4-0-8

Introduction to probability and statistics emphasizing applications to management problems. Such topics as set theory, basic probability theory, an introduction to decision making under uncertainty, Bernoulli, Poisson, normal, and Markov processes and aspects of statistical inference.

L. S. White

### 15.092 Mathematics for Management II

Prereq.: —

Year: G (2) 4-0-8

Introduction to mathematical programming emphasizing applications to management problems. Such topics as matrix algebra, classical optimization techniques, linear programming, integer and non-linear programming, dynamic programming, and heuristic programming.

L. S. White

### 15.093 Statistics for Model Building (A)

Prereq.: 15.091

Year: G (1) 3-0-6

Applied statistics for management. Topics: regression analysis, non-linear regression, simultaneous equations, discriminant analysis, factor analysis, experimentation,

and other special topics. Oriented toward applications, but sufficient theory covered for assuring proper use. Applications project required.

Montgomery, Pogue

### 15.094 Statistical Decision Theory I

Prereq.: 6.28

Year: U (2) 3-0-6

Decision making under uncertainty. Rationales of decision makers, utility, the concept of the value of perfect information. The Bayesian approach. Pre-posterior, optimal fixed-size, and other forms of analysis of statistical decision problems.

Kaufman

### 15.095 Statistical Decision Theory (A)

Prereq.: 6.28

Year: G (2) 3-0-6

Development of a basic theory of decision making under uncertainty. Rationales of decision makers, utility, the concept of the value of perfect information. The Bayesian approach to decision making; its relationship to classical statistics. Pre-posterior analysis and optimal fixed-size analysis for common random processes. Discussion of normal vs. extensive form analysis of statistical decision problems.

Kaufman

### 15.099 Seminar in Applied Mathematics (A)

Prereq.: 15.092

Year: G (2) 3-0-6

Discussion of current literature in the field with the purpose of reviewing and building upon the basic material covered in 15.091 and 15.092. Emphasis on mathematical techniques applicable in interdisciplinary theses and other studies and their applications in fields of interest to management. (Restricted to doctoral candidates in the Sloan School of Management.)

Staff

### 15.10 Quantitative Methods in Management

Prereq.: 15.05, 18.10 or 18.034

Year: U (1) 3-0-6

Mathematical models and methods appropriate to the analysis of management problems. Emphasis on deterministic models. Formulation and solution of mathematical programming problems.

Staff

### 15.11 Introduction to Industrial Management

Prereq.: —

Year: U (1, 2) 3-0-6

Basic treatment of fundamental principles and general practices of industrial management. Specific coverage of selected important facets of marketing, finance, production, accounting, and managerial psychology. Information and procedures utilized in managerial decision making. Relationship of scientist and engineer to functions and decisions of management and the management of research and development. (Not open to Course xv students.)

### 15.17 Advanced Historical Studies (A)

Prereq.: 15.201T

Year: G (1, 2) 2-0-7

Opportunity for individual study with a staff member. Social and economic problems historically considered. Program determined by student and staff members to suit individual requirements; subject to approval of professor in charge.

Staff

### 15.181 Management Information and Controls

Prereq.: —

Year: G (S) 3-0-6

Theory and techniques underlying the generation of information measuring results of managerial efforts and the uses of such information for financial reporting, evaluation of alternative courses of action, motivation of efficient behavior, control, and managerial decision making. Application of theory to project analyses, transfer pricing, and issues arising out of decentralized structures. (Restricted to Sloan Fellows.)

**15.182 Quantitative Methods**

Prereq.: —

Year: G (S)

3-0-6

Mathematical and statistical tools necessary for modern managerial analysis. Introduction of fundamental theories underlying various techniques recently developed to facilitate managerial decision making under uncertainty. Emphasis on the role and evaluation of modern quantitative techniques rather than technical expertise. (*Restricted to Sloan Fellows.*) *Crowston*

**15.183 Readings in Power and Responsibility (A)**

Prereq.: —

Year: G (1, 2)

3-0-6

Detailed examination of major historical ideas affecting American industrial philosophy and processes. (*Restricted to Sloan Fellows.*)

**15.184 Structure of American Law**

Prereq.: —

Year: G (S)

3-0-6

Analysis of the American legal system as a process for ordering our society. Consideration of selected legal problems to reveal the operation of the major component elements of the system: the judicial, legislative, administrative and private law-making power. Consideration of substantive law primarily from the standpoint of the process for generating and modifying legal policy. Emphasis on the problems of the law of business institutions. Extensive reading of case law as well as textual materials and legal essays. Research projects involving use of a law library. (*Restricted to Sloan Fellows.*) *Jacks, Nyhart*

**15.185 Operations Management (A)**

Prereq.: 15.181, 15.182

Year: G (1)

3-0-6

Theoretical approaches to problems faced by an operating manager. Introduction of philosophy and methodology of industrial dynamics in context of over-all systems description and improvement. Introduction of such techniques as mathematical and heuristic programming as aids to individual decision making within complex systems. (*Restricted to Sloan Fellows.*) *Crowston, Roberts*

**15.186 Marketing (A)**

Prereq.: 15.181, 15.182

Year: G (1)

3-0-6

Structure of consumer and industrial demand. Study of problems of achieving suitable distribution within the perspective of total promotional problem. Intensive study of several marketing management problems, such as formation of sound product policy, evaluation of promotion programs, and determination of market potentials. (*Restricted to Sloan Fellows.*) *Staff*

**15.201 Management Environment**

Prereq.: —

Year: G (1, 2)

3-0-6

Opportunity for survey coverage and intensive study of the executive's interactions with, and responsibilities to, his environment. Factors examined may include the employees; the local community; the labor force; other corporations; consumers; local, national and foreign governments; and local, national and world economies. Emphasis on student participation both in planning and execution of subject program. *Staff*

**15.221 International Business Management I (A)**

Prereq.: 15.012

Year: G (2)

3-0-6

Theory of, and institutional restraints acting on, international business, with emphasis on the pressure to effect harmonization of a firm's objectives with those of foreign

business associate or customer, host government, and parent government. Discussion of historical flows of trade and investment and the impact of such flows on host and parent societies, followed by coverage of institutional restraints in the legal, informational, financial, and commercial areas. Specific problem areas dealt with: sources of foreign market information and evaluation of same, conflict of law regarding property and rights of aliens, taxation of international income, antitrust law, adjudication of international business disputes, investment guarantees, international banking operations, foreign exchange controls, financing of foreign trade, trade agreements and trading areas, international shipping and communications. Term project: an analysis of a foreign market for a specified product and firm. *Robinson*

**15.222 International Business Management II (A)**

Prereq.: 15.221

Year: G (1)

3-0-6

In-depth examination of two or three foreign environments and familiarization with several important analytical constructs relevant to their understanding, followed by focus on characteristic organizational and operational problems arising from the international nature of the firm. Specific problem areas: development of an international business structure, selection of the appropriate form of international business relationship, communication across national cultural frontiers, selection of management personnel, management of labor-management relations under diverse circumstances, impact of different factor mixes on production, reduction of financial risk, development of an optimum control system. Term project: a role-playing game calling for design of the legal, administrative, and control structure of an internationalizing firm. *Robinson*

**15.223 Industrial Structure of Europe (A)**

Prereq.: 15.012

Year: G (1)

3-0-6

Seminar focusing on policy problems faced by firms operating in Europe. Specific topics: trends in European business environment (the nature of institutional, legal, and trade relationships to be expected in the foreseeable future); adaptation of company policy to expected future environmental changes; constraints on business management in Europe (i.e., technological gap, managerial gap, labor rigidities, relative immobility of factors); special corporate problems (i.e., financial resources, mergers-acquisitions-joint ventures, production, marketing). Class discussions with guest speakers, faculty, and students as leaders. One or more research reports, with both oral and written presentation. Over-all stress on development of business policies appropriate to the changing European environment. *Robinson*

**15.232 Development Finance (A)**

Prereq.: 15.012

Year: G (2)

3-0-6

Financing private and public enterprise in the developing countries: problems, institutional framework, and accompanying theory. The role and functions of capital market, international and local development finance institutions in enlarging financial flows to the developing world. Structure and management problems of development banking: procedures, organization, ownership, project evaluation, project financing, performance measurement. *Nyhart*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## MANAGEMENT

### 15.31 *Statistics for Behavioral Science*

Prereq.: —  
Year: U (1, 2) 3-0-6

The tools required for proper treatment of behavioral science research data. Descriptive and inductive statistics. Introduction of parametric and non-parametric techniques for the analysis of data. Fundamentals of measurement theory as a basis for determining the applicability of alternate techniques for data analysis. *Staff*

### 15.312 *Human Factors in Management II*

Prereq.: —  
Year: G (1, 2) 3-0-6

Structure and functioning of management and unions in handling of industrial relations; union policies; problems likely to arise. Reconciliation of union and management policies. Public policy in labor-management relations. (Restricted to Sloan School of Management graduate students; others admitted only by permission of instructor.)

*D. V. Brown, Mills*

### 15.32 *Social Psychology*

Prereq.: 15.06  
Year: U (2) 3-0-6

Cognitive processes such as learning, perception, and problem solving as individual phenomena and within the social context. Detailed examination of basic social psychological concepts such as influence, attitudes, communication, conflict, and interpersonal relations to provide understanding of the dynamics of group behavior. Provision of conceptual tools for application in the study of human behavior in organizations. *Farris*

### 15.322T *Management of Human Resources (A)*

Prereq.: 15.312  
Year: G (2) 2-0-7

Seminar with emphasis on managerial responsibilities and policies in the effective utilization of people in organizations. Topics: managers and their personnel concepts, management organization for personnel administration, organization planning and management development, manpower planning and personnel budgets, recruitment and selection, promotion and transfer, training, performance appraisal, discipline, managing change, and wage and salary administration. Field research on selected problems. *C. A. Myers*

### 15.33 *Complex Organizations*

Prereq.: 15.32  
Year: U (1) 3-0-6

Patterns of authority and control, socialization processes, member reference, group orientations (cosmopolitan vs. local), decision making structures, methods of conflict resolution as essential elements in any organization. Examination and comparison of different forms of organization (e.g., manufacturing companies, administrative agencies, research laboratories, hospitals) within the framework of these factors in terms of their implications for various dimensions of organizational performance (e.g., productivity, innovation and creativity).

### 15.331 *Human Factors in Management I*

Prereq.: —  
Year: G (1, 2) 3-0-6

Opportunity for the student to become familiar with the methods, subject matter, and findings of social psychology, to look into literature in the field, and to raise questions about his reading. Detailed examination of a few subjects within social psychology which are particularly relevant to the problems of industrial management, with

class discussions and reading on such subjects as motivation, learning and behavior change, leadership. (Restricted to Sloan School of Management graduate students; others admitted only by permission of instructor.) *Staff*

### 15.332 *Advanced Seminar in Social Psychology (A)*

Prereq.: 15.331  
Year: G (2) 3-0-6

More intensive coverage of the topics covered in 15.331. Detailed examination of basic social psychological factors such as power, communication, conflict, change, and interpersonal and group relations. Students will be expected to formulate research projects. (Restricted to Ph.D. candidates in the Sloan School of Management, others admitted only by permission of instructor.) *Haire*

### 15.333 *Seminar on Influence, Attitude Change and Adult Socialization (A)*

Prereq.: 15.331  
Year: G (1) 3-0-6

Seminar for advanced Master's and doctoral students in organization studies, covering organization influences on attitudes and values, the development of occupational identity, and models of attitude change. Emphasis on gathering data and student research projects. *Schein*

### 15.334 *Practicum in Organization Development (A)*

Prereq.: 15.373  
Year: G (1) 3-0-6

An intensive examination of organization development methods such as laboratory training, action research, grid organization development, job enlargement and organization design. Case analysis of the application of these methods to educational, governmental and industrial organizations. Use of previous summer work placements in organization development departments as a foundation for developing organization development skills. Integral part of specialization in organization development for Master's candidates, together with 15.331, 15.373, and a thesis on organization development. (Admission by permission of instructor. Limited to students who have participated in previous supervised summer work placement in organization development.) *Kolb*

### 15.335 *Personality Theory and Assessment (A)*

Prereq.: 15.334  
Year: G (2) 3-0-6

Application of psychological theory and method to understanding individual personality. Development of clinical skills through intensive analysis of live subjects and case studies. (Enrollment limited to ten students; admission by permission of instructor.) *Kolb*

### 15.339 *Seminar in Behavioral Sciences (A)*

Prereq.: 15.331  
Year: G (2) 3-0-6

Development of basic concepts for understanding organizational behavior through critical analysis of important works in the field. Areas covered: motivation, perception, personality, learning, problem solving, decision making, group dynamics, organization theory, organizational development, and conflict resolution. (Restricted to doctoral candidates in the Sloan School of Management.) *Haire*

### 15.34 *Interpersonal Dynamics Laboratory*

Prereq.: 15.06  
Year: U (1) 0-3-3

Opportunity to study human behavior through observation in interpersonal relationships that develop within an unstructured learning group. Readings in interpersonal behavior and nature of human relationships with particular focus upon the factors that influence effective performance within groups. *Staff*

**15.35 Behavioral Science Research Methods**

Prereq.: 15.31, 15.33, 15.34

Year: U (1) 3-0-9

Introduction to methods of behavioral science research. General strategy of behavioral research (systematic vs. impressionistic investigation, hypothesis formulation, the probabilistic nature of data, etc.): research design (purposes, variance control, control of extraneous variables, use of control groups, randomized designs, factorial designs, two-group, multigroup and correlated-groups designs). Specific technologies of various designs (questionnaire construction, sampling, interviews, systematic observation). Theory and research findings. Organization of research project. Staff

**15.351 Industrial Sociology (A)**

Prereq.: 15.331

Year: G (1) 3-0-6

Examination of some sociological problems of industrial organizations: technological change and organizational specialists; professionalization of management; relations of industry to community and society. Field studies, secondary analysis of survey data, and library research on selected problems. —

**15.36T Behavior Science Research Practicum**

Prereq.: 15.35

Year: U (2) 2-8-8

Development and completion of research project planned in 15.35 during previous term. Interpretation and application of research findings in management environment. Experimentation with such techniques as field survey work, laboratory experimentation, computer simulation, field consulting relationships. (Restricted to undergraduates in the Sloan School of Management who are in the Behavioral Science Program.) Staff

**15.371 Comparative Analysis of Organizations (A)**

Prereq.: 15.331

Year: G (1) 3-0-6

Comparative analysis of the structure and functioning of different types of organization: manufacturing organizations, research laboratories, schools, hospitals, armies, courts, administrative agencies, occupational associations, etc. Review of social science literature on organizations with special attention to problems of authority structures, management succession, and inter-organizational relations. Integral part of specialization in organization theory and research for Master's candidates, together with 15.373, 15.374, 15.381 and a thesis on organization theory and research. —

**15.372 Organizational Psychology (A)**

Prereq.: 15.184

Year: G (1, 2) 3-0-6

Analysis — through lectures, discussions, and class exercises — of management of human resources in industry. Emphasis on internal relations of management. (Restricted to Sloan Fellows.) Beckhard, Haire, Schein

**15.373 Seminar on Organization Change (A)**

Prereq.: 15.331

Year: G (1) 3-0-6

The processes of deliberate organizational change: the "change-agent" and "client-systems," criteria for and of effective change programs, strategic variables affected in change (e.g., power, communication, conflict), and technologies for producing change (e.g., consulting, training, research). Integral part of specialization in organization theory and research for Master's candidates, together with 15.371, 15.374, 15.381, and a thesis on organization theory. (Enrollment limited to 15 students; admission by permission of instructor.) Beckhard

**15.374 Organization (A)**

Prereq.: 15.331

Year: G (1) 3-0-6

Study of organizational theory as it applies to actual organizational behavior. Specific examples of organizational behavior problems analyzed at policy level: how policy, explicit and implicit, affects behavior in the total organization. Discussion of selected organization research studies, papers, cases. (Enrollment limited to 20 students; admission only by permission of instructor.) Gil

**15.375 Behavioral Theories of the Firm (A)**

Prereq.: 15.374

Year: G (2) 3-0-6

Research seminar for students of organizational behavior. Study of a small number of researchable topics in that area. Derivation of a model and set of operational hypotheses for describing and explaining each type of behavior. Design and planning of a research project to test a subset of these hypotheses. Discussion, critique, and aid of seminar members' own dissertation research plans, time and mutual interests permitting. Integral part of specialization in organization theory for Master's candidates, together with 15.371, 15.373, 15.381, and a thesis in organization theory. (Primarily for doctoral candidates; others admitted by permission of instructor.) —

**15.376 Surveys and Experiments on Organizations (A)**

Prereq.: 15.331

Year: G (1, 2) 3-0-6

Review of methodological problems of designing sample surveys, laboratory experiments, and field experiments. Introduction to problems of experimental design and techniques for analyzing data. Analysis of the nature of organizational experiments and the interplay between surveys, laboratory experiments, and field experiments. Practice in designing and conducting surveys and experiments on organizational problems. (Enrollment limited to 16 students; admission by permission of instructor.) Sirota, Marquis

**15.377 Mathematical Behavioral Science (A)**

Prereq.: 15.012, 15.092, 15.331

Year: G (2) 3-0-6

Subject designed to develop a student's capability in applying mathematical techniques to behavioral science research problems. Use of research literature relating to the particular technique being discussed. Emphasis on understanding the heuristics for applying and the implicit assumptions underlying each mode of mathematical expression. Relevant theorems derived and illustrated only to the extent necessary for analysis. Applications of analytical techniques to include: game theory, information theory, selected stochastic models, linear dynamics, analysis of general functional forms, structure of mathematical programs, discrimination functions, and complex determinate systems. (Primarily for doctoral candidates; others admitted by permission of instructor.) —

**15.38 Administrative Theory and Practice**

Prereq.: 15.71T

Year: U (1) 3-0-6

Organizational and operational problems of administration. Typical areas include productivity and morale, manager development, personnel management. Readings, case analyses, term papers, and outside speakers where appropriate. L. B. Moore

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## MANAGEMENT

- 15.381 Administrative Theory and Practice (A)**  
*Prereq.:* 15.312, 15.412, 15.712, 15.812  
*Year:* G (1) 3-0-6  
 Selected significant administrative areas with emphasis upon organization and its operational problems. Comparative study of current practice and relevant research findings. Typical areas include productivity and morale, manager development, personnel practices, communication, appraisal, motivation and performance, ethics and morality. Readings, case problems, term papers, and outside speakers where appropriate. Integral part of specialization in organization theory and research for Master's candidates, together with 15.371, 15.373, 15.374 and a thesis on organization theory and research.  
*L. B. Moore*
- 15.382 Management of Industrial Change (A)**  
*Prereq.:* 15.331  
*Year:* G (1) 3-3-3  
 Examination of the improvement function in management. Review of literature on creativity as it affects innovation in industrial operation. Human relations problems in industrial change. The role of the manager in fostering improvement. Use of the conference as an improvement tool. Field work in comparative analysis of representative improvement programs.  
*L. B. Moore*
- 15.383 Seminar in Managerial Behavior (A)**  
*Prereq.:* 15.333 or 15.373; 15.374  
*Year:* G (2) 2-0-7  
 Independent study and reports by individual students (or teams of students) within the field of the social psychology of managerial behavior. (*Admission by permission of instructor.*)  
*Beckhard*
- 15.384 Research Management (A)**  
*Prereq.:* 15.331  
*Year:* G (1) 2-0-7  
 Lectures and discussion on topics ranging from the performance of individual scientists and engineers to the organization and management of research and development groups and laboratories, and the impact of research and development on the national economy.  
*Marquis*
- 15.385 Managerial Communication (A)**  
*Prereq.:* 15.372  
*Year:* G (2) 3-0-6  
 Managerial communication considered in the organization setting and as a function of motivation. The communication process, media, and technique employed by the manager. Selected managerial problem areas in individual and group relations. (*Restricted to Sloan Fellows.*)  
*L. B. Moore*
- 15.386 Seminar on Management Problems in Science and Technology (A)**  
*Prereq.:* 15.384  
*Year:* G (1, 2) 2-0-7  
 Discussions of problems and current research in the management of science and technology. Weekly seminars led by members of the faculty and invited speakers. Independent study and preparation of reports by individual students or teams of students.  
*Staff*
- 15.387 Seminar on Communication Problems in Science and Technology (A)**  
*Prereq.:* 15.331  
*Year:* G (1) 3-0-6  
 Utilization of scientific and technological information by research and development "problem solvers." Nature of the flow of information in science and technology. The "publication explosion" and the system's response to it. Role of the professional societies in dissemination of information. Impact of bureaucratic organization on flow of information. Problems of information flow between science and technology. Transfer of technology among nations.  
*Allen*
- 15.391 Doctoral Seminar in Organization Studies I (A)**  
*Prereq.:* —  
*Year:* G (1, 2) 2-0-7
- 15.392 Doctoral Seminar in Organization Studies II (A)**  
*Prereq.:* 15.391  
*Year:* G (1, 2) 2-0-7  
 Seminar covering the basic fields of social psychology, individual psychology, and sociology for purposes of preparing the doctoral candidate for his doctoral examinations. Basic concepts, theories, and research methods serving as focus for the seminar. (*Restricted to doctoral candidates.*)  
*Schein*
- 15.393 Doctoral Seminar on Career Development and Adult Socialization (A)**  
*Prereq.:* 15.333  
*Year:* G (2) 2-0-7  
 Seminar for doctoral students in organization studies, covering the topics of career choice, career paths in organizations, career crises, personal changes induced by occupational career, and organizational factors such as recruitment, training, and management development. Emphasis on research and theory. (*Admission by permission of instructor.*)  
*Schein*
- 15.412 Financial Management**  
*Prereq.:* 15.501T  
*Year:* G (2) 3-0-6  
 Analysis of financial decisions central to firm's choice of assets. Central question of what assets to acquire and how to finance them covered under the following areas: forecasting the need for funds and techniques of cash budgeting; analysis of volume of short-term assets and sources of short-term funds; evaluating investment projects and programs and their financing; determinants of internally generated funds; analysis of securities and the capital markets. (*Primarily for Sloan School of Management graduate students; others admitted only by permission of instructor.*)  
*S. Myers*
- 15.422 Investments (A)**  
*Prereq.:* 15.092 or 15.591; 15.412  
*Year:* G (1) 3-0-6  
 Analysis of investments in common stocks, bonds and other financial assets. Primary focus on inputs to portfolio construction, efficient diversification of investments, and the selection of portfolios by investors. Consideration of capital asset pricing under uncertainty and its implications for evaluating the performance of investment trusts and portfolios. Discussion of random-walk "efficient" market and emphasis on its implications for charting techniques and security analysis. Other areas covered: effects of dividend policy, earnings projections, primary and secondary issues, and mergers on security prices. Strong emphasis on empirical testing of hypotheses. Original research paper required.  
*Scholes*
- 15.423 The Management of Financial Intermediaries (A)**  
*Prereq.:* 15.422  
*Year:* G (2) 3-0-6  
 Management of assets and liabilities under conditions of uncertainty. Portfolio considerations underlying asset diversification, the interrelationships between yields and the liabilities which finance those assets. Techniques for the reduction and specialization of risk. The nature and formation of expectations under conditions of uncertainty. (*Not offered 1969-70.*)  
*Cootner*
- 15.432 Capital Markets and Financial Institutions (A)**  
*Prereq.:* 15.412  
*Year:* G (2) 3-0-6  
 The role and functioning of the capital and money markets as a device for the allocation of resources, the

channeling of investable funds, and the reallocation of risk; financial institutions operating in these markets, principles governing the management of their assets and liabilities. *Modigliani*

**15.442 Business Forecasting (A)**

Prereq.: 15.091

Year: G (2)

3-0-6

Forecasting problems of concern to production and financial decisions within the firm. Time divided about equally between short-run (daily, weekly, monthly) forecasting using exponential smoothing and related techniques, and aggregate industry and economy-wide economic forecasting with longer horizons of six months or more. Two term papers required. Computer-oriented subject. Usage of a programming facility, TROLL, developed particularly for econometric simulation and forecasting problems. *Kuh*

**15.452 Taxation and Business Management (A)**

Prereq.: 15.412

Year: G (1)

3-0-6

Analysis of effect of taxation on conduct of business. Concentration on major decisions in which taxes impinge on the firm or its managers; concern with both theory and relevant empirical evidence. Topics covered: the "double-taxation" of dividends; the effect of capital gains taxation on the flow of capital and labor to business; incentives for investment; compensation planning; the effect of taxation on effort; alternatives to income taxation. *D. M. Holland*

**15.46 Financial Administration of Industry (A)**

Prereq.: 15.412

Year: G (1)

3-0-6

Analysis of specific financial problems confronting business managers. Emphasis on the analysis and development of criteria and models for financial decision making under conditions of uncertainty. *Pogue*

**15.483J Flight Transportation (A)**

(Same subject as 1.221J, 16.751J)

Prereq.: 15.412; 15.591 or 16.30

Year: G (1)

3-0-6

Integrated discussion covering basic concepts and operational characteristics of flight transportation systems. Methods of predicting vehicle performance, anticipating future design trends, and determining direct operating cost, airport design and functional layout; guidance and control techniques, both in terminal area and en route, communication and radar system performance. *S. Myers, Bone, R. H. Miller*

**15.484J Flight Transportation Seminar**

(Same subject as 1.222J, 16.752J)

Prereq.: —

Year: G (1)

1-0-2

Economics of airline operation, problems of financing and of domestic and international route allocation. Subject developed around seminars presented by speakers from the regulatory agencies, national and international organizations and industry on particular phases of flight transportation. Preparatory lecture preceding each seminar. Opportunity for students to conduct studies in their area of major specialization on a particular topic covered by the subject. *S. Myers, Bone, Browne*

**15.501T Information and Decision Systems I**

Prereq.: —

Year: G (1)

4-0-8

Introduction to basic concepts and techniques of collecting, processing, and reporting information generated by various organizations. Emphasis on basic financial and management accounting concepts. Introduction to computers and techniques of financial decision making. Examination of the organizational goal structure and decision-making process which determines information needs. *Rockart*

**15.502 Information and Decision Systems II**

Prereq.: 15.501T

Year: G (2)

4-0-8

Introduction to the functional fields of finance, marketing, and operations. Exposure to a number of major problems in these fields with special emphasis on the interdependence of the functions. Not an exhaustive treatment but enough depth in each field to serve as a basis for further study, with overview and integration to provide context in which further detailed study has more meaning. Development of problem-solving skills in defining problems, creating alternatives, assessing consequences of alternatives, and developing criteria for choice of alternatives. *Galbraith*

**15.503T Managerial Accounting (A, except XV)**

Prereq.: —

Year: G (1, 2)

4-0-8

Concepts and methods pertinent to financial information and control systems with emphasis on managerial uses. Relevant content of 15.501T plus selected topics from 15.511 and 15.522. Designed to provide comprehensive coverage for students electing only a small number of management subjects. (Not open to students who have taken 15.501T.) *T. M. Hill*

**15.511 Managerial Information and Controls (A)**

Prereq.: 15.501T or 15.503T

Year: G (1, 2)

3-0-6

Consideration of issues involved in the use of control systems as an effective management tool and in building a framework useful in the design and evaluation of management control systems. Critical evaluation of uses and limitations of various forms of management control systems presently used by companies. Systems involving budgeting, profit planning and use of investment or profit centers. Examination of several issues bearing on management control systems, including program planning and budgeting, cost-effectiveness analysis and experience with centralized systems such as those operating in Eastern European countries. Case materials from a variety of organizational settings to supplement readings. *Morton*

**15.512 Advanced Concepts in Managerial Information for Planning and Control (A)**

Prereq.: 15.502

Year: G (2)

3-0-6

Analysis of fundamental elements and requirements of efficient planning and control systems. Examination of the way objectives are formed and translated into operationally meaningful propositions; the role of signals in hierarchy of planning and of managerial information system needed to apply measurements and generate appropriate signals. Analysis of hierarchical relations between means and ends and the factors affecting the organization structure, presentation of quantitative approaches to issues underlying centralization and decentralization. Relationship between information system and the transformation and feedback-control process. Development of requirements for probabilistic, functional and associative systems. Justification for such future systems on basis of need for causal-diagnostic and prognostic information rather than post-mortem symptomatic. Discussion of implications of information technology on system design, with orientation centered on managerial needs rather than hardware. *Zannetos, Rockart*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## MANAGEMENT

### 15.522 Accounting Measurement Theory and Problems (A)

Prereq.: 15.501T or 15.503T  
Year: G (2)

3-0-6

In-depth examination of issues underlying accounting theory as applied to measurement of income and wealth. Analysis of various meanings of concepts such as value, progress, objectivity, reliability, freedom from bias, validity, verifiability, and efficiency and methods for quantifying them. Emphasis on relationships between measurements of economic theory, statistics and accounting theory. Detailed examination of implications of computerized systems for measurements for assessing managerial efficiency and for financial reporting.

T. M. Hill, Zannetos

### 15.531 Control Processes and Systems (A)

Prereq.: 15.501T or 15.503T  
Year: G (1)

3-0-6

Examination of various control concepts and systems, such as engineering, biological and social, and their implications for management sciences. Attempt to unify these concepts as a first step toward the evolution of a unified theory of managerial control systems. Class participation and individual exploration of ideas. Choice by students of a management situation which they will represent as a control process, analyze its structure and identify its necessary components.

Morton

### 15.54 Management Information Technology

Prereq.: 15.05  
Year: U (1, 2)

3-0-6

Introduction to basic computer technology. Formulation of procedures for use in a computer. Data representation and coding. Laboratory experience in machine language programming. Survey of computer hardware. Assemblers, computers, loaders, etc. Higher level languages.

Gorry

### 15.541 Management Information Technology (A)

Prereq.: 15.501T or 15.503T  
Year: G (1, 2)

3-0-6

More intensive coverage of subject matter in 15.54.

Gorry

### 15.542 Management Information Systems (A)

Prereq.: 15.541, 15.712, 15.812  
Year: G (1, 2)

3-0-6

Managerial applications of digital computers. Emphasis on the use of computers in integrated information and decision systems. Topics covered include information-based theories of management, a brief survey of information technology, the cost and value of information, techniques of system analysis and design, organizational implications of information technology. Lectures, case studies, programming project, and field studies.

Morton, Rockart

### 15.544 Systems Simulation (A)

Prereq.: 15.091, 15.541  
Year: G (1)

2-0-7

Introduction to simulation and model building using high-speed digital computers. Study of discrete (as opposed to continuous) simulation systems and specialized languages such as GPSS, SIMSCRIPT, SIMULA, and GASP. Techniques required to use FORTRAN for event-oriented simulation. Consideration of the proper experimental design, statistical analysis of results, effects of random-number generation techniques and validation. Several homework problems involving computer programs for both the IBM 1130 and 360. Term project required.

M. M. Jones

### 15.555 Advanced Computer Systems (A)

Prereq.: 6.251 or 15.542  
Year: G (1, 2)

2-0-7

Seminar in advanced computer systems. Topics of current faculty interest, such as operating systems, time sharing, multiprocessing and multiprogramming.

Gorry, Ness

### 15.56 Management Science Field Study

Prereq.: 6.28, 14.371, 15.10  
Year: U (1)

4-0-8

Problems of practical application of management science techniques. Review of pertinent literature, field work, and case studies. Consideration of organizational, data, computational and dynamic aspects of automatic decision systems in production, marketing, and financial areas.

Carroll, Kaufman, Little

### 15.565 Seminar in Information and Control Systems (A)

Prereq.: 15.512, 15.542  
Year: G (2)

2-0-7

Advanced treatment of various topics in the area of sophisticated information and control systems. Characteristics of systems which possess the necessary intelligence to filter, analyze, and associate cause and effect before reporting exceptions to management. The impact of developments in cybernetics, artificial intelligence, and management sciences in the design of managerial information and control systems. Presentation and study of the result of ongoing research of faculty and students. (Primarily for doctoral candidates and other advanced graduate students.)

Zannetos

### 15.571 Feedback Dynamics Laboratory

Prereq.: —  
Year: U (1, 2)

2-6-4

Laboratory experience with the dynamics and stability of feedback systems. Emphasis on feedback loops using physical equipment but including model experimentation in the form of analog and digital simulation and group role-playing simulation of feedback behavior in economic and management systems. Student design of laboratory experiments to illustrate system dynamic behavior. Readings and discussion stressing the generality of feedback processes as concepts unifying the physical sciences, engineering, the social sciences, and management. (Open to students in the Dynamics of Management Systems Program in Course xv. Others by permission as resources permit.)

Forrester

### 15.572 Principles of Systems

Prereq.: 15.571, 18.034  
Year: U (1, 2)

3-0-6

Principles of system structure and dynamic behavior. Similar to 15.573. Intended as a basis for the project work in 15.576.

Forrester

### 15.573 Principles of Systems (A)

Prereq.: 18.034  
Year: G (1, 2)

3-0-6

Principles of system structure and dynamics. Emphasis on managerial, economic, and social systems. Non-mathematical treatment of feedback loop behavior. Development of concepts that allow one to understand stability and growth processes extending to multiloop, non-linear systems. Aim of building an intuitive foundation as a basis for simulation studies of complex systems.

Forrester

### 15.574 System Mathematics

Prereq.: 15.572, 18.034  
Year: U (1, 2)

3-0-6

Mathematics of dynamic behavior in feedback systems. Similar to 15.575.

Pugh

**15.575T System Mathematics (A)**

Prereq.: 18.034

Year: G (1, 2)

3-0-6

Development of dynamic system principles through analytic techniques. Review of linear differential equations. Frequency domain: Laplace and Fourier transforms, stability criteria, and root loci. Transfer functions and signal flow graphs. Relationship of component behavior to system behavior. Pugh

**15.576 Industrial Dynamics I**

Prereq.: 15.572, 15.574

Year: U (1, 2)

3-0-6

Similar to 15.58 but with more emphasis on projects for students who have completed 15.572. Swanson

**15.577 Industrial Dynamics II**

Prereq.: 15.576

Year: U (1, 2)

3-0-6

Similar to 15.582. Roberts

**15.578 Research Seminar in Dynamics of Management Systems I**

Prereq.: 15.577

Year: U (1)

3-0-6

**15.579 Research Seminar in Dynamics of Management Systems II**

Prereq.: 15.578

Year: U (2)

3-0-6

Special research topics and papers relating to dynamics of management, economic, or social systems. Special emphasis on quality of writing. Forrester, Roberts

**15.58 Industrial Dynamics**

Prereq.: —

Year: U (1, 2)

3-0-6

Study of the firm as a complex system emphasizing the interactions between decision, actions, and information flows. Analysis of the dynamic behavior of firms by computer simulation with emphasis upon designing policies and information flow to generate more effective behavior. Treatment and analysis of the properties of complex feedback systems. Organizational control and the growth of a firm viewed as feedback processes. Discussion of the applications of industrial dynamics ideas in real situations. Student projects to analyze a situation using the concepts of industrial dynamics and computer simulation. Swanson

**15.581 Industrial Dynamics I (A)**

Prereq.: 15.012 or 18.034

Year: G (1, 2)

3-0-6

Policy formulation and managerial decisions treated from an over-all systems view; primary emphasis on interaction of separate elements of a firm, industry, or nation. Recognition of underlying structure of such organizations, including the flows of men, materials, money, capital equipment and orders, tied together by information flows used in the decision-making network. Computer simulation of feedback models of such situations forms the basis of managerial policy experimentation. Treatment and analysis of the properties of complex feedback systems. Student projects to analyze a situation using the concepts of industrial dynamics and computer simulation. Swanson

**15.582 Industrial Dynamics II (A)**

Prereq.: 15.58 or 15.581

Year: G (1, 2)

3-0-6

Treatment of the process and problems of application and implementation of industrial dynamics. Class divided into teams, each studying the major systems problems of a

cooperating organization. Goal of student effort: eventual implementation of policy changes in the organization. Study of previous and current industrial dynamics applications in industry and government. Discussion sessions with management consultants and operations research staff. Selected readings to help develop understanding of the implementation process. (Enrollment limited, admission by permission of instructor.) E. B. Roberts

**15.586 Professional Writing Tutorial**

Prereq.: 15.571, 15.572

Year: U (2)

3-0-6

Intensive writing practice and tutorial. Stress on re-writing short papers to achieve high quality in presentation, purpose, clarity of underlying thought processes, suitability to audience, choice of structure, selection of words, and conciseness. Mutual coaching and criticism within student terms. High standard of accomplishment a requirement. Selection of topic for 15.578 at end of term. (Required in Program 5 of Course xv. Other students admitted by permission of instructor as resources permit.) Forrester

**15.587 Research Seminar in Dynamics of Management Systems I (A)**

Prereq.: 15.573, 15.581, 15.582

Year: G (1, 2)

Arr.

**15.588 Research Seminar in Dynamics of Management Systems II (A)**

Prereq.: 15.587

Year: G (1, 2)

Arr.

Focus of each seminar on a theme within which student research will produce short papers chosen to fill gaps in literature of dynamics of social systems. High written quality as a goal aimed at occasional publication of collections of student papers. A research activity in itself or a companion to thesis or project research. (Admission by permission of the instructor and after prior demonstration of writing ability.) Forrester, Roberts

**15.591 Mathematical Programming I**

Prereq.: 18.034

Year: G (1, 2)

3-0-6

Linear programming. Systems of linear equations, simplex method, duality theory. Sensitivity analysis, geometric view of linear programming. Transportation and network flow problems. Introduction to advanced topics such as integer programming and generalized programming. J. F. Shapiro

**15.592 Mathematical Programming II (A)**

Prereq.: 15.092 or 15.591

Year: G (2)

3-0-6

Non-linear, integer, and dynamic programming. Topics: convex set theory, gradient methods, Kuhn-Tucker theorem, quadratic programming and a study of non-linear programming algorithms. Integer programming topics: branch and bound methods, group theoretic algorithms, and the cutting plane method. J. F. Shapiro

**15.593 Stochastic Systems (A)**

Prereq.: 6.28; 15.092 or 15.591

Year: G (1)

3-0-6

Birth and death processes, renewal theory, Markov chains, diffusion processes. A wide variety of applications in queuing theory. Additional applications in inventory, economic growth, and mathematical learning theory. Staff

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## MANAGEMENT

### 15.597 *Bayesian Analysis Studies (A)*

Prereq.: 15.095

Year: G (1)

3-0-6

Primary emphasis on Bayesian methods in multivariate problems. Content varying from year to year. Typical topics: the multivariate normal distribution, best of several processes problem, stratified sampling, bias, extended natural conjugate analysis of the normal process, multiple regression, multivariate regression, simultaneous equation systems, Bayesian interpretation of standard multivariate inference statements. Term paper on selected multivariate statistical problems.

Kaufman

### 15.598 *Case Studies in Quantitative Analysis (A)*

Prereq.: 6.28; 15.092 or 15.591

Year: G (1)

3-0-6

Discussion of the successes and difficulties experienced in applying quantitative methods to management decision making in areas such as inventory and production control, scheduling, marketing strategy, research and development planning, equipment replacement and reliability control. Consideration of business, industrial, and military problems in terms of their basic elements. Case studies and field work.

Kaufman

### 15.599 *Research Seminar in Quantitative Analysis (A)*

Prereq.: —

Year: G (1, 2)

2-0-7

Special topics in quantitative management forming the basis for student research. Review of technical literature, guest lectures, and general discussion.

Staff

### 15.61 *American Legal System*

Prereq.: 14.01

Year: U (1, 2)

3-0-6

Analysis of the American legal system as a process for ordering our society. Consideration of selected legal problems to reveal the operation of the major component elements of the system: the judicial, legislative, administrative and private law-making power. Consideration of substantive law primarily from the standpoint of the process for generating and modifying legal policy. Emphasis on the problems of the law of business institutions. Extensive reading of case law as well as textual materials and legal essays. Research projects involving use of a law library.

Jacks

### 15.62J *Legal Aspects of New Technology*

(Same subject as 2.96J and 16.79J)

Prereq.: —

Year: G (1)

3-0-6

Intellectual property and the law. The nature and progress of invention past and present, the evolution of relevant legal doctrines as an expression of public policy, and present legal doctrines for the treatment of intellectual property as trade secrets, proprietary data, copyrighted materials and patents. Critical analysis of the patent and copyright systems and pending legislation. The impact of selected new technologies — computer technology and xerography. The role of the Federal agencies — with emphasis on the Department of Defense and NASA. The employer-employee relationship, incentives for innovation, employment restraints and employee mobility. Term paper or project required.

Baram

### 15.65 *Labor Law*

Prereq.: 15.61

Year: U (1)

3-0-6

The legal structure of labor-management relations. Review of evolution of labor relations law in the twentieth

century and intensive study of the current Federal labor legislation. Among subject areas examined from the legal standpoint are the organization of labor, negotiation and administration of the collective agreement, the status of economic weapons (strikes, boycotts, lockouts, etc.), the relations between the individual and his union, and the role of federalism in the law of labor relations. Extensive use of case materials, including tape-recorded cases.

Jacks

### 15.661 *American Legal System (A)*

Prereq.: 15.012

Year: G (1, 2)

3-0-6

More intensive coverage of subject matter covered in 15.61.

Jacks

### 15.671J *Labor Economics (A)*

(Same subject as 14.671J)

Prereq.: 14.64T or 15.312

Year: G (1)

3-0-6

Primary emphasis on the determination of wage levels and wage differentials through an analysis of labor supply and labor demand, as affected by economic as well as by institutional factors. The impact of unions on both wage and non-wage elements of collective bargaining in the light of the characteristics and objectives of particular unions. Other special topics growing out of recent research in labor economics.

C. A. Myers, Piore

### 15.672J *Public Policy on Labor Relations (A)*

(Same subject as 14.672J)

Prereq.: 14.64T or 15.312

Year: G (2)

3-0-6

Major trends in labor legislation, the legality of union activities, protection of the right to organize and bargain collectively, regulation of wages and hours, governmental machinery for the adjustment of labor disputes, and social insurance. The broad economic and social questions raised by these trends. (Not offered 1969-70.)

D. V. Brown, Piore

### 15.673 *Labor-Management Relations and Public Policy (A)*

Prereq.: 15.184

Year: G (1)

3-0-6

Brief survey of the background of labor law, followed by analysis of the nature of the collective bargaining process, its major issues and points of contention. Discussion of selected problems in public policy. (Restricted to Sloan Fellows.)

C. A. Myers, D. V. Brown

### 15.674J *Comparative Systems of Industrial Relations and Human Resource Development (A)*

(Same subject as 14.674J)

Prereq.: 14.64T or 15.312

Year: G (2)

3-0-6

International and comparative analysis of industrial relations systems and systems of human resource development. Concentration on an examination of selected issues involving interest groups and the strategies of economic development, including discussion of the nature and functions of labor and management organization in different contexts; the role of the state in establishing procedures and in shaping the substance of industrial relations; the participation of interest groups in the formulation of economic and social policy; manpower and economic growth in the context of comparative systems of human resource development; external influences on national industrial relations systems and human resource development.

C. A. Myers

- 15.691J Research Seminar in Industrial Relations (A)**  
(Same subject as 14.691J)  
Prereq.: 15.671J or 15.672J  
Year: G (1) 3-0-6  
Discussion of important areas for research in industrial relations, frameworks for research, research techniques, and methodological problems. Centered mainly on the thesis research of advanced graduate students.  
*C. A. Myers*
- 15.692J Research Seminar in Industrial Relations (A)**  
(Same subject as 14.692J)  
Prereq.: 15.691J  
Year: G (2) 3-0-6  
Continuation of 15.691J.  
*C. A. Myers*
- 15.70T Information and Decision Systems I**  
Prereq.: —  
Year: U (1) 4-0-8  
Introduction to basic concepts and techniques of collecting, processing, and reporting information generated by an organization. Emphasis on basic financial and management accounting concepts. Introduction to computers and techniques of decision making for various management decisions such as capital budgeting.  
*Rockart*
- 15.71T Information and Decision Systems II**  
Prereq.: 15.70T  
Year: U (2) 4-0-8  
Introduction to the functional fields of finance, marketing and operations. Exposure to a number of major problems in these fields with special emphasis on the interdependence of the functions. Not an exhaustive treatment but enough depth in each field to serve as a basis for further study, with overview and integration to provide context in which further detailed study has more meaning. Students are expected to develop problem-solving skills in defining problems, creating alternatives, assessing consequences of alternatives, and developing criteria for choice of alternatives.  
*Galbraith*
- 15.712 Operations Management (A)**  
Prereq.: 15.012, 15.092, 15.331  
Year: G (1, 2) 3-0-6  
Study of decision-making techniques for the economic problems of operations management, including operations scheduling, inventory control and facilities design, with emphasis on problems of implementation. Examination of a wide variety of institutional settings, including factories, utilities, and government offices. Applied theory from prerequisite subjects including mathematical programming, simulation, statistical models and organizational design.  
*Crowston, Pierce*
- 15.73 Management Laboratory**  
Prereq.: 14.01 or 15.71T  
Year: U (1, 2) 3-3-3  
Philosophy and methodology of industrial improvement. Application of tools and techniques of improvement to real problems in industry. Formation of a planned program for continued improvement within a company. Economic and human factors in the improvement process. Problems in management creativity. Laboratory experimentation. Participation in actual company situations.  
*Goodwin*
- 15.741 Advanced Management Laboratory (A)**  
Prereq.: 15.501T  
Year: G (1, 2) 3-3-3  
Improvement as a management philosophy. Coordination of methods of analysis, design, measurement, and control of improvement activity. Critical analysis and various improvement techniques and methods of implementing improvement in industry. Involvement in actual industrial situations.  
*Goodwin*
- 15.781 Studies in Manufacturing Analysis (A)**  
Prereq.: 15.712  
Year: G (1) 4-0-5  
Examination of studies from current literature devoted to formal methods for analyzing production management problems. General readings bearing on each method of analysis also included. Analysis of case studies as time permits.  
*Crowston*
- 15.791 Operations Planning and Control Systems (A)**  
Prereq.: 15.712  
Year: G (2) 3-0-6  
Treatment of operations planning and control system design problems from the mathematical, economic, information, and operational points of view. Critical path methods and extensions. Job shop scheduling including underlying sequencing theory and research in heuristic methods. Flow shop control with emphasis on information systems aspects. Lectures, case studies, and term project.  
*Carroll*
- 15.792 Manufacturing Decisions Seminar (A)**  
Prereq.: 15.712  
Year: G (2) 3-0-6  
Primary focus on the improvement of decision processes regulating the organization's operations. Design variables affecting the decision process: organizational structure, information system, decision programs and algorithms, and the reward-penalty system. Mutual interdependence of the four classes of design variables as they affect organizational performance; selection of appropriate combination of design variables to accomplish given tasks.  
*Galbraith*
- 15.812 Marketing**  
Prereq.: 15.092  
Year: G (1, 2) 3-0-6  
Analysis of the marketing problems of businesses and other public and private institutions. Consideration of the marketing environment of an organization and its strategies with respect to marketing decisions. Development of an understanding of the consumer or other client of an organization based on behavioral science concepts. Study of marketing decision areas, including product planning, pricing, advertising, selling, promotion, distribution, and competitive strategies. Models and information system concepts presented as applicable.  
*Urban*
- 15.821 Business Game (A)**  
Prereq.: 15.71T or 15.812  
Year: G (1, 2) 3-0-6  
Managerial decision making brought out through team participation in a complex computerized business game. Marketing planning, decision planning, decision making in product development, distribution channels, pricing, sales force, advertising, production and inventory control, and financial planning. Appreciation for interactions and the need for imaginative strategies and integrated policies. Emphasis on producing workable solutions to ill-structured problems by systematic problem definition, strategy formulation, data collection, and evaluation of alternatives.  
*Anstutz*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## AERONAUTICS AND ASTRONAUTICS

### 15.832 *Management Measurement and Information (A)*

Prereq.: 15.091

Year: G (2)

3-0-6

Focus upon management's need for non-accounting measurements and information from sources both internal and external to the organization. Analysis of secondary sources of information and methods for generating primary measurements, generally from human respondents. Development of scales of measurement and psychometric procedures. Sampling theory from both a classical and a Bayesian viewpoint. Non-parametric statistical procedures for analyzing measurements. Examples from all areas of management. *Montgomery*

### 15.842 *Influence Processes and Mass Communications (A)*

Prereq.: 15.091

Year: G (2)

3-0-6

Focus upon management problems arising in connection with attempts to communicate with and influence a market or some other "public" in an organization's external environment. The sociological and social psychological literature on mass communications, attitude change, and the diffusion of innovations as the foundation of the subject. Primary emphasis on bringing models and research findings from these fields to bear on the problems of marketing communication. Lectures, discussions, case problems, and research project. *Silk*

### 15.852 *Marketing Models (A)*

Prereq.: 15.092, 15.812

Year: G (2)

3-0-6

Examination of the state of the art in marketing models with emphasis on recent advances. Topics include: new product planning models, adaptive control models, microanalytic simulation of competitive environments, stochastic models of consumer behavior, and on-line interactive use of models. Criticism in depth of a number of models and participation in model development project. *Montgomery, Urban*

### 15.891 *Research Seminar in Marketing (A)*

Prereq.: 15.812

Year: G (2)

3-0-6

Seminar on current marketing literature and current research interests of faculty and students. Topics such as the theory of consumer behavior, simulation of consumer product markets, marketing experimentation, and the development of behavioral models from consumer panel data. *Staff*

### 15.901 *Study and Research in Management System Dynamics*

Prereq.: —

Year: U (1, 2)

Arr.

Integrated program for juniors and seniors in the Sloan School of Management departing from the usual format of separate academic subjects in management and the engineering minor. Research and tutorial program in system dynamics supported by individual study of the normal functional subject matter in management. Research and guided study supervised by the staff of the School. (Enrollment limited to ten students per class, admission only by permission of the systems curriculum committee of the Sloan School of Management.) *Forrester*

### 15.921 *New Enterprises (A)*

Prereq.: 15.412, 15.501T

Year: G (1)

2-0-7

Organization and management of technically based companies. Financing of new enterprises through private, corporate and public capital sources. The role of government and the impact of Federal R and D on corporate growth. Trends in science and technology in terms of business opportunities. Preparation of cases by study of the operations of local companies and detailed

development of plans for launching of new business ventures. (Enrollment limited to 15 students: admission by permission of instructor.) *R. S. Morse*

### 15.93 *Business Practice and Policy Determination (A)*

Prereq.: 15.312, 15.412, 15.712, 15.812

Year: G (1, 2)

3-0-6

A terminal subject dealing with the approach to general management problems affecting all facets of the enterprise. Discussions and readings tracing objectives, policy determinations, and practices of business units at all stages of growth from foundation to corporate maturity. Attempt to develop the integrative ability of students to use knowledge gained in core subjects and to prepare them for launching their careers in industrial management with a balanced understanding of their business as an entity. —

### 15.944 *Foreign Policy for Executives*

Prereq.: —

Year: G (2)

3-0-6

Examination of significant problems of contemporary American foreign policy and international relations of particular concern to management. Special attention given to developments in Communist countries, problems of the emerging nations, changes in Western Europe, issues of defense and arms control, and planning and administering foreign policy operations. (Restricted to Sloan Fellows.) —

### 15.95 *Special Studies in Management*

Prereq.: —

Year: U (1, 2)

Arr.

Special tutorial arrangement with a faculty member for guided reading, research, laboratory, or teaching experience. *Staff*

### 15.951-15.959 *Special Studies in Management (A)*

Prereq.: —

Year: G (1, 2)

Arr.

For graduate students who desire to do advanced work or to carry out some special investigation of a management problem not specifically covered elsewhere and not qualifying as a thesis. Readings, conferences, laboratory and field work, and reports. *Staff*

### 15.98 *Seminar in Administration (A)*

Prereq.: 15.181

Year: G (1)

3-0-6

### 15.99 *Seminar in Administration (A)*

Prereq.: 15.181

Year: G (2)

3-0-6

Study of fundamental economic, financial, organizational and administrative relationships analyzed and discussed by experienced leaders in business, labor and public administration. Examination of managerial philosophies and practices in the field and in seminar discussions. (Restricted to Sloan Fellows.) *Gil*

## 16.

### *Aeronautics and Astronautics*

### 16.001T *Thermodynamics and Statistical Mechanics*

Prereq.: 8.02, 18.02

Year: U (2)

4-0-8

Introductory concepts and definitions. First and second

laws of thermodynamics. Thermodynamic temperature, entropy, and availability, with application to flow processes and energy conversion. Statistical thermodynamics and chemical equilibrium. Properties of simple systems. *Wachman*

### 16.01 Dynamics

Prereq.: 8.02, 18.034

Year: U (1, 2)

4-2-6

Dynamics, with applications to aeronautical and astronautical problems. Kinematics and dynamics of particles and of groups of particles. Relative motion as seen by accelerating and rotating observers. Particles of variable mass. Mass properties of rigid bodies, the inertia tensor, geometric and mass symmetries. Kinematics and dynamics of a rigid body in general motion. Euler's dynamical equations, gyroscope equations. *Potter, Wrigley*

### 16.02 Aerodynamics

Prereq.: 16.001T

Year: U (1, 2)

4-2-6

Introduction to the aerodynamics of flight vehicles. One-dimensional flow of a perfect gas, shock and expansion waves, converging-diverging nozzles, supersonic airfoils. Motion of fluid in three dimensions, conservation equations. Vorticity, Kelvin's theorem, Bernoulli's equation. Two-dimensional constant-density potential flows. Discussion of boundary layers and elementary viscous flows. Small perturbation theory, airfoils, and three-dimensional wings in subsonic and supersonic flow. *Covert*

### 16.03 Gasdynamics

Prereq.: 16.001T, 18.034

Year: U (1)

4-2-6

Introduction to continuum gas dynamics with emphasis on basic fluid mechanical phenomena. Kinetic theory foundations. Nature of fluids — kinetic and continuum pictures. Boltzmann equation and general conservation theorems. Navier-Stokes equations as continuum approximation. Momentum theorems. Kinematics of fluids. Kelvin's and related theorems. Dynamics and thermodynamics of compressible, rotational flows. Disturbances in gases at rest. Ackeret theory. Quasi-one-dimensional flows. Normal and oblique shocks. Prandtl-Meyer theory. Incompressible, inviscid flow theory. Elementary viscous flows. *McCune*

### 16.031 Topics in Fluid Mechanics

Prereq.: 16.02 or 16.03

Year: U (2)

3-0-6

Application of potential theory to inviscid flow problems. Green's theorem and source, doublet, and vortex distributions. Application to thin wing problems. Two-dimensional thin airfoil theory. Prandtl lifting-line theory. Prandtl-Glauert transformation for subsonic flows. Unsteady potential flows, theory of acoustic disturbances. Application to supersonic airfoil problems. Application of Navier-Stokes equations to viscous fluid problems. Some exact solutions exhibiting boundary layer behavior. Derivation of boundary layer equations and certain classical results. Karman momentum integral equation and its use. Brief discussion of separation, transition and turbulence. *McCune*

### 16.041 Aerodynamics — Viscous Fluids (A)

Prereq.: 16.02, 18.05

Year: G (1)

3-0-9

Introduction to viscous flows. Basic flow equations; exact solutions; low Reynolds number cases; boundary layer flows; brief discussion of stability; transition; turbulent boundary layers. Lectures to be supplemented by occasional demonstrations. *Finston*

### 16.042 Aerodynamic Heating (A)

Prereq.: 16.041, 18.06

Year: G (2)

3-0-9

Extension of discussion in 16.041 to include thermodynamic aspects. Kinetic heating at high speeds; heat transfer through boundary layers; discussion of methods of reducing surface temperatures. Application to hypersonic aircraft and re-entry bodies, including real gas effects at high temperatures. *Finston*

### 16.051 Advanced Gas Dynamics (A)

Prereq.: 16.02 or 16.03; 18.05

Year: G (1)

3-0-9

Introduction to real gas description in terms of kinetic theory and statistical mechanics. Dynamics of a perfect gas. Irrotational and rotational flows. Character and analysis of subsonic, transonic, supersonic and hypersonic, inviscid, multidimensional flows. Non-steady flow, shock waves, similarity concepts, blast waves, characteristics, small disturbances, approximation procedures, integral and numerical methods. Application to shock tubes, wings, blunt and slender bodies, blast waves. *Moran, Baron*

### 16.052 Real Gas Dynamics (A)

Prereq.: 16.051

Year: G (2)

3-0-9

Dynamics of a real gas. High-temperature and rarefied flow under situations including vibrational excitation, translational, chemical, and radiative non-equilibrium. Radiation coupled gas dynamics. Wave propagation with relaxation phenomena, dispersion. Extension of similarity, characteristics, and shock concepts. Surface reaction coupling. Application to hypersonic test facilities, mass transfer, blunt and slender configurations, viscous layers, wakes. *Baron*

### 16.065 Physics of High-Speed Gas Flows (A)

Prereq.: 16.03, 18.06

Year: G (1)

3-0-9

### 16.066 Physics of High-Speed Gas Flows (A)

Prereq.: 16.065

Year: G (2)

3-0-9

Elements of statistical mechanics and kinetic theory. Discussion of the Boltzmann equation and its integration to give the Navier-Stokes equations. Rarefied gas dynamics. Elements of quantum mechanics. Mechanisms of dissociation, ionization, radiation, and relaxation. Elements of electrodynamics of continuous media. The physics of a continuous medium in motion. *Trilling*

### 16.067 Gas-Surface Interactions (A)

Prereq.: 8.05 or 8.211

Year: G (1)

3-0-9

Discussion of behavior of a rarefied gas at a solid boundary in terms of processes occurring on collisions of gas molecules with the surface. Processes including reflection and diffraction of molecular beams, energy and momentum accommodation, and adsorption. Experimental and theoretical methods for treating accommodation coefficients and free molecule drag coefficients. Discussion of the origin of van der Waals forces and the application of Lennard-Jones potential to interface problems. *Wachman*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

AERONAUTICS AND ASTRONAUTICS

- 16.071 Aerodynamics of Wings and Bodies (A)**  
Prereq.: 16.02 or 16.03  
Year: G (1) 3-0-9

- 16.072 Aerodynamics of Wings and Bodies (A)**  
Prereq.: 16.071  
Year: G (2) 3-0-9

Coordinated presentation of theoretical methods useful for predicting performance and stability of thin lifting surfaces and slender vehicles in high-speed flight. Review of fluid mechanics, with emphasis on potential aerodynamics. Constant-density flow and procedures for indirectly introducing real-fluid effects. Application of the method of inner and outer solutions as a framework for analyzing cases such as the following: slender bodies or wing-body combinations, thin airfoils, and thin planar wings in subsonic and supersonic flight. Drag optimization techniques, non-planar lifting surfaces, flows with free vortices, transonic motion, unsteady flows, and other special topics selected in the light of currently important aeronautical problems. *Widnall*

- 16.09 Fields in Continuous Media**  
Prereq.: 8.02, 18.02  
Year: U (1, 2) 4-2-6

Definition of a continuous medium as an idealization of reality; kinematics, force and stresses; statement and formulation of fundamental laws (conservation of mass and charge, Newton, Maxwell, first and second thermodynamics, gravitation, with couplings among them); constitutive and dissipative relations and their connection with experiment or the molecular world; initial and boundary conditions; discontinuities and interfaces. Numerous demonstrations and sample applications with special interest in aeronautics and astronautics to be carried out throughout the term; mathematical tools introduced or developed as needed. *Trilling, Covert*

- 16.105 Applied Aerodynamics (A)**  
Prereq.: 16.02, 16.11  
Year: G (2) 3-0-6

Studies of flight vehicle performance including aerodynamics and characteristics of various types of power plant for a wide range of Mach numbers. *Larrabee*

- 16.11 Aerodynamics of Flight Vehicles**  
Prereq.: 16.02 or 16.03  
Year: U (2) 3-0-6

Development and examination of the potential and viscous flow concepts useful in evaluating the aerodynamic loads on flight vehicles. Attention directed toward the validity and limitations of the concepts. Introduction to the mechanics of boundary layers and heat transfer. *Bicknell*

- 16.12 Multivariable System Dynamics (A)**  
Prereq.: 16.01  
Year: G (2) 3-0-6

Case studies of multivariable dynamic systems ranging from traditional conservative mechanical vibrations, linear circuits, and feedback control systems to vehicle dynamics, optimization of non-linear systems, and optimal filtering. Treatment of sets of linear, variable-coefficient, differential equations using matrix and vector notations, adjoint functions, the state-space approach, and digital computation. *Halfman, Potter*

- 16.13T Special Problems in Interplanetary Flight (A)**  
Prereq.: 16.46 or 18.15  
Year: G (2) 3-1-6

Applications of linear perturbation theory to the problems of mission planning, trajectory selection, navigation, and guidance for interplanetary flight. Emphasis on the physical interpretation of optimum, analytic solutions to these problems. Comparisons between accurate but complex mathematical models and approximate but simple models. Numerical examples based on manned

missions to Venus and Mars. Analysis of ballistic as well as continuous-thrust trajectories. *Hollister, Stern*

- 16.15 Advanced Flight Vehicle Stability and Control (A)**  
Prereq.: 16.11  
Year: G (1) 3-0-6

Analytic solutions for non-linear problems in flight mechanics. Linear approximations to flight vehicle dynamics, including: classical airplane stability theory, stability derivative estimation, dynamic similarity laws, gust response, inertial cross coupling and spinning. Dynamics of simple aircraft-controller combinations. Analysis of flight test dynamic stability data. *Larrabee*

- 16.20 Solid Mechanics I**  
Prereq.: 8.01, 18.02  
Year: U (1, 2) 4-2-6

Fundamentals of solid mechanics. Principles of mechanics, vector properties of forces and moments, equilibrium of groups of particles. Statics, applications to trusses and beams, simple statically indeterminate structures. Concepts of strain and stress, with emphasis on tensor properties, transformation, principal axes. Stress equilibrium and strain compatibility. Stress-strain relations including anisotropy. Equations of elasticity, boundary conditions, applications to rods, beams, and plane stress. Introduction to plasticity. *Bisplinghoff, Mar, Pian, Statics of Deformable Solids. Witmer*

- 16.201 Solid Mechanics II**  
Prereq.: 16.20  
Year: U (1, 2) 4-0-6

Fundamentals of solid mechanics applied to analysis of flight vehicle structures. Plane stress, plane strain problems in curvilinear coordinates. Bending, shear, torsion of rods and thin wall beams. Introduction to energy principles and applications to statistically indeterminate structures. Buckling of columns and stability phenomena. Theories and modes of structural failure. *Dugundji*

- 16.21 Plates, Stability and Thermoelasticity (A)**  
Prereq.: 16.201  
Year: G (2) 3-0-9

Analysis of thermal stress arising from supersonic and hypersonic flight. Analysis of homogeneous, orthotropic and stiffened plates. Stability theory applied to structural problems. *Pian*

- 16.22 Shell Structures (A)**  
Prereq.: 16.201  
Year: G (1) 3-0-9

- 16.23 Shell Structures (A)**  
Prereq.: 16.22  
Year: G (2) 3-0-9

Elements of tensor analysis. General formulation of elasticity in curvilinear coordinates. Introduction to differential geometry. Development of shell equations in tensor form. Membrane behavior of thin shells. Bending behavior of thin shells. Various topics such as shallow shells, shells of revolution, asymptotic integration, large deflections, buckling, and inflated shells. (Not offered 1969-70.) *Dugundji*

- 16.24 Plasticity, Viscoelasticity and Creep (A)**  
Prereq.: 16.201  
Year: G (1) 3-0-9

Problems associated with viscoelastic and creep behavior of materials. Plastic and viscoelastic stress-strain relations. Discrete-element viscoelastic models, creep compliance and relaxation modulus. Linear viscoelastic stress analysis. Alfrey's theorem and its generalizations. Non-linear creep laws. Structural analyses in presence of creep. Creep buckling. Mechanical problems associated with solid propellants. Damping by means of viscoelastic materials. *Pian*

**16.25 Advanced Topics in Structural Mechanics (A)**  
 Prereq.: 16.201  
 Year: G (2) 3-0-9  
 Varying content. New methods and problems in the structural design and analysis of aerospace vehicles. (Not offered 1969-70.) *Mar*

**16.26 Solid Mechanics Laboratory (A)**  
 Prereq.: 16.62  
 Year: G (1 or 2) *Arr.*  
 Graduate laboratory subject in solid mechanics and experimental stress analysis, conducted as individual projects arranged between student and instructor. *Pian*

**16.27 Variational and Matrix Methods of Structural Mechanics (A)**  
 Prereq.: 16.201  
 Year: G (2) 3-0-9

**16.28 Variational and Matrix Methods of Structural Mechanics (A)**  
 Prereq.: 16.27  
 Year: G (1) 3-0-9  
 Structural analysis through the use of variational principles. Derivation of the governing differential equations. Principles of virtual work and complementary virtual work. Principles of stationary potential energy, stationary complementary energy, Reissner's principles and generalizations. Approximate solutions of solid continua and complex flight vehicle structures. Solutions by finite-element idealization and matrix structural methods. Finite difference methods. Inclusion of initial stresses, initial strains, non-uniform temperatures, small deflections, large deflections, elastic stability, plasticity and temperature-dependent behaviors. (16.28 not offered 1969-70.) *Tong*

**16.30 Principles of Automatic Control**  
 Prereq.: 6.14T, 16.01  
 Year: U (1, 2) 3-0-9  
 Analysis of automatic control systems, including analytical, graphical, and analog methods. Formulation of control system performance equations leading to solutions for transient and steady-state inputs. Non-dimensionalized treatment of simple linear systems and extension to more involved automatic control loops. Selected aeronautical and astronautical control problems. *Whitaker, Deyst*

**16.31 Principles of Instrumentation and Control (A)**  
 Prereq.: 16.30  
 Year: G (1) 3-0-9  
 Generalized concept of system design and synthesis with consideration of intercoupled relationships among multiple inputs and outputs, practical limitations of physical components to satisfy the static and dynamic specifications of system response to control inputs and disturbing inputs, and the adaptation to parameter variations. Use of analog and digital computers as design tools. Principles of random processes and optimum linear system design for random inputs. Sampled data system analysis and the design of on-line digital controllers. *Li, Meiry*

**16.32 Principles of Instrumentation and Control (A)**  
 Prereq.: 16.31  
 Year: G (2) 3-0-9  
 Brief treatment of time-varying linear control systems. General treatment of the principles of analysis and design of feedback control systems incorporating non-linear components. Extensive treatment of the multiple-input

describing function method as applied to stability analysis, steady-state response to forcing functions and transient response. Introduction of modern control theory for the determination of control logic for optimum transient response with discrete or continuous signals in open and closed loop configurations. Brief discussion of optimum filtering estimation and identification concepts. *Li, Vander Velde*

**16.33 Automatic Control System Laboratory (A)**  
 Prereq.: 16.30  
 Year: G (1) 2-2-6  
 Study of open loop and closed loop characteristics of feedback control systems. Experimental verification of various compensation schemes designed with root-locus and phase-gain diagram techniques. Exploitation of the particular properties of electrical, hydraulic, and pneumatic drive systems. Study of a non-linear adaptive control system and an optimum switching control system. Case experiments include the Apollo IMU control system, delta-modulated instruments and statistical identification techniques. Use of a hybrid computer in control applications emphasized. *Meiry*

**16.34 Automatic Control of Flight Vehicles (A)**  
 Prereq.: 16.30  
 Year: G (2) 3-0-9  
 Application of design techniques and principles to advanced automatic control systems for air and space vehicles. Synthesis of control systems from standpoint of meeting mission specifications. Analysis of adaptive control systems; their use in meeting performance requirements over widely changing environments encountered by high-speed aircraft and manned spacecraft. Typical engineering problems associated with design of control equipment, considering limitations and uncertainties of components, random input effects, mass cross-coupling effects, etc. (16.15 recommended as preparation.) *Whitaker*

**16.35 Special Problems in Instrumentation Control and Guidance (A)**  
 Prereq.: 16.30  
 Year: G (1 or 2) *Arr.*  
 Problems of interest to qualified individual students in consultation with the instructor. *Staff*

**16.36 Comparative Instrumentation (A)**  
 Prereq.: 16.30  
 Year: G (2) 3-0-6  
 Generalized fundamental treatment directed toward planning of measuring systems. Analysis of measurement concepts, components, system configurations and test methods with emphasis on comparison between different techniques. Detailed examination and error analysis of important classes of practical instruments stressing the general techniques used to improve accuracy. Students may also elect 16.361, an associated laboratory subject. *L. R. Young*

**16.361 Comparative Instrumentation Laboratory (A)**  
 Prereq.: 16.30  
 Year: G (2) 0-2-1  
 Individual laboratory projects for detailed investigation of one phase of instrument accuracy, emphasizing current research and development. (Restricted to students taking 16.36.) *L. R. Young*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

AERONAUTICS AND ASTRONAUTICS

## 16.37 *Statistical Problems in Automatic Control (A)*

Prereq.: 16.30, 18.05

Year: G (2)

3-0-9

Statistical problems of importance to control system engineers. Review of probability theory with application to such problems as system reliability and multidimensional random errors. Measurement of the statistics of random variables and processes. Extensive treatment of random processes in linear systems using both transfer function and state space descriptions. Design of optimum filters according to Wiener and Kalman. *Vander Velde*

## 16.371 *Estimation and Control of Stochastic Processes (A)*

Prereq.: 16.37

Year: G (2)

3-0-9

Study of methods of estimation and control of stochastic processes. Prediction, filtering and smoothing for non-stationary systems. Brownian motion, Markov processes and the Fokker-Planck-Kolmogorov equations. Optimal control in the presence of system process and measurement disturbances. Applications to the control and guidance of spacecraft. *Deyst*

## 16.38 *Physical Components of Control Systems (A)*

Prereq.: 6.14

Year: G (2)

3-0-6

Effect of component performance characteristics on the control system problem. Consideration of mechanical, electrical and electromechanical components with emphasis on non-ideal effects. Specification of components to meet particular system requirements. Numerous lecture references to applications in aircraft, missile, and spacecraft guidance. *R. K. Mueller*

## 16.39T *Applied Optimal Control (A)*

Prereq.: 18.15

Year: G (1)

3-0-9

Design of optimal and near-optimal controls and systems emphasizing computational techniques for finding the solutions to complex problems which do not admit analytic solution. Treatment of both parameter optimization and functional optimization methods. Computer facilities available to the class for computational experiments on a voluntary basis. *Vander Velde*

## 16.40 *Principles of Flight Guidance*

Prereq.: 16.30

Year: U (1)

3-0-9

Guidance requirements for representative space and atmospheric flight missions analyzed in terms of mission phases, navigation, flight path corrections and steering laws. Implementation of guidance systems using celestial, inertial, and radio techniques in conjunction with data processing. Examples include air traffic control and a complete manned space flight. *Hollister*

## 16.41 *Space Dynamics and Gyroscopic Instruments (A)*

Prereq.: 16.01

Year: G (1)

4-0-8

Consideration of origins of inertial space concepts and application to interpretation of measured data. Generalized theory of accelerations and velocities of bodies in spaces which are moving with respect to inertial space. Application of general theory and of Newtonian mechanics to theory of gyroscopic instruments. Space integrators and stabilization. Development of treatment from standpoint of engineer, using methods of vectors and of conventional analysis. Application to gyroscopic devices in airborne and marine navigation. *Wrigley, Hollister*

## 16.42 *Inertial Guidance (A)*

Prereq.: 16.30, 16.41

Year: G (2)

4-0-8

Principles of design of inertial navigation systems, starting from dynamics of measurement components and kinematics of system behavior. Methods of mechanizing equations of motion of physical pendulum and gyro compass. Inertial navigation systems for space close to earth and marine use. Characteristics of five-gimbal, three-gimbal and gimballless systems. Mechanization of a satellite navigator. Question of extension to interplanetary regions. *Markey, Wrigley*

## 16.43J *Life Support and Physiological Modeling in Manned Systems (A)*

(Same subject as 2.181J)

Prereq.: —

Year: G (2)

3-3-6

Environmental control and physiological characteristics of man as related to unusual acceleration, thermal, atmospheric radiation or other stresses. Advanced models of sensory and neuromuscular systems. Lectures and student critique of current research. Design of systems involving man. Student projects in small groups throughout the term. (*Permission of instructor required.*) *L. R. Young, Sheridan*

## 16.441J *Dynamical Astronomy (A)*

(Same subject as 8.953J and 12.613J)

Prereq.: 8.03, 18.05

Year: G (1)

3-0-9

Astronomical background, central orbits, potential theory, the two-body problem, orbital elements and coordinate systems, orbit determination, three- and n-body problems, perturbation theory and techniques of computation, observations and statistical theory of data analysis. Applications to the motion of planets, natural and artificial satellites. *Wrigley, I. I. Shapiro, Counselman*

## 16.442J *Dynamical Problems of the Solar System (A)*

(Same subject as 8.954J and 12.614J)

Prereq.: 16.441J

Year: G (2)

3-0-9

Introduction to current research in solar systems dynamics, tidal friction, spin and orbital resonances, evolution of the earth-moon system, and tests of gravitational theories. *Wrigley, I. I. Shapiro, Counselman*

## 16.45J *Space Communications (A)*

(Same subject as 6.569J)

Prereq.: —

Year: G (1)

3-0-9

Study involving the important interaction between the orbital and dynamical characteristics of spacecraft, the transmission of electromagnetic signals over long distances, and the concepts of modern communication theory. Stress on interplay between these diverse topics in practical space communication systems. Discussions of spacecraft dynamics, stabilization, attitude control, propagation effects and pertinent modulation and coding methods. (*Some background in space dynamics or in communications assumed. Permission of instructor required.*) *Harrington*

## 16.46 *Astronautical Guidance I (A)*

Prereq.: 18.05

Year: G (1)

3-0-6

Fundamentals of celestial mechanics; orbital initial value, boundary value and orbital transfer problems; two-body and n-body approximate and precision orbit determination. One-way and round-trip trajectory problems to the moon and planets. Fundamentals of space vehicle navigation with particular emphasis on self-contained techniques; statistical error analysis. Techniques of linear perturbation theory, vector and matrix algebra freely applied. *Battin*

**16.47 Astronautical Guidance II (A)**

Prereq.: 16.37 or 16.46

Year: G (2)

3-0-6

Techniques of powered-flight guidance and navigation; velocity-to-be-gained methods; terminal control. Linearized and explicit techniques for fixed- and variable-time-of-arrival guidance. Optimum navigation and guidance policies. Guidance of continuous and low-thrust vehicles; guidance for satellite rendezvous; atmospheric entry guidance. Effect of component inaccuracies on performance of missions.

Battin

**16.48 Elements of Digital Guidance Computers (A)**

Prereq.: 6.251 or 6.47

Year: G (1)

3-0-6

Introduction to the composition and use of digital computers for guidance systems. Reviews methods of logical analysis and deals with digital computer organizations, logical circuit elements, input-output methods, fixed and erasable memory systems, and basic supervisory program structures. Discussion of power, speed, and size relationships.

Alonso

**16.49 Special Problems in Weapons Systems (A)**

Prereq.: 16.41

Year: G (1 or 2)

Arr.

Problems of interest to qualified students in consultation with the instructor.

Wrigley

**16.50 Vertical Take-Off Aircraft (A)**

Prereq.: 16.11

Year: G (1)

3-0-6

Analysis of inherent performance stability and control characteristics of vertical take-off and landing aircraft, including helicopters and ducted fan, tilt wing, jet vectored-lift, and jet vertical-lift aircraft.

Ham

**16.51 Advanced Vertical Take-Off Aircraft (A)**

Prereq.: 16.50 or 16.91

Year: G (2)

3-0-6

Application of fundamental principles of aeroelasticity, airplane dynamics, aerodynamics, and automatic control to problems encountered in the design of helicopters. Problems of control and stability during transition to horizontal flight, design of stabilization systems, vibration and flutter of rigid or articulated rotors, and analysis of rotor airloads in forward flight.

Ham

**16.53 Rocket Propulsion**

Prereq.: 16.001; 16.02 or 16.03

Year: U (2)

3-0-6

Velocity requirements for orbital and interplanetary trajectories. Solid propellant grain design, nozzle performance. Thermochemistry of liquid propellant rockets, flow of chemically reacting gases, calculation of specific impulse. Turbopumps. Heat transfer in nozzles. The rocket engine treated as a complete system.

Lewellen

**16.531 Mechanics of Two-Phase Flow (A)**

Prereq.: 16.02 or 16.03

Year: G (2)

3-0-9

Introduction to the mechanics of fluid-particle flow with emphasis on an understanding of the roles played by each phase in various physical phenomena. Transport properties of particle-fluid suspension. Continuum description of particle-fluid flow. Dynamics of particles in nozzle flows, normal shocks and mixing and combustion zones. Incompressible fluid-particle flow. Sedimentation and fluidization. Electrodynamics of suspensions.

Tam

**16.54 Aircraft Engines**

Prereq.: 16.001; 16.02 or 16.03

Year: U (1)

3-0-6

Performance characteristics of ramjets and gas turbine engines, related to the characteristics of components — inlets, compressors, combustors, turbines, nozzles. Engine-airframe performance characteristics. Emphasis on factors which will determine future trends in engine development.

Kerrebrock

**16.55 Ionized Gases (A)**

Prereq.: 8.211

Year: G (1)

3-0-9

Equilibrium description of ionized gases, composition, energy states, statistical mechanics and ionization equilibrium. Kinetic theory, motion of charged particles in magnetic fields, distribution function, collisions, Boltzmann equation, characteristic lengths and times, cross sections, transport properties. Gas-surface interaction, thermionic emission, surface ionization, sheaths, probe theory. Radiation in plasmas, diagnostics.

Soltes

**16.561 Nuclear Rockets (A)**

Prereq.: 16.53, 18.05

Year: G (1)

3-0-9

Study of the problems and potentialities of utilizing nuclear energy for space propulsion systems. Typical subjects: suitable missions, fission reactor physics, compromises involved in designing a solid-core nuclear rocket, radiation shielding, and the fluid dynamic and heat transfer problems which must be solved to make various advanced nuclear systems technically feasible.

Lewellen

**16.562 Space Power (A)**

Prereq.: 16.55

Year: G (2)

3-0-9

Fundamentals of space power systems; thermodynamic and systems considerations for maximum power to mass ratio. High-temperature energy converters; plasma diodes, liquid metal magnetohydrodynamic generators, magnetoplasmadynamic generators. Emphasis is on power for electric propulsion and other applications requiring high power.

Kerrebrock, Soltes

**16.57 Electric Propulsion (A)**

Prereq.: 16.55

Year: G (2)

3-0-9

Study of the most promising electrostatic, electromagnetic and electrothermal thruster concepts. Identification and evaluation of major loss mechanisms and determination of resultant performance and efficiency using both analytical models and experimental data. Application of these electric propulsion concepts to space flight missions to determine trajectory characteristics and mission performance capability compared with other propulsion system types.

Kerrebrock

**16.581J Advanced Topics in Plasma Kinetic Theory (A)**

(Same subject as 22.69J)

Prereq.: 22.68J

Year: G (2)

3-0-9

Varying content including topics of current interest. Typical subjects: theories of non-linear phenomena in plasma, particularly in the regime described by the Vlasov equation; general normal mode analysis, Van Kampen modes, radiation, limitations of the linear

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

AERONAUTICS AND ASTRONAUTICS

theory, resonance and trapping, continuum modes; multiple length-and-time-scale formulations; non-linear stationary wave solutions, shock waves; unstable plasmas, phase space and statistical considerations, entropy; computer experiments; perturbation methods, quasi-linear theory, mode coupling; N-momentum space description, master equation, general H-theorem, equilibrium.

*McCune, Dupree*

## 16.59 Introduction to Plasma Kinetic Theory (A)

Prereq.: 6.58 or 8.311

Year: G (1)

3-0-9

Collective behavior in collisionless fully ionized plasmas; theory of the Vlasov equation. Waves in plasma without magnetic field, particle-wave resonance; Landau damping. Resonant and non-resonant electrostatic instabilities. Dynamics of a magnetized plasma; particle drifts, currents, constants of the motion; adiabatic invariants. Moment equations and the "double-adiabatic" approximation. Drift-kinetic equation; low-frequency instabilities. Examples of micro-instability in anisotropic plasmas. Micro-turbulence and "collisions"; approximations to the plasma kinetic equation.

*McCune*

## 16.60 Advanced Special Projects (A)

Prereq.: —

Year: G (1, 2)

Arr.

Study or laboratory project work of graduate level by qualified students. Topics selected in consultation with the instructor.

*Staff*

## 16.605 Special Projects

Prereq.: —

Year: U (1, 2)

Arr.

Study or laboratory project work of undergraduate level by qualified students. Topics selected in consultation with the instructor.

*Staff*

## 16.62 Experimental Projects

Prereq.: 8.02

Year: U (1, 2)

2-6-4

Designed to help the student to gain practical insight through "project" experiments. Emphasis on preparation of the project goals, planning of details for the necessary apparatus, conducting of the experiment and relation of the experimental results to the initial goals. Provides not only an opportunity for the student to assemble and apply the knowledge he has gained, but also provides him with a link between theory and practice.

*Staff*

## 16.65 Experimental Techniques in Aerodynamics (A)

Prereq.: 16.02 or 16.03

Year: G (1)

3-0-9

Study of experimental techniques in aerodynamics from two points of view. First, discussion of the problems of specific instrumentation. Then, consideration of the relative motion between the model and airstream in terms of both moving and stationary models. Attention given to practical considerations that may be encountered in actual test programs, as well as consideration of the problems of using testing facilities now being developed.

*Covert*

## 16.70 Aircraft and Spacecraft Design

Prereq.: —

Year: U (1)

2-4-0

Lectures on preliminary design procedure with applications to an airplane and a satellite. Practice in drawing and in the detail design of components.

*Bentley*

## 16.71 Flight Vehicle Engineering

Prereq.: —

Year: U (1)

2-3-7

Design of an atmospheric flight vehicle to satisfy stated performance, stability, and control requirements. Emphasis on individual initiative and application of fundamental principles and the compromises inherent in the engineering design process. (Restricted to seniors in Course XVI.)

*Ham*

## 16.73 Space Systems Engineering

Prereq.: 16.01, 16.201

Year: U (1)

4-0-8

Review of fundamental principles used in engineering development of space vehicles and application to specific mission analysis. Trajectory kinematics, booster requirements, entry dynamics, propulsion systems, structural design, thermal protection, weight estimation, environmental control and component layout.

*Miller*

## 16.74 Advanced Space Systems Engineering (A)

Prereq.: 16.201 or 16.53 or 16.73

Year: G (2)

2-3-7

Application of the engineering sciences to a typically complex aerospace systems design project. Mission analysis, system analysis and design, system integration. Specialized technical fields supported by outside guest lecturers. Students will participate as teams, each responsible for one of several subsystems, providing actual experience in project organization and the methods by which individuals and teams work together to define and achieve a mutual goal.

*Sandorff*

## 16.751J Flight Transportation (A)

(Same subject as 1.221J, 15.483J)

Prereq.: 16.30

Year: G (1)

3-0-6

Integrated discussion covering basic concepts and operational characteristics of flight transportation systems. Methods of predicting vehicle performance, anticipating future design trends, and determining direct operating costs; airport design and functional layout; guidance and control techniques, both in terminal area and en route; communication and radar system performance.

*R. H. Miller, Bone, S. Myers*

## 16.752J Flight Transportation Seminar

(Same subject as 1.222J, 15.484J)

Prereq.: —

Year: G (1)

1-0-2

Economics of airline operation, problems of financing, and of domestic and international route allocation. Subject developed around seminars presented by speakers from the regulatory agencies, national and international organizations and industry on particular phases of flight transportation. Preparatory lecture preceding each seminar. Opportunity for students to conduct studies in their area of major specialization on a particular topic covered by the subject.

*Broune, Bone, S. Myers*

## 16.77 Flight Transportation Operations Analysis (A)

Prereq.: 1.143 or 15.591 or 16.751J

Year: G (2)

3-0-6

Study of the application of network flow theory to a variety of economic and operational problems in flight transportation systems. Review of graph theory and network flow theory and examples of application in scheduling, passenger traffic flow, aircraft and crew routing, terminal location, timetable optimization, flight planning, etc. Student use of computer to solve large-scale problems and for a term project.

*R. W. Simpson*

**16.79J Legal Aspects of New Technology**

(Same subject as 2.96J and 15.62J)

Prereq.: —

Year: G (1)

3-0-6

Intellectual property and the law. The nature and progress of invention past and present, the evolution of relevant legal doctrines as an expression of public policy, and present legal doctrines for the treatment of intellectual property as trade secrets, proprietary data, copyrighted materials and patents. Critical analysis of the patent and copyright systems and pending legislation. The impact of selected new technologies — computer technology and xerography. The role of the Federal agencies — with emphasis on the Department of Defense and NASA. The employer-employee relationship, incentives for innovation, employment restraints and employee mobility. Term paper or project required.

Baram

**16.81 Flight Vehicles**

Prereq.: —

Year: U (1)

3-0-3

The role of science and engineering in the development of aircraft and spacecraft. Examination of the fundamental problems and solutions of these problems in the light of current technology.

Koppin

**16.82 Aerospace Engineering**

Prereq.: —

Year: U (2)

3-0-3

The work of engineers and scientists in aerospace technology with the Apollo moon project and the supersonic transport as examples. Mission analyses, research and development problems in fluid mechanics and propulsion, materials and structures, automatic control and flight guidance. Interaction among these disciplines in flight vehicle design.

Staff

**16.84 Aerospace Engineering**

Prereq.: —

Year: U (2)

3-2-7

Same lectures and subject matter as 16.82 but with additional discussion meetings and outside preparation.

McKay

**16.85 Industrial Practice**

Prereq.: —

Year: U (2)

0-8-0

Seven months of engineering practice carried out by the cooperative students at the plants of organizations participating in the cooperative program.

R. H. Miller

**16.91 Continuum Vibrations (A)**

Prereq.: 16.201

Year: G (1)

3-0-6

Dynamics of elastic structures. Free and forced vibrations of bars, beams, strings, plates, multi-mass systems. Differential and integral equations formulation, matrix methods, energy methods. Self-excited vibrations and approximate methods for their solution.

Bucciarelli

**16.92 Advanced Aeroelasticity (A)**

Prereq.: 16.02 or 16.03; 16.91

Year: G (2)

3-0-9

Presentation of field of aeroelasticity from unified viewpoint applicable to all types of flight vehicles throughout range of airspeeds. Derivation of aeroelastic operators and unsteady airloads from governing variational principles. Forced response, static and dynamic eigenvalues of simplified systems, one-dimensional structures and two-dimensional structures. Special topics of interest to the aeroelastician, with emphasis on aerodynamic operators.

Tong

**16.94 Dynamics of Structures (A)**

Prereq.: 16.91

Year: G (2)

3-0-9

Review of Hamilton's principle, Lagrange's equations, natural mode shapes and frequencies. Normal mode equations of motion. Response of elastic structures to varied dynamic loading: gust loading, random excitation, shock, etc. Prediction of large dynamic responses and permanent deformations of shell structures by elastic-plastic and rigid-plastic analysis.

Bucciarelli

**17.****Political Science****17.01 Society and Man**

Prereq.: One first-year Humanities sequence

Year: U (1, 2)

3-0-6

Introduction to the social sciences. Focus on the relation of the individual to his society, considering both the individual's capacity to affect his society and his society's effect on him. Life in the contemporary world examined by such methods as sociological surveys, psychological experiments, mathematical models, and political and anthropological studies.

Feldman

**POLITICAL COMMUNICATION AND BEHAVIOR****17.111 Public Opinion and Propaganda**

Prereq.: —

Year: G (2)

3-0-6

History and development of public opinion as a factor in public policy; relationship of public opinion and private attitudes; organization of political parties and pressure groups; techniques used by them; conditions of effective and ineffective communications.

Pool

**17.112 Mass Media and Communication Systems**

Prereq.: —

Year: G (1)

Arr.

Examination of the pattern of communication in societies at different stages of development. Comparison of networks of oral communication with systems based on mass media. The role of opinion leaders, informal communication networks, literacy, the press, radio, film, and international communications. (Not offered 1969-70.)

Pool

**17.121 Political Socialization (A)**

Prereq.: —

Year: G (2)

3-0-6

Study of the processes by which societies and groups regularly teach their members how to behave politically. Examination of approaches to socialization of anthropology, psychoanalysis, and social psychology. Analysis of the main socializing agencies (family, peer group, school, occupation, religion, and voluntary association) to ascertain their distinctive influences. Investigation of national differences in political socialization and ideas of national character.

F. W. Frey

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## POLITICAL SCIENCE

### 17.122 *The Analysis of Power (A)*

Prereq.: 17.721 or 17.722

Year: G (1)

3-0-6

Study of the concepts, measurement techniques, research findings, and hypotheses used in the analysis of interpersonal and intergroup power relations. Emphasis on American political institutions, but with consideration of other institutions and other societies where appropriate evidence is available.

F. W. Frey

### 17.131 *Survey Research Methods (A)*

Prereq.: 17.731 or 17.732

Year: G (1)

3-0-6

Introduction to survey research, with some study of problems in the philosophy of social science and of social scientific experimentation. For students needing to secure or evaluate data about public opinion and attitude formation.

F. W. Frey

### 17.14T *Power, Influence and Policy Decisions*

Prereq.: 17.28T

Year: U (1)

3-0-6

Study of the distribution of power in selected types of social units: small groups, organizations, communities, institutions, and nations. Emphasis is placed upon the development of concepts and research techniques necessary for empirical power analysis. Data are drawn from social units in the United States. (Not offered 1969-70.)

F. W. Frey

### 17.15T *Political Psychology*

Prereq.: 17.01

Year: U (2)

2-1-6

Selected topics in the relevance of psychology to political behavior including the relationship between personality and political systems and recent psychological findings on the social control of men's behavior. (Enrollment limited to 15 students. Admission by permission of instructor.)

Feldman

### 17.151 *Changing Outlooks and Identities in World Affairs (A)*

Prereq.: —

Year: G (1)

3-0-6

Changes in human relations resulting from changes in power relations, new conceptions of others and of self arising, e.g., out of the end of colonial rule and the emergence of new national sovereignties in Asia and Africa; changes in national identities and in patterns of race attitudes and behavior; the consequences of the recession of white supremacy in Asia, the world, especially the United States; problems of psychological retooling in the new modes of interaction among Americans, Europeans, Asians, and Africans, particularly as between whites and non-whites.

Isaacs

### 17.161 *Personality, Society, and Politics*

Prereq.: —

Year: G (2)

Arr.

The gradual inclusion of the social environment in psychoanalytic theory. The psycho-sexual and psycho-social stages of man in their relation to social institutions. Personality in followership and in leadership. Application to selected political problems.

Pye

### 17.162 *Identity and Ideology*

Prereq.: 17.01

Year: G (2)

3-0-6

Study of personality theory and political behavior with special emphasis upon the relationships between characterological elements and themes and appeals in political ideologies. Case studies of the personal development of historic leaders and the impact of their personalities upon historical processes. (Not offered 1969-70.)

Pye

### 17.163T *Graduate Seminar in Political Psychology (A)*

Prereq.: —

Year: G (2)

Arr.

Examination of the influence of personality, situational and cultural factors on the individual's reaction to perceived authority. Emphasis on experimental socio-psychological data and the design of new experiments. Investigation of differences in cognitive and behavioral characteristics which may be found in different populations. A required original laboratory or field experiment. (Alternate years.)

Feldman

### 17.191 *Research Seminar in International Communications (A)*

Prereq.: 17.111 or 17.112

Year: G (1)

Arr.

### 17.192 *Research Seminar in International Communications (A)*

Prereq.: 17.111 or 17.112

Year: G (2)

Arr.

Cooperative examination of key problems in this field.

Lerner

## COMPARATIVE POLITICS

### 17.21T *The American Political Process*

Prereq.: —

Year: U (1, 2)

3-0-6

Examination of the functioning of the American political system in terms of the bases of political power, the evolution and contemporary problems of the modern presidency, and the complementary roles of Congress and the judicial system. Particular emphasis on the interrelationships of power in the system at the national level.

Staff

### 17.211 *American Federal System (A)*

Prereq.: 17.21T

Year: G (1)

3-0-6

Study of the American federal system as it exists today, in the light of its adequacy in dealing with modern public problems and political trends. The strength of the system as a going political concern, its democratic characteristics, its influence upon the pattern of American politics, its effectiveness as an instrument of policy making, and its adjustment to the impact of technological change will be major topics of discussion. Particular emphasis will be given to the problems caused by the emergence of new metropolitan communities and to alternative systems of organizing government below the national level. (Not offered 1969-70.)

Staff

### 17.213 *Graduate Seminar in American Politics (A)*

Prereq.: 17.21T

Year: G (1)

Arr.

Analysis of the American political system with primary emphasis on the national level. Examination of American political culture, federalism and the American party system. The executive and legislative power structures, the decision making process, and representation and public policy. Special attention to contemporary and comparative research on American politics and government.

Saloma

### 17.222 *Comparative Asian Politics (A)*

Prereq.: 17.721

Year: G (2)

Arr.

Comparative analysis of political systems of Asia. Special attention to the processes of social change and the problem of political stability. Study will cover the transition from traditional and colonial systems to the contemporary ones. (Not offered 1969-70.)

Pye

**17.223T Migration and Political Development**

Prereq.: — 3-0-6  
 Year: G (1)

Exploration of the political causes and consequences of population movements across international boundaries and within states. Detailed examination of the following: the political effects of urban migration; the political behavior of political refugees; the consequences of internal population movements in multi-ethnic societies; the economic and political impact of migrants on the receiving country; the effects of migration on the country of origin. Case materials drawn from historic Europe and America as well as from contemporary Asia and Africa. *Weiner*

**17.224 Chinese Politics (A)**

Prereq.: 17.722 or 17.723 3-0-6  
 Year: G (2)

Analysis of contemporary Chinese politics, both pre-Communist and Communist. Special focus upon the process of modernization and political development of the Chinese civilization. *Pye*

**17.225 Comparative Asian Politics: Political Development in India (A)**

Prereq.: 17.01; 17.24T or 17.721 3-0-6  
 Year: G (2)

Examination of the Indian political system focusing on problems of modernization. Topics: India's traditional political and social organization; the impact of the West; the development of political parties and interest groups; patterns of political participation; the ideology and characteristics of Indian political elites; problems of national integration; the "value" debate in Indian economic development; the political dimensions of economic policy. (*Open to undergraduate majors in the Humanities and Social Sciences.*) *Weiner*

**17.226 Comparative African Politics (A)**

Prereq.: 17.61T or 17.65J 3-0-6  
 Year: G (2)

Comparative analysis of the political systems of tropical Africa with particular attention to special problems concerning traditional social and political organizations, the impact of imperialism and colonialism, the rise of nationalism, and post-independence institutions. *Rotberg, W. R. Johnson*

**17.232 Seminar: Politics and Government of Sub-Sahara Africa (A)**

Prereq.: 17.61T 3-0-6  
 Year: G (2)

Study of problems relating to nation building, political development, political integration, and broader political union in Africa. Study of the interrelation of political structures, ideas, and processes. *W. R. Johnson*

**17.24T Comparative Political Systems**

Prereq.: 17.01 3-0-6  
 Year: U (2)

Comparative study of the organization and use of political and economic power in contemporary foreign political systems: Britain, West Germany, and France. Emphasis on the development of attitudes and political customs and the components of democratic political systems. *Staff*

**17.241T The International Politics of the West European States (A)**

Prereq.: 17.242T 3-0-6  
 Year: G (2)

Introduction on the present position of Western Europe in the world, covering particularly economics, security,

and the technological gap, followed by discussion of the foreign policies of the major West European states. Instruction by the professors in charge, with guest lectures by other members of the faculty. *Lerner, W. E. Griffith*

**17.242T Domestic Politics of Western Europe**

Prereq.: — 3-0-6  
 Year: G (1)

Comparative study of politics and society in France, Great Britain, Germany and Italy. Analysis of the following three "cases": the integration of feudal remnants; the problems of democratic control of economic planning; and the response of domestic politics to changes in the international system. (*Open to undergraduates by permission of instructor.*) *Berger*

**17.243 Research Seminar in Comparative Politics: Western Europe**

Prereq.: — 3-0-6  
 Year: G (2)

For students planning research in Western European countries. Discussion of current work in the field. Training in the use of European primary source materials and in research methods applicable to European problems. Presentation of students' own research projects. *Berger*

**17.244 Politics in the Transitional Middle East (A)**

Prereq.: 17.24T 3-0-6  
 Year: G (2)

Comparative analysis of structures of power in Turkey, Iran, and Egypt. Problems in locating and explaining changes in configurations of power in the Middle East, especially related to efforts at social and economic development. The relationship between attitudinal patterns and social structure. Various political science approaches to the common analysis of both Western and non-Western politics; the development of political theories of cross-cultural generality. *F. W. Frey*

**17.25T State and Local Politics**

Prereq.: 17.21T 3-0-6  
 Year: U (1)

Analysis of state and local political systems and their interaction in dealing with contemporary metropolitan problems. Emphasis on sociocultural bases of political systems and sources of political influence. *Lipsky*

**17.26T The Politics of National Economic Control**

Prereq.: — 3-0-6  
 Year: U (2)

Analysis of the policy-making processes and major political issues associated with government efforts to guide the American economy and produce a just distribution of wealth. (*Not offered 1969-70.*) *Altshuler*

**17.261 Communism and Revolution**

Prereq.: — 3-0-6  
 Year: G (1)

The ideology and practice of Communist political and social revolution, with primary emphasis on Soviet experience through the Stalin era. Marx, Lenin, and the Bolshevik seizure of power; role of the Communist party; the trauma of forced change in a backward society; the totalitarian model. Introduction to the problems of contemporary Soviet politics. *Blackmer*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## POLITICAL SCIENCE

### 17.262 *Soviet Foreign Policy and the Communist World (A)*

Prereq.: 17.261

Year: G (1)

3-0-6

Primarily an examination of recent Sino-Soviet relations, but including also Soviet dealings with East Europe and, to a lesser extent, with the non-ruling parties. Brief review of Soviet state and party relations with China and East Europe during the Stalin period, followed by a more detailed analysis of the course of events since 1953.

W. E. Griffith

### 17.263 *Soviet Political System (A)*

Prereq.: 17.261

Year: G (2)

3-0-6

Research seminar on the operation of the Soviet system, with special emphasis on change and continuity since Stalin's death. The transition from a developing to a modern industrial society and its consequences for the Communist party and other Soviet institutions. Case studies of such contemporary problems as literature, industrial management, agriculture, elite politics. Interest group theory and other comparative approaches to the evolution of Soviet society.

Blackmer

### 17.264 *Research Seminar on Sino-Soviet Relations and International Communism (A)*

Prereq.: 17.262

Year: G (2)

Arr.

Techniques of research in Communist affairs, with special reference to Sino-Soviet relations after the death of Stalin: the decipherment of esoteric communications with respect to changes of policy and personnel and to inter-party relations. Readings, research problems, and a seminar paper. (Not offered 1969-70.)

W. E. Griffith

### 17.265 *Communist Propaganda (A)*

Prereq.: 17.261

Year: G (2)

3-0-6

After brief consideration of Nazi and other totalitarian propaganda doctrine and practice, a detailed study of doctrine, strategy, and tactics of Soviet and Chinese propaganda operations. Some attention to other Communist propaganda operations. (Not offered 1969-70.)

W. E. Griffith

### 17.266 *Domestic and Foreign Politics of East Europe*

Prereq.: —

Year: G (1)

3-0-6

Analysis of the domestic problems and foreign relations of the Communist states of East Europe since World War II.

W. E. Griffith

### 17.267 *Radical and Revolutionary Ideologies*

Prereq.: 17.261

Year: G (2)

3-0-6

Consecutive treatment of the following: the background of Marxism in German idealistic philosophy; the thought of Marx, Engels, Bakunin and Anarchism; the revisionists, the orthodox Marxists, the leftist Marxists, the origins of Russian radicalism and Russian Marxism; Lenin, Trotsky, Bukharin, Stalin; Fascism; the interwar neo-Marxists; Titoism; East European revisionism; Maoism; ideology in the Sino-Soviet split; revisionist Marxism in Eastern Europe, in Western Europe; radicalism in Cuba; the Chinese Cultural Revolution; Asian and African Socialism; North Vietnam; Radicalism and the New Left in North America and Western Europe (the civil rights movement, Black Power; the U.S., English, French, German, and Italian student movements and rebellions). W. E. Griffith, Keeskemetti

### 17.27T *Bureaucracy*

Prereq.: 17.21T

Year: U (2)

3-0-6

Study of the structure of public organizations and the politics of bureaucracy in the United States. Examination of major theories of bureaucracy and public administration with reference to specific cases involving policy making, policy execution and the relationship among elected and appointed officials. Special emphasis on the roles of scientists and professionals in the administrative process.

Sapolsky

### 17.271 *Theories and Approaches to the Study of Comparative Politics (A)*

Prereq.: 17.723

Year: G (2)

3-0-6

A comprehensive examination of various approaches which underlie our study of comparative politics, with literature drawn primarily from Western Europe. The utility of alternate conceptualizations and theoretical formulations found in the general literature on comparative politics. (Alternate years.)

Pye

### 17.275 *Private Organizations and the Political Process*

Prereq.: —

Year: G (2)

3-0-6

Analysis of the roles private organizations play in the American political system. Examination of the internal government and external political relations of voluntary associations, professional societies, labor unions, and business firms. Special emphasis on theories of formal organization useful in explaining political behavior.

Sapolsky

### 17.28T *Political Parties*

Prereq.: 17.21T or 17.24T

Year: U (2)

3-0-6

Analysis of political parties and their role in decision making in the political system. Primary attention to the American party system, national party organization, Presidential nominating conventions, electoral strategies, and party leadership in Congress. Comparison with parliamentary, totalitarian, and developing political systems. (Not offered 1969-70.)

Saloma

### 17.282 *Comparative Politics of Latin America (A)*

Prereq.: —

Year: G (2)

Arr.

Exploration of issues in making cross-national and international comparisons of political systems emphasizing the specific problems raised by the need to use and integrate diverse data bases (historical, economic, organizational, attitudinal).

Staff

### 17.29T *The Governance of Cambridge*

Prereq.: —

Year: U (2)

3-0-6

Study of a unique city charter (Plan E-PR) and practical problems in making it operative. Emphasis, inter alia, on selected topics such as: the roles of the city council and the manager; public housing; the redevelopment authority; traffic; health and hospitals; and public education.

Mahoney

## DEFENSE POLICY

### 17.31T *Evolution of Strategic Nuclear Systems*

Prereq.: 17.52T

Year: U (1)

3-0-6

Introduction to the history of the development of strategic nuclear forces and strategy. Consideration of major alternative postures and their implications for deterrence and arms control. Projections of the future role and limitations of strategic nuclear forces.

Kaufmann

**17.311 Development of General War Systems and Strategies (A)**

Prereq.: 17.511 or 17.53T

Year: G (1)

3-0-6

Analysis of major U.S. policy decisions concerning general war systems and strategies in the postwar period. Emphasis on the technological, strategic, political, budgetary, and environmental factors that have affected these decisions. Examination of the role of innovation and analysis in the evolution of general war systems and strategies. *Kaufmann*

**17.312 Development of Limited War Systems and Strategies (A)**

Prereq.: 17.311

Year: G (2)

3-0-6

Analysis of major U.S. policy decisions concerning limited war systems and strategies in the postwar period. Emphasis on the determination of force structures and on changing views about the utility of nuclear weapons, the problem of escalation, and the relationship between limited war and general war forces and strategies. *Kaufmann*

**17.32T Evolution of Forces for Limited War**

Prereq.: 17.31T

Year: U (2)

3-0-6

Introduction to the history of concepts about limited war developed since World War II. Comparison of nuclear and non-nuclear forces for the deterrence and conduct of limited war. Analysis of the problem of escalation and its control. Consideration of current U.S. requirements for limited war forces. *Kaufmann*

**17.322 Research Problems in Defense (A)**

Prereq.: 17.331

Year: G (2)

3-0-6

Examination of a major problem-area in the realm of U.S. defense policy. Main focus on history of the evolution of the problem, consideration of U.S. objectives, and examination of alternative solutions to the problem. *Kaufmann*

**17.331 Principles of Systematic Policy Analysis (A)**

Prereq.: 17.731

Year: G (1)

3-0-6

Systems analysis of policy choices. Cost-benefit analysis and related techniques. Political and bureaucratic constraints on analytic procedures. The role of judgment in problem formulation and in the selection of cost and benefit criteria. *Staff*

**17.332 Seminar in Systematic Policy Analysis (A)**

Prereq.: 17.331

Year: G (2)

3-0-6

Collaborative research on simplified policy choices illustrative of the problems facing the Federal and local governments today. Cases selected from such areas as defense, poverty programs, urban affairs, and education. Cost-benefit calculations. *Staff*

**17.342 Negotiation and Force in International Relations (A)**

Prereq.: 17.31T or 17.311; 17.52T

Year: G (2)

3-0-6

Analysis of tacit bargaining and negotiation: the role of diplomatic customs, commitments, threats and military force. The use of force for bargaining: coercion, deterrence, war aims and war termination. Interaction between negotiation and the formulation of foreign policy. *Staff*

**17.352 Research and Development and National Security (A)**

Prereq.: —

Year: G (2)

3-0-6

Management of government sponsored research and

development in the U.S., its interrelations with national policy and organization; the problem of ascertaining those relations among the technological community, the Congress, the Executive Branch, and industry which will best facilitate the generation of new ideas and the further development of technology; case studies and problems in other countries. *A. G. Hill*

**SCIENCE AND PUBLIC POLICY****17.412 Scientific Development and Government Policy (A)**

Prereq.: 17.21T

Year: G (1)

3-0-6

History of development of science and technology in the American government, especially post-war. Current science policy issues, with emphasis on allocation of resources, government/private sector relations, decision-making machinery in government and role of scientists and engineers. First section of a two-part sequence (see 17.413). Each may be taken separately by special permission. *Sapolsky*

**17.413 Technology and Policy (A)**

Prereq.: 17.412

Year: G (2)

3-0-6

Important subject areas in which science and technology take form as substantive issues of public policy. Intensive examination of several illustrative areas such as atomic energy, outer space, the marine environment, arms and arms control, and health. Basically, an exploration in depth of concrete policy examples of the general principles and problems discussed in 17.412T. (Not offered 1969-70.) *Bloomfield, Skolnikoff*

**17.42T Government, Politics and Technology**

Prereq.: —

Year: U (1)

3-0-6

An examination of the impact of science and technology on political structures and processes; the major public policy issues that technological advance poses for governments; the ways in which science modified patterns of political activity and institutions; the role of the scientist in political decision making. Special emphasis on actual cases of political controversy involving technological change. *Sapolsky*

**17.422 Public Management of Science**

Prereq.: —

Year: G (1)

3-0-6

A study of the Federal government's support and use of science and technology, emphasizing major organizational issues. An analysis of the problems of organizational competition, policy planning and coordination, Executive-Congressional relations, the science advisor's role in administration, the management of research, and institutional autonomy. (Not offered 1969-70.) *Sapolsky*

**17.431 Science and American Foreign Policy (A)**

Prereq.: 17.412

Year: G (2)

3-0-6

Examination of the scientific component in U.S. foreign-policy making, including the scientific and technological bases of key issues in foreign policy, opportunities scientific programs offer for the more effective realization of U.S. objectives; pattern of international scientific collaboration; role of scientists in foreign policy process. (Not offered 1969-70.) *Skolnikoff*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## POLITICAL SCIENCE

### 17.442 *American Science and Its Development: Current Issues and Problems (A)*

Prereq.: 17.412

Year: G (2)

Arr.

Seminar designed to bring together selected faculty members and graduate students to consider a single major public issue in science-government relations each year and to subject it to sustained analysis. Seminar report representing the collective contributions of the participants issued at the end of the term. (Not offered 1969-70.)  
Skolnikoff

### 17.443J *Public Policy and Use of the Seas*

(Same subject as 13.92J)

Prereq.: —

Year: G (1)

3-0-6

Policies of the United States and other nations toward possession and use of the seas. Interfaces between technology and public policy. Laws and agreements relating to jurisdiction in the maritime frontier, use of Continental Shelf, navigation, exploitation of ocean resources, deep submergence, and pollution. Role of the U.N. and other agencies. New goals for national policy.

Padelford

## INTERNATIONAL POLITICS AND FOREIGN POLICY

### 17.51T *International Relations*

Prereq.: 14.01T or 17.01 or 21.05

Year: U (1, 2)

3-0-6

Basic factors and trends in contemporary world politics. Models of the international system; dynamics of politics; imperialism; nationalism; east-west struggle; revolution in developing nations; impact of technology. Decision making processes and basic interests of the great powers. Comparative instruments of foreign policy; the United Nations; regional arrangements. Case study of the war in Vietnam.

Padelford, Giddens

### 17.511 *Theories of International Relations (A)*

Prereq.: 17.51T or 17.52T

Year: G (1)

3-0-6

Selective review and critical discussion of the literature of international relations. Comparison of disciplinary foci and conceptual frameworks proposed by authors such as Aron, Lasswell and Wright. Examination of work by Carr, Claude, Deutsch, Guetzkow, Haas, Hoffman, Kaplan, Kelman, Lenin, Morgenthau, and other materials for their substantive hypotheses, normative orientations, data resources, and research possibilities.

Atker

### 17.513 *Function of Law in the World Community (A)*

Prereq.: 17.511 or 17.521 or 17.53T

Year: G (1)

3-0-6

Role of international law in the development of political community at the regional and global levels. Nature and subjects of international law. Rights and duties of states. The law and the individual. Territorial questions with special reference to boundaries, territorial waters, the high seas, air and outer space. Peaceful settlement of disputes; peace-keeping; place of the U.N. Use of force and the international rule of law. (Not offered 1969-70.)

Padelford

### 17.514 *The U.N. System and Problems of Political Development (A)*

Prereq.: 17.511 or 17.53T

Year: G (2)

3-0-6

The structure, process, and politics of international organizations, particularly within the U.N. system. Special emphasis on the role of international agencies in relation to political and economic development. Concepts of integration and community. Problems of collaboration with international institutions. (Not offered 1969-70.)

Padelford

### 17.516 *Research Seminar in International Relations (A)*

Prereq.: 17.53T

Year: G (2)

3-0-6

Individual directed research and reading on problems of international politics, law and organization. (Not offered 1969-70.)

Staff

### 17.518 *Research Seminar in Imperialism and Colonialism*

Prereq.: —

Year: G (1)

3-0-6

Topics in the economic, social, and cultural bases of imperialism and colonialism, its theory and practice. (Not offered 1969-70.)

Rotberg

### 17.52T *Principles and Problems of American Foreign Policy*

Prereq.: 17.51T

Year: U (1, 2)

3-0-6

The American experience — underlying assumptions and major objectives of American foreign policy. Emphasis on relationship between social and institutional structures within which foreign policy is made, and substantive foreign policy issues: NATO, relations with the Soviet bloc and China, the United Nations, and the underdeveloped world.

Giddens

### 17.521 *U.S. Foreign Policy—Process and Problems (A)*

Prereq.: 17.51T or 17.52T

Year: G (1)

3-0-6

A critical analysis of the contemporary U.S. foreign policy scene in the context of broad national strategy. The process of policy making including organization, formulation, and execution. Analysis in depth of selected issues.

Bloomfield

### 17.522TU.S. Foreign Policy — Plans and Strategies (A)

Prereq.: 17.521

Year: G (2)

Arr.

The planning of foreign policy in the context of broad national strategy. The questions of foreign policy goals and interests and of developing short- and long-term political doctrines and strategies. Illustrative problems, with emphasis on simulation (political-military gaming) and other special techniques for contingency planning.

Bloomfield

### 17.523 *Research: International Relations and Foreign Policy (A)*

Prereq.: 17.521 or 17.522T

Year: G (1)

Arr.

Problem approach to selected areas and issues, based on particular student interests.

Bloomfield

### 17.53T *Seminar in International Politics*

Prereq.: 17.52T

Year: U (1, 2)

3-0-6

Selected problems to complete a three-term sequence in international relations. Problems varying from year to year, but most recently emphasizing the international relations of Asia, and with special regard for American policy.

Field, C. Schaefer

### 17.54T *Arms Control, Disarmament, and Foreign Policy*

Prereq.: 17.51T

Year: U (1)

3-0-6

Analysis of the problems of disarmament and arms control and the issues involved for American foreign and defense policy, against a background of diplomatic history, technological change, and politico-military strategy. (Not offered 1969-70.)

Bloomfield

## POLITICAL AND ECONOMIC DEVELOPMENT

**17.61T Political and Economic Development of Tropical Africa**

Prereq.: 17.01 or any political science subject  
Year: U (1) 3-0-6

Study and evaluation of the major theories, facets and problems of economic and political development in tropical Africa. *W. R. Johnson*

**17.61IT Personality, Social Stability, and Social Change (A)**

Prereq.: 17.15T  
Year: G (1) Arr.

Relation of personality to social structure in the explanation of social stability and change. Traditional societies as social-cultural-personality systems. Analysis of their stability or instability. Emphasis on evidence from village studies. Limited analysis of factors affecting societal change, especially "modernization." *Hagen*

**17.612 Seminar in Social Stability and Change (A)**

Prereq.: 17.611T  
Year: G (2) 3-0-6

Amplified discussion of selected literature relating personality to social structure in the analysis of social change. Study of two societies, probably Burma and Japan, to illustrate the theoretical analysis. Alternatively, studies of "childhood and adulthood." Term paper concerning an empirical problem. *Hagen*

**17.621 The Development of Political Organizations (A)**

Prereq.: 17.722  
Year: G (1) 3-0-6

Examination of the factors involved in the origins, development, and maintenance of various types of political organizations. Particular attention given to the creation of political parties and the maintenance of local party organizations in underdeveloped areas. (Not offered 1969-70.) *Weiner*

**17.623 Social Organization and Political Change in Developing Areas (A)**

Prereq.: 17.721 or 17.722  
Year: G (1) 3-0-6

Analysis of principles of social organization, social stratification, and social mobility as they affect various aspects of political development such as political participation, political leadership, political organization, legitimacy, and political integration. *Weiner*

**17.63T Seminar: Mechanisms and Forms of Protest**

Prereq.: —  
Year: U (1) 3-0-6

Comparative analysis of the varieties of self-assertion: resistance movements, rebellions, millennialism, and struggles for independence. In 1969, concentration on the nature and methodology of rebellion. (For advanced undergraduates and graduate students.) *Rotberg*

**17.631 Theories of Political Development (A)**

Prereq.: 17.52T  
Year: G (1) Arr.

Study of various analytical models of the political process in transitional societies. Systematic examination of factors influencing political behavior in changing societies; functions of politics in such societies. *Pye*

**17.64T Political Science Seminar**

Prereq.: —  
Year: U (2) 3-0-6

Seminar for students in political science program with

members of the faculty to explore various aspects of selected problems in political science. Coordination of thinking from the varying points of view of political science and development of ability to deal with issues of decision making. (Not offered 1969-70.) *Staff*

**17.65J Nationalism in Africa**

(Same subject as 21.551J)  
Prereq.: One first-year Humanities sequence  
Year: U (2) 3-0-6

Examination of the ideological, political, and economic bases of imperialism, colonialism and nationalism; the partition of Africa, the nature of alien rule, and the response of Africans thereto during the nineteenth and twentieth centuries. *Rotberg*

**17.652 Field Research in Political Development (A)**

Prereq.: 17.131  
Year: G (2) Arr.

Seminar in field research methods for political research in developing areas. Intended only for students who will begin field research the following academic year. *Weiner*

**17.66 Political Ideas and Industrial Society**

Prereq.: 17.01  
Year: U (1) 3-0-6

Identification of certain fundamental problems of industrial society through readings of selected nineteenth- and twentieth-century political and social theorists. Use of economic and historical materials in an attempt to relate political ideas to the problems raised by industrialism. *Berger*

**17.71, 17.72 Reading Seminar in Social Science**

Prereq.: —  
Year: U (1, 2) Arr.

Reading and discussion of special topics in the fields of social science. Open to advanced undergraduates by arrangement with individual staff members. *Staff*

**17.711-17.715 Reading Seminar in Social Science (A)**

Prereq.: —  
Year: G (1, 2) Arr.

Reading and discussion of special topics in the fields of social science. Open to advanced graduate students by arrangement with individual staff members.

**17.72 See above, following 17.71.**

## POLITICAL ANALYSIS

**17.721 Concept Formation and Research Technique in the Social Sciences**

Prereq.: —  
Year: G (1) 3-0-6

Requirements for testable concepts and theory building with behavioral data. Logical foundations of evidence and inference, quantity and quality, parts and wholes, cause and effect. Research technique in sample surveys, controlled experiment, clinical diagnosis, statistical tests. Emphasis on reanalysis of extant and created data. (Not offered 1969-70.) *Lerner*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## POLITICAL SCIENCE

### 17.722 *Theory of Political Processes*

Prereq.: —

Year: G (2)

Arr.

Analysis of various theories of the political process. Particular attention paid to theories concerning the formation of a consensus about the legitimacy of a government and the consequences of conflict and conformity within nations. A different author read and discussed each week. Pool

### 17.723 *Introduction to the Social Sciences (A)*

Prereq.: —

Year: G (1)

3-0-6

Extensive reading and analysis of the classic works in modern social and political science theory. Systematic review of the various traditions of contemporary social science. Primarily designed for the first-year graduate student without a broad background in social science. Pye

### 17.724 *Topics in Political Theory*

Prereq.: —

Year: G (1)

Arr.

*International interaction:* The balance of power. Shifting coalitions, feedback, and multipolarity. Empire-building and the decomposition of empire. The initiation and termination of conflict. *Political Power and Society:* The dimensions of power: coercion, influence, authority. Authority and influence. The ruling class. The Marxian hypothesis. Political stability and instability. Revolution. *Typology of Political Systems:* Classical typologies (Plato, Aristotle, Polybius). Imperial and feudal rule. The problem of "oriental despotism." Bureaucratic absolutism. Consensual, pluralistic and totalitarian democracy. Kecskemeti

### 17.725 *Logic of Social Research*

Prereq.: —

Year: G (2)

Arr.

Reading of theoretical treatments and discussion of the application to major social science studies of the following topics: observation, experimentation, measurement, explanation, theory, and models. Pool

### 17.73T *Mathematical Politics*

Prereq.: 17.01

Year: U (2)

Arr.

Mathematical modeling of political processes including alternate descriptions and evaluations of their inputs, mechanisms and outcomes. Election or referendum campaigns, national decision making, and international conflict. A year of previous social science work or reading required. (Not offered 1969-70.) Staff

### 17.731 *Introduction to Mathematical Models in the Social Sciences*

Prereq.: —

Year: G (2)

3-0-6

Introduction to the use of mathematical models and formal mathematical analysis in sociology and political science. Study of the necessary mathematics as a part of the subject. For students with little mathematical background. Lehrer

### 17.732 *Statistics for the Social Sciences*

Prereq.: —

Year: G (1)

3-0-6

Basic concepts and techniques useful in social science. Summarizing empirical distributions, random variables and theoretical distributions; estimation of unknown parameters; measuring and testing statistical relationships between variables, including correlation, regression, and non-parametric methods, with emphasis on the question of which techniques are appropriate to which kind of data. No mathematical or statistical prerequisites. Staff

### 17.733 *Introduction to Automatic Computation*

Prereq.: —

Year: G (1)

2-2-2

Direct communication between students and a large-scale digital computer. (Registration limited. Permission of instructor required.) Weizenbaum, Fenichel

### 17.734 *Data Structure for Symbol Manipulation*

Prereq.: 17.731

Year: G (2)

2-0-6

Basic structure of the MAD compiler. Communication of parameters. FAP and MAD external functions. Imbedding subsystems in MAD. List processing. The available space issue. The responsibility issue and list erasure. Sequencing over complex list structures. Modifying complex list structures. Text manipulation within SLIP. Input-output of list structures. Extensions of list processing ideas to more general data structures. (Not offered 1969-70.) Weizenbaum

### 17.735 *Seminar in Model Building in Political Science*

Prereq.: —

Year: G (2)

2-0-6

Specific political or social organization studied from the point of view of designing a computer model representing it. Model built and run by the seminar. McIntosh, Griffel

### 17.736 *Multivariate Political Analysis (A)*

Prereq.: 17.731, 17.732

Year: G (2)

Arr.

Focus on multivariate data analysis procedures. Second half of a year sequence with first half being taught as Government 200 at Harvard by H. D. Price. Topics: multiple regression analysis, analysis of variance and covariance, treebuilding, ecological inference, recursive and non-recursive causal modeling, cluster analysis, factor analysis, and multidimensional scaling. Social and political research applications undertaken and discussed. Some but not all topics in the second term require knowledge of material covered in the first. Students without first-term background consult the instructor in deciding their topical coverage of the subject. Alker

### 17.737 *Interactive Data Analysis*

Prereq.: —

Year: G (1)

2-3-4

Instruction in the use of the ADMINS system on CTSS for preparing and analyzing files of social science data. Codebook preparation, data cleaning, index construction. Analysis of panel studies, longitudinal surveys and aggregate data. Derivation of new files from existing ones. Some discussion of relevant statistics. Weekly problem sets and laboratory work. McIntosh, Griffel

### 17.738 *Seminar on Complex Models of Social Systems*

Prereq.: 17.731, 17.732

Year: G (1)

2-0-7

Seminar intended to be preparatory to further study of statistical, mathematical, and computer utilization skills needed for modeling cognitive, interpersonal, organizational, governmental, and societal processes and structures. Critical analysis of modern systems theory and a comparison (using case studies) of the different tools of contemporary formal analysis offered. Taught in conjunction with Professors Price and Stone of Harvard University as part of a coordinated training program in modeling complex social and political systems. Alker, Weizenbaum

### 17.75T *Prediction in Social Science and Public Policy*

Prereq.: —

Year: U (1)

3-0-6

Methodological problems in sociology and political

science relevant for policy decisions. Description, causation, and prediction. Population trends and their consequences. Indicators of social change and of social problems. The relationship between prediction and decision making. *Staff*

**17.76 Political Science Laboratory**

*Prereq.:* 17.01  
*Year:* U (2) 2-6-4

Coordinated set of project-type research experiences concerning individual, community, national, and international affairs. Emphasis on using procedures of experimental or quasi-experimental inference to test normatively significant hypotheses about political life. Enrollment limited to 30. *Alker*

URBAN STUDIES

**17.81 Structure of Urban Life**

*Prereq.:* 17.21T  
*Year:* U (2) 3-5-10

Intensive survey of the political, economic and social systems in organized urban life today and the major public policy issues of urban regions, combining class and field work in a joint seminar with students from Dartmouth College. A weekly class meeting, in addition to an extensive coordinated field investigation of a highly urbanized area in Boston, employing the principal research techniques of social science. *Staff*

**17.81I Seminar in Urban Politics (A)**

*Prereq.:* 17.21T or 17.25T  
*Year:* G (1) 3-0-8

Examination of the major political issues and policy-making processes of urban America. First of two terms with special emphasis this term on the politics and sociology of race. *Altshuler*

**17.812J Seminar on Urban Development**

*Policy (A)*  
(Same subject as 11.58J)  
*Prereq.:* 17.811  
*Year:* G (2) *Arr.*

Focus this term on urban planning and policy making. Analysis of selected policies, ranging from welfare, community action, and education to transportation, urban renewal, and Model Cities. Special attention to their bases of political support and their relation to problems of race and poverty. *Altshuler, Frieden*

**17.813 Research Seminar in Urban Politics (A)**

*Prereq.:* 17.21T  
*Year:* G (2) *Arr.*

Social and political aspects of urban school systems. *Fein*

**17.814 Urban Politics and Problems (A)**

*Prereq.:* 17.811  
*Year:* G (2) 3-0-6

Examination of policy-making processes of urban America and certain specific urban political issues, with particular emphasis on intergovernmental relations and metropolitan decision making. *R. C. Wood*

**17.818J Special Studies in Systems**

*Engineering (A)*  
(Same subject as 1.16J, 2.191J, 6.604J, 13.47J)

*Prereq.:* 17.25T or 17.81 or 17.813 or 17.814  
*Year:* G (2) 2-4-6

Introduction to basic techniques employed in planning and design of complex systems. Detailed design of subsystems by individual student groups with emphasis upon use of parametric design principles in arriving at suitable tradeoffs between subsystems. Supplementing lectures covering general principles of the operational complex and subsystems by guest lecturers. The particular oper-

ational complex chosen for each term to be announced before start of the term. Students encouraged to discuss subject with staff prior to registration. (Previous projects: Group 1—an integrated urban transportation system; Group 2—a manned satellite inspection and retrieval system.) *R. C. Wood, Baumann, Seifert, Frankel*

**17.82 Seminar in Contemporary Urban Sociology**

*Prereq.:* 17.21T or 17.24T  
*Year:* U (1) 3-0-6

Examination of the sociology of urban life; ethnicity, class, poverty; special attention to race. *Fein*

**17.83 Politics of Urban Education**

*Prereq.:* 17.01  
*Year:* U (1) 3-0-6

Analysis of current educational criticism in light of traditional educational theories, with particular attention to the forms of control of public education through centralization, decentralization, and "community control." Contributions to the development of subject matter by those students interested in field work in education through teaching and tutoring. *Menand*

**17.84 Theory and Practice of Community Action**

*Prereq.:* 17.01  
*Year:* U (2) 3-0-6

Examination of representative and participatory democratic principles both historic and contemporary, with particular attention given to the evolution and practice of "community action." Field work combined with study. *Menand*

18.

Mathematics

**18.00 Elementary Number Theory**

*Prereq.:* —  
*Year:* U (1) 2-0-4

Elementary theory of whole numbers, including such topics as divisibility, prime and composite numbers, greatest common divisors, solutions of equations in integers, the congruence notation and its application, sums of squares, rational approximations of real numbers, continued fractions, distribution of primes. Emphasis on mathematical rigor and methods of proof. *H. Rogers*

**18.01 Calculus**

*Prereq.:* —  
*Year:* U (1) 4-0-8

Study of functions of one variable. Brief review of the elementary functions. Basic properties of functions, such as boundedness, periodicity, growth rate. Limits and continuity. Differentiation, with applications. Solution of the simplest differential equations. Integrability, the definite integral, fundamental theorem of calculus. Applications to geometrical problems. Integration techniques, improper integrals. The mean value theorem and its generalization to Taylor's theorem, with applications to calculation of the elementary functions. Primarily for students with some previous knowledge of calculus or for those who are mathematically inclined. *Mattuck*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## MATHEMATICS

- 18.011 Calculus**  
Prereq.: —  
Year: U (1, 2) 4-0-8  
Similar to 18.01; primarily for students having little or no previous acquaintance with calculus. *W. T. Martin*
- 18.02 Calculus**  
Prereq.: 18.01 or 18.011  
Year: U (1, 2) 4-0-8  
Study of functions of several variables. Vector algebra in three-space. Scalar functions of two and three variables; partial differentiation, gradient, approximation techniques. Double and triple integration, with applications. Vector functions of one variable, analysis of space motion, Kepler's laws. Vector functions of two and three variables, vector fields. Line integrals, Green's theorem in the plane, conservative fields. Surface integrals in space; the divergence (Gauss's) theorem; Stokes' theorem. *Benney, Mattuck*
- 18.021 Calculus**  
Prereq.: 18.011  
Year: U (2) 4-0-8  
Similar to 18.02; continuation of 18.011. Switching from one of the two calculus sequences (18.01-02, 18.011-021) to the other at the end of the first term possible. *W. T. Martin*
- 18.025 The World of Mathematics**  
Prereq.: 18.02 or 18.021  
Year: U (2) 3-0-9  
Survey of a limited number of topics of current interest and of broad cultural significance, designed for students not majoring in mathematics, and stressing the central role of mathematics in today's world. Topics varying from year to year, and including: current developments in logic, the evolution of geometry, contemporary views on space and time, discrete vs. continuous mathematics, the mathematics of communication, chance and choice, elements of group theory, transfinite arithmetic, elements of field theory, non-standard analysis, etc. (*Not open to mathematics majors.*) *Rota*
- 18.031 Linear Mathematical Systems**  
Prereq.: 18.02 or 18.021  
Year: U (1) 3-0-9  
Systems of linear equations, determinants, matrices and linear operators, eigenvalue problems, structure of normal matrices; systems of linear differential equations with constant coefficient; relevant numerical methods. (*Limited enrollment.*) *L. N. Howard*
- 18.032 Ordinary Differential Equations**  
Prereq.: 18.031 or 18.20  
Year: U (2) 3-0-9  
Existence and numerical computation for initial value problems; structure of linear systems with variable coefficients; boundary-value problems; techniques for non-linear problems; regular and singular perturbation theory. (*Limited enrollment.*) *L. N. Howard*
- 18.034 Differential Equations**  
Prereq.: 18.02 or 18.021  
Year: U (1, 2) 3-0-9  
Elementary linear algebra, linear differential equations with constant coefficients, geometry of solutions, existence and numerical computation of solutions, non-linear equations, phase plane, linear systems with variable coefficients, series solutions. *L. N. Howard*
- 18.05 Advanced Calculus for Engineers (A, except Courses II, VI, VIII, XII, XIII, XVI, XVIII, XXII)**  
Prereq.: 18.034  
Year: G (1); U (1, 2, S) 3-0-9  
Functions of a complex variable; calculus of residues; conformal mapping. Ordinary differential equations; integration by power series; Bessel and Legendre functions. Expansion in series of orthogonal functions, including Fourier series. Hildebrand, *Advanced Calculus for Applications*. *Hildebrand*
- 18.06 Advanced Calculus for Engineers (A, except Courses II, VI, XVI, XVIII, XXII)**  
Prereq.: 18.05  
Year: G (1, 2, S) 3-0-9  
Vector analysis: orthogonal curvilinear coordinates. Calculus of variations. Solution of classical equations of mathematical physics, including applications of conformal mapping and the Laplace transformation. Partial differential equations; characteristics. Hildebrand, *Advanced Calculus for Applications*. *Hildebrand*
- 18.07 Review of Mathematics**  
Prereq.: —  
Year: G (S) 8-0-12  
Review of calculus and differential equations. (*Restricted to selected officers of the U.S. Army, Air Force, Navy and Coast Guard.*) *Staff*
- 18.081 Principles of Applied Mathematics**  
Prereq.: 18.034  
Year: U (1) 3-0-9
- 18.082 Principles of Applied Mathematics**  
Prereq.: 18.034  
Year: U (2) 3-0-9  
A general introduction to the fundamental principles of applied mathematics: optimization, cybernetics, random processes, propagation, equilibrium and stability. Development of the related mathematics and applications. *Papert (18.081), Greenspan (18.082)*
- 18.091 Advanced Calculus (A, except Courses II, VI, VIII, XII, XIII, XVI, XVIII, XXII)**  
Prereq.: 18.034  
Year: G (1) 3-0-9
- 18.092 Advanced Calculus (A, except Courses II, VI, XVI, XVIII, XXII)**  
Prereq.: 18.091  
Year: G (2) 3-0-9  
Functions of a complex variable, ordinary differential equations, special functions, Sturm-Liouville problems. Advanced vector analysis, potential theory, Fourier series and integral transforms, boundary value problems. (Essentially the same material as that covered in 18.05 and 18.06, but at an advanced level to satisfy the prerequisites for the Methods of Applied Mathematics sequence beginning with 18.653. Students should have A's and B's in previous mathematics subjects, and should not be mathematics majors.) *E. J. O'Neil*
- 18.10 Applications of Probability and Random Variables**  
Prereq.: 18.02 or 18.021  
Year: U (1, 2) 3-0-9  
Theory of probability and random variables on an elementary level with emphasis upon mathematical models having wide applicability. Discrete and continuous random variables, joint distributions, derived distributions, expected value, difference equations, generating functions, some elementary aspects of queuing theory and Markov processes, decision making, and some probabilistic methods in the control of operations. Stress on applications from a wide choice of fields. *Wadsworth*
- 18.13 Numerical Analysis (A)**  
Prereq.: 18.05 or 18.651  
Year: G (1) 3-2-7

**18.14 Numerical Analysis (A)**

Prereq.: 18.13  
Year: G (2) 3-2-7

Introduction to the theory and practice of the solution of equations, interpolation, numerical differentiation and integration, and the numerical solution of ordinary and partial differential equations. Additional topics from the following: summation of series, least-squares methods, smoothing of data, Gaussian quadrature, Chebyshev approximation, harmonic analysis, approximation by exponential functions and by rational functions, determination of characteristic numbers of matrices. Hildebrand, *Introduction to Numerical Analysis*. (18.14 not offered 1969-70.) Hildebrand

**18.15 Methods of Applied Mathematics for Engineers (A, except VI and XVIII)**

Prereq.: 18.05  
Year: G (1, 2) 3-0-9

Operations with matrices and determinants; linear vector spaces; characteristic-value problems. Techniques of calculus of variations; constraints, direct methods. Formulation and treatment of integral equations; Green's function; analytical and numerical methods of solution. Hildebrand, *Methods of Applied Mathematics*. Hildebrand

**18.16J Heuristic Programming and Artificial Intelligence (A)**

(Same subject as 6.544J)  
Prereq.: —  
Year: G (2) 3-0-9

The problem of making machines behave intelligently. Application of machines to problems of learning, induction, pattern-recognition, game-playing, theorem-proving, neural nets, self-organizing systems, and other areas where problems have been solved by heuristic programming. Problems in administration and allocation of effort within programs. Models of cognitive processes. Machine aids for human problem solving. (*Ability to program a computer required.*) Papert, Minsky

**18.16I Introduction to Mathematical Theory of Computation**

Prereq.: —  
Year: U (1) 3-0-9

Algebraic theory of finite automata. Perceptrons and iterative arrays. Push-down automata, counter machines, Turing machines. Measures of complexity. Introduction to recursive function theory. Unsolvability results. Paterson

**18.162T Computers and Logic (A)**

Prereq.: 6.262J or 18.886  
Year: G (2) 3-0-9

Discussion of two major topics: (1) theorem proving. Herbrand's theorem, resolution principle, proof strategies and heuristics, recent developments. (2) Problems of correctness, termination and equivalence of computer programs and abstract programs. Recursion induction, satisfiability methods and unsatisfiability methods, program schemas, unsolvability results. Paterson

**18.163 Theory of Computers (A)**

Prereq.: 6.253 or 18.25  
Year: G (1) 3-0-9

Recursive function theory with special emphasis on the results which reveal the fundamental properties of computing systems. Recursion theorem and the related self-scanning machines. Machine-independent theorems on speed and efficiency of computation, length of algorithms, real-time computation. Papert

**18.17 Combinatorial Theory (A)**

Prereq.: 18.031 or 18.034  
Year: G (1) 3-0-9

Survey of combinatorial problems of current research interest. Topics include enumerative analysis, theory of partitions, graph theory, knot theory, network flow, theory of matroids, matrices of zeros and ones, combinatorial designs, representations of the symmetric group, combinatorial methods in statistical mechanics, combinatorial geometry, Ramsey's theorem, matching theory, asymptotic enumeration. Varying content from year to year, so that students may take the subject in successive years. Kleitman

**18.18 Probability**

Prereq.: 18.02 or 18.021  
Year: U (2) 3-0-9

Introduction to probabilistic thinking in all branches of science. Starting from specific examples and phenomena, students gradually exposed to the underlying mathematical theories. Content varying from year to year, but most material drawn from Feller, *Introduction to Probability Theory*, Vols. 1 and 2, and possibly including: fluctuation theory for sums of random variables, random walks, Poisson processes, renewal theory, Markov chains, branching processes. Rota

**18.182 Introduction to Stochastic Processes (A)**

Prereq.: 18.18  
Year: G (2) 3-0-9

Independence. Zero-one laws of Borel-Cantelli and Kolmogorov. Chebyshev's and Kolmogorov's inequalities. Distribution functions and transforms. Classical limit theorems (deMoivre-Laplace, Poisson, strong law of large numbers). Random walks, Markov chains, Poisson processes, Brownian motion and diffusion. Connection with differential and integral equations. (*Not offered 1969-70.*) Ray

**18.20 Linear Algebra**

Prereq.: 18.031 or 18.034  
Year: U (1, 2) 3-0-9

Vector spaces, euclidean spaces, linear transformations, linear equations, matrices, determinants, quadratic forms, canonical forms of matrices. If 18.20 is taken after credit has been received in 18.25, then credit is not permitted in both 18.20 and 18.26. Hoffman and Kunze, *Linear Algebra*. Curtis

**18.21 Analysis (A, except XVIII)**

Prereq.: 18.031 or 18.034  
Year: U (1, 2); G (1, 2) 3-0-9

Real numbers and euclidean n-space; open, closed and compact subsets of n-space. Continuous and differentiable functions. Uniform convergence. Fourier series, power series and analytic functions. Note: 18.20 or 18.031 will be helpful as additional preparation. K. M. Hoffman

**18.22 Analysis (A, except XVIII)**

Prereq.: 18.20 or 18.26; 18.21  
Year: G (2) 3-0-9

Normed linear spaces. Lebesgue integration in euclidean space. Differentiable maps, Jacobians and the inverse function theorem. Change of variables. Differential forms and Stokes theorem. K. M. Hoffman

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## MATHEMATICS

### 18.23 Seminar in Mathematics

Prereq.: 18.21

Year: U (1, 2)

3-0-9

Seminars for mathematics majors in several topics, each under the direction of a faculty member whose special interest is in the field of the seminar. Reports and discussion by students on topics taken from current journals or from texts not regularly used in other mathematics subjects. Certain topics may require an additional prerequisite.

Staff

### 18.24 Elementary Differential Geometry

Prereq.: 18.21

Year: U (1, 2)

3-0-9

Emphasis on classical theory of space curves and surfaces. Frenet formulas, fundamental forms, theorems of Meusnier and Euler, lines of curvature, asymptotic and conjugate lines, geodesics, equations of Gauss, Cadazzi and Weingarten, special surfaces, mapping problems and existence theorems. Additional topics to be chosen from geometry in the large, classical tensor theory and Riemannian geometry.

K. D. Johnson

### 18.241 Introduction to Topology

Prereq.: 18.20 or 18.25; 18.21

Year: U (1, 2)

3-0-9

Topological spaces, connectedness, compactness, continuous functions, separation axioms, product space and function space topologies, plus several additional topics to be chosen by the instructor.

Maskit

### 18.242 Riemannian Geometry

Prereq.: 18.22, 18.241

Year: U (2)

3-0-9

Elementary manifold theory, differential forms and the De Rham theorem, first and second fundamental forms for surfaces, curvature and the Gauss-Bonnet theorem, embedded surfaces.

I. M. Singer

### 18.25 Modern Algebra

Prereq.: 18.034

Year: U (1)

3-0-9

### 18.26 Modern Algebra

Prereq.: 18.25

Year: U (2)

3-0-9

Groups, subgroups, factor groups, homomorphism theorems; rings and ideals, factorization theory for euclidean rings; vector spaces and elementary field theory. Modules over a ring of operators. Applications to vector spaces and linear algebra. Normal forms for matrices. Quadratic forms. Tensor and Grassman algebras.

Mattuck

### 18.27 Introduction to Functions of a Complex Variable (A, except XVIII)

Prereq.: 18.034

Year: G (1)

3-0-9

### 18.28 Introduction to Functions of a Complex Variable (A)

Prereq.: 18.27 or 18.31

Year: G (2)

3-0-9

Complex numbers, analytic functions, Riemann surfaces for certain functions, Cauchy's theorem, singularities, residues, contour integral, conformal mapping, Schwarz-Christoffel transformation, series and sequences, analytic continuation, harmonic functions, conjugate functions, the gamma function, second-order linear differential equations and special functions, Laplace transforms, asymptotic series, saddlepoint method, Hilbert transforms. Singular integral equations.

Baxter (18.27); Lieb (18.28)

### 18.31 Theory of Functions (A)

Prereq.: 18.21

Year: G (1)

3-0-9

Cauchy's integral theorem, residue theorem and applica-

tions. Series and product representations of analytic functions. Entire and meromorphic functions. Simple Riemann surfaces. Conformal mapping. Additional topics may be included.

Artin

### 18.32 Theory of Functions (A)

Prereq.: 18.31

Year: G (2)

3-0-9

Topics selected by the instructor, e.g., harmonic functions, Dirichlet problem, Riemann surfaces, uniformization, quasi-conformal mapping, Fourier and Laplace transforms, special functions.

### 18.33 Functions of Complex Variables (A)

Prereq.: 18.31

Year: G (1)

3-0-9

### 18.34 Functions of Complex Variables (A)

Prereq.: 18.33

Year: G (2)

3-0-9

Various aspects of the theory of analytic functions. Content varying from year to year, so that students may take the subject in successive years. (18.34 not offered 1969-70.)

Shiffman

### 18.35 Functions of Real Variables (A)

Prereq.: 18.22

Year: G (1)

3-0-9

### 18.36 Functions of Real Variables (A)

Prereq.: 18.35

Year: G (2)

3-0-9

Elements of the theory of metric spaces, category and Baire theorem. Lebesgue integration, absolute continuity and differentiation of functions of bounded variation. Abstract measure theory, Radon-Nikodym and Fubini theorems,  $L^p$  spaces. Elements of Banach spaces, Hahn-Banach and closed graph theorems. Topics on linear transformations of  $L^p$  spaces.

Dudley

### 18.363 Abstract Analysis (A)

Prereq.: 18.25, 18.36

Year: G (1)

3-0-9

### 18.365 Abstract Analysis (A)

Prereq.: 18.363

Year: G (2)

3-0-9

Basic theoretical results about the structures of a mixed analytical-algebraic-geometrical character that are significant in modern analysis, with illustrative applications. (Not offered 1969-70.)

Segal

### 18.365 Mathematical Analysis of Fundamental Physics (A)

Prereq.: 18.36

Year: G (1)

3-0-9

Mathematical analysis of contemporary physical theory accompanied by a rigorous treatment of the underlying mathematics.

Segal

### 18.366 Mathematical Analysis of Fundamental Physics (A)

Prereq.: 18.365

Year: G (2)

3-0-9

Mathematical treatments of recent developments in areas selected from: constructive quantum field theory; elementary particle models; non-linear relativistic partial differential equations in the large; etc.

Segal

### 18.368 Hilbert Space (A)

Prereq.: 18.36

Year: G (1)

3-0-9

General theory of operators and operator algebras in Hilbert space with applications.

Segal

- 18.37 Functional Analysis (A)**  
*Prereq.:* 18.27 or 18.31; 18.35  
*Year:* G (2) 3-0-9
- 18.38 Functional Analysis (A)**  
*Prereq.:* 18.37  
*Year:* G (2) 3-0-9  
 General theory of linear topological spaces. Locally convex spaces, duality; category theorems. Distributions and generalized functions; tensor products and kernels. Applications. (18.38 not offered 1969-70.)  
*Helgason*
- 18.41 Differential Equations (A)**  
*Prereq.:* 18.15 or 18.20; 18.31  
*Year:* G (1) 3-0-9
- 18.42 Differential Equations (A)**  
*Prereq.:* 18.41  
*Year:* G (2) 3-0-9  
 Existence theorems in real and complex cases. Linear systems. Regular singular points. Irregular singular points and asymptotic series. Boundary value problems including the non-self adjoint case and the case of infinite intervals. Stability theory and perturbation theory for non-linear differential equations. Periodic orbits. Limit cycles. Differential equation on a torus. (Not offered 1969-70.)  
*Levinson*
- 18.43 Partial Differential Equations (A)**  
*Prereq.:* 18.22  
*Year:* G (1) 3-0-9
- 18.44 Partial Differential Equations (A)**  
*Prereq.:* 18.43  
*Year:* G (2) 3-0-9  
 The Cauchy-Kowalewski theorem, existence and regularity of solutions of the Dirichlet problem for linear elliptic equations, existence and regularity of solutions of the Cauchy problem for hyperbolic linear equations, fundamental solutions for linear equations with constant coefficients.  
*Kotake*
- 18.49 Harmonic Analysis and Potential Theory**  
*Prereq.:* 18.22  
*Year:* U (2) 3-0-9  
 Elementary theory of Fourier series and Fourier integrals; Riesz-Fischer and Plancherel theorems; Fourier-Stieltjes transforms; potentials of mass distributions; harmonic functions; the Dirichlet problem.  
*R. W. Goodman*
- 18.51 Singular Integrals (A)**  
*Prereq.:* 18.35  
*Year:* G (1) 3-0-9  
 Interpolation of operators. Riesz interpolation theorem. Marcinkiewicz interpolation theorem. Lorentz spaces. Applications. Singular integrals. Hilbert transform. Riesz transforms. Calderon-Zygmund operators. Marcinkiewicz multiplier theorem. Littlewood-Paley theorem. Sobolev spaces. (Not offered 1969-70.)
- 18.53 Theory of Probability (A)**  
*Prereq.:* 18.22 or 18.49  
*Year:* G (2) 3-0-9  
 Survey of contemporary theory of stochastic processes. Independence, zero-one laws, martingales, stopping rules, stationary processes, elements of ergodic theory; Markov chains, characteristic functions, central limit problems, stable laws; renewal theory, Tauberian theory, Gaussian processes and their spectral theory, Brownian motion, the strong Markov property, the variance theorem; Kolmogorov-Smirnov statistics, processes with independent increments, diffusion theory. Topics selected each year from these and others. Students may take this subject repeatedly.  
*Rota*

- 18.54 Theory of Probability (A)**  
*Prereq.:* 18.53  
*Year:* G (2) 3-0-9  
 Topics selected by the instructor, for example, Markov processes, stationary processes, ergodic theory, diffusion processes and stochastic differential equations. (Not offered 1969-70.)  
*Ray*
- 18.57 Theory of Approximation Methods (A)**  
*Prereq.:* 18.20 or 18.26  
*Year:* G (1) 3-0-9  
 Analysis of constructive methods for the solution of algebraic and differential equations and eigenvalue problems. Applications of functional analysis. Constructive theory of functions. Over-relaxation and other iterative schemes for large systems of difference equations. (Not offered 1969-70.)  
*Strang*
- 18.58 Partial Difference Equations (A)**  
*Prereq.:* 18.20 or 18.26  
*Year:* G (2) 3-0-9  
 Parallel treatment of initial-value problems for partial differential equations and their finite difference analogs; equivalence of convergence and stability for linear systems; von Neumann's method of stability analysis in  $L_2$  by Fourier transform; Lax theory of non-linear conservation laws. (Not offered 1969-70.)  
*Strang*
- 18.59 Statistical Mechanics (A)**  
*Prereq.:* 8.421  
*Year:* G (1) 3-0-9  
 Selected topics, primarily in equilibrium statistical mechanics, with emphasis on rigorous mathematical results on specific problems. Discussion in detail of exactly soluble models such as the two-dimensional ferromagnet and ferroelectric models. Mathematical theories of phase transitions. (Not offered 1969-70.)  
*Lieb*
- 18.60 Introduction to Fluid Mechanics**  
*Prereq.:* 18.05 or 18.651  
*Year:* U (1) 3-0-9  
 Dynamics of frictionless fluids; mathematical description; some basic concepts and theorems. Equilibrium configurations. Potential flows; vortex motion; conformal transformations. Gravity waves; normal modes, group velocity; Kelvin-Helmholtz instability. Sound waves and atmospheric oscillations. Shallow-water theory; characteristics; bores and shocks. Elements of the theory of viscous fluids; some exact solutions; boundary layer theory.  
*Benney*
- 18.601 Theoretical Hydrodynamics (A)**  
*Prereq.:* 18.60  
*Year:* G (2) 3-0-9  
 Dynamics of compressible fluids; shock waves; hypersonic flow. Theory of hydrodynamic stability. Introduction to the theory of turbulence; mixing-length concepts. (Not offered 1969-70.)  
*Orszag*
- 18.611 Rotating Fluids (A)**  
*Prereq.:* 18.60, 18.653  
*Year:* G (2) 3-0-9  
 General theory of rotating fluid motions; transient flows; effects of viscosity, stratification, and compressibility; non-linear interactions; wave motions; applications.  
*L. N. Howard*
- (A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## MATHEMATICS

### 18.612 Seminar in Fluid Dynamics (A)

Prereq.: 18.60, 18.653  
Year: G (1) 3-0-9

Discussion exploring frontier and cul-de-sac in stability theory, turbulence, hydromagnetics and geophysical fluid dynamics. Presentation by students, with assistance, of a critique of a recent paper or the formulation and defense of a novel problem. *Malkus*

### 18.62 Hydrodynamic Stability and Turbulence (A)

Prereq.: 8.08  
Year: G (1) 3-0-9

Introduction to the statistical theory of turbulence. Homogeneous turbulence. Direct-interaction theory. Applications to turbulent diffusion, plasma turbulence, shear and thermal turbulence. (Not offered 1969-70.) *Orszag*

### 18.63 Mathematical Learning Theory (A)

Prereq.: 18.05  
Year: G (1) 3-0-9

Introduction of a learning theory with psychological and physiological implications in terms of some non-linear difference — differential networks. Interpretation also as a non-stationary statistical and/or deterministic prediction theory. Global limit and oscillation theorems. Influence of geometry on dynamics (i.e., "anatomy of learning"). Time evolution of entropy. Study of reversible and irreversible behavior. Applications to data: e.g., verbal learning (bowing, chaining, backward learning, reminiscence, presentation rate, list length, chunking, context effects), lateral inhibition, thresholds, spiking frequencies, transmitter production and release, ionic fluxes, reaction time, masking, pattern learning, extinction and spontaneous recovery, anatomical examples such as cerebellum. Comparison with classical developments: such as, Gestalt, Hull, Pavlov. (Not offered 1969-70.) *Grossberg*

### 18.634 Topics in Applied Mathematics (A)

Prereq.: —  
Year: G (2) 3-0-9

Content varying from term to term enabling student to take subject in successive terms. *Approximation Methods in Statistical Mechanics*. Distribution functions of a classical fluid. Cluster expansions and functional methods. Ornstein-Zernike relation. Delye-Huckel approximation for a plasma. Born-Freen, Percus-Yevick and hypernetted chain approximations. Monte Carlo methods. Scaled particle approximation. *Baxter*

### 18.635 Dynamical Problems of Astronomy and Astrophysics

Prereq.: 18.05 or 18.091 or 18.651  
Year: U (2) 3-0-9

Introductory subject covering classical and modern topics, including gravitational problems of 2-, 3- and n-bodies; the structure and stability of gravitating bodies and systems; tidal phenomena. Applications of theory to the solar system, the motion of artificial satellites, the earth, binary stars. (Not offered 1969-70.) *Hunter*

### 18.636 Stellar Dynamics and Galactic Structure (A)

Prereq.: 8.06; 18.06 or 18.652  
Year: G (1) 3-0-9

Types and compositions of galaxies; mass distributions and kinematics. General dynamics of stellar systems: Liouville and Boltzmann equation, isolating integrals; encounters, relaxation times; epicyclic stellar orbits. Dynamics of interstellar material: observations; hydro-magnetic equations; gravitational stability of a gas. Theory of star clusters and elliptical galaxies. Gravitational stability of a disk-shaped galaxy; spiral structure. *C. C. Lin*

### 18.641 Mathematical Theory of Modern Physics (A)

Prereq.: 18.28  
Year: G (2) 3-0-9

Mathematical theory of modern physics. Analytic properties of scattering amplitudes in the energy, the momentum transfer, and the angular momentum variables; single dispersion relation; double dispersion relation; Regge pole and representation theory; symmetry principles and particle physics; quantum electrodynamics at high energy. *Cheng*

### 18.65 Integral Equations (A, except XVIII)

Prereq.: 18.034  
Year: G (2) 3-0-9

Objectives: (1) to show how to express physical problems in the form of integral equations, (2) to provide a treatment of the theory of integral equations, and (3) to describe the methods available for solving such equations. Applications to problems arising in several branches of physics and engineering. *Crout*

### 18.651 Introduction to Applied Mathematics

Prereq.: 18.20 or 18.26; 18.21  
Year: U (1) 3-0-9

Interdependence of mathematics and scientific problems, examples; deterministic and random processes; particle mechanics and differential equations, Brownian motion and random walk. Fourier series; tensors; partial differential equations of mathematical physics and continuum mechanics. Linear programming. Calculus of variations. *Cheng*

### 18.652 Introduction to Applied Mathematics

Prereq.: 18.651  
Year: U (2) 3-0-9

Potential theory, boundary value problems for the partial differential equations of mathematical physics, method of separation of variables. Sturm-Liouville problems, Fourier integrals. Applications of the calculus of variations. Information theory. *Lieb*

### 18.653 Methods of Applied Mathematics I (A)

Prereq.: 18.092 or 18.27  
Year: G (1) 3-0-9

### 18.654 Methods of Applied Mathematics II (A)

Prereq.: 18.28, 18.653  
Year: G (2) 3-0-9

General mathematical theory of partial differential equations and methods of solution with applications to physical problems. Topics include single equations of the first order; characteristic surfaces and the classification of equations of higher order and systems of equations; properties of hyperbolic, parabolic, and elliptic equations, boundary conditions and well-posed problems, the application of integral transform and other methods to their solution. Asymptotic approximations. Integral equations: Fredholm and Hilbert-Schmidt theory, singular integral equations, application of integral transforms including Wiener-Hopf method, dual integral equations, Riemann problem. Calculus of variations. *Wan*

### 18.655 Methods of Applied Mathematics III (A)

Prereq.: 18.652 or 18.653  
Year: G (1) 3-0-9

Asymptotic methods of non-linear mechanics. Singular perturbation theory, matched asymptotic expansions, P.L.K. method, multiple scaling procedures, boundary layer techniques, applications to non-linear problems. (Not offered 1969-70.)

### 18.656 Wave Motion (A)

Prereq.: 18.653  
Year: G (2) 3-0-9

Introduction to diffraction theory. Asymptotic methods for scattering by edges, smooth bodies, etc. Geometrical

theory for propagation, refraction, diffraction in inhomogeneous media. Extensions of geometrical theory to uniform asymptotic expansions. The inverse problem. Special topics. (Not offered 1969-70.)

**18.66 Introduction to Elasticity**

Prereq.: 18.05 or 18.651  
Year: U (2) 3-0-9

Analysis of stress and strain. Stress-strain relations. General stress and displacement function solutions. Variational principles and uniqueness theorems. Applications of functions of complex variables and transforms. Wave propagation in elastic media. St. Venant theory of stretching, bending, torsion and flexure of prismatic bodies. Linear theory of plates. *Wong*

**18.67 Theoretical and Applied Elasticity (A)**

Prereq.: 2.071 or 18.66; 18.06  
Year: G (1) 3-0-9

**18.68 Theoretical and Applied Elasticity (A)**

Prereq.: 18.67  
Year: G (2) 3-0-9

Analysis of stress and strain in three dimensions. Stress-strain relations. Variational principles. Parametric expansion methods. Theories of beams, plates and shells. *Reissner*

**18.681 Theoretical and Applied Elasticity (A)**

Prereq.: 18.68  
Year: G (1) 3-0-9

Special topics in the linear and non-linear theory of beams, plates and shells. (Not offered 1969-70.) *Reissner*

**18.69 Tensor Calculus (A)**

Prereq.: 18.15 or 18.20  
Year: G (2) 3-0-9

Classical theory of tensors and Riemannian geometry. Applications to mechanics and general relativity. *Greenberg*

**18.721 Algebraic Geometry (A)**

Prereq.: 18.731  
Year: G (1) 3-0-9

**18.722 Algebraic Geometry (A)**

Prereq.: 18.721  
Year: G (2) 3-0-9

Introduction to contemporary algebraic geometry. Content varying from year to year with topics selected from the following: elementary properties of algebraic varieties over arbitrary ground fields, linear systems, Riemann-Roch theorem for curves and surfaces; algebraic groups and abelian varieties, complex toruses and theta functions; equivalence theories, rational equivalence ring, Chern classes, generalized Riemann-Roch theorem; Grothendieck schemes, sheaves, cohomology of varieties and schemes in various senses, holomorphic functions, Hilbert schemes, Picard scheme, fundamental group. *Kleiman (18.721); Mattuck (18.722)*

**18.731 Algebra (A)**

Prereq.: 18.20 or 18.26; 18.25  
Year: G (1) 3-0-9

**18.732 Algebra (A)**

Prereq.: 18.731  
Year: G (2) 3-0-9

Elementary theory of sets, groups, rings, fields, and linear algebra presupposed. More advanced topics in group theory: Sylow theorems, Jordan-Holder theorem, p-groups. Galois theory of field extensions with inseparability theorems. Transcendental extensions. Module theory over Noetherian rings. Other topics varying yearly, such as: Wedderburn theory of algebras, group representations, homological algebra, sheaves and general category theory, non-associative algebras. *Kostant (18.731); Epp (18.732)*

**18.735 Homological Algebra (A)**

Prereq.: 18.732  
Year: G (1) 3-0-9

**18.736 Homological Algebra (A)**

Prereq.: 18.735  
Year: G (2) 3-0-9

Abelian categories, derived functors, spectral sequences, the functors Tor and Ext, cohomology of sheaves, homological properties of noetherian rings. Grothendieck topologies, the derived category of an abelian category, local duality theory, semi-simplicial methods and a unified cohomology theory for algebraic structures. (Not offered 1969-70.) *Quillen*

**18.74 Topics in Algebra (A)**

Prereq.: 18.731  
Year: G (2) 3-0-9

Content varies yearly so that graduate students may take the subject in successive years. Topics in the past few years have included algebraic groups, non-commutative rings and algebras, Lie algebras, local rings. *Artin*

**18.75 Nonassociative Algebras (A)**

Prereq.: 18.731  
Year: G (1) 3-0-9

Non-associative algebras. Alternative and Jordan algebras. Relationships with Lie algebras, particularly the exceptional simple Lie algebras. Power-associative algebras, or other additional topics as time permits. *Schafer*

**18.763 Algebraic Number Theory (A)**

Prereq.: 18.731  
Year: G (1) 3-0-9

**18.764 Algebraic Number Theory (A)**

Prereq.: 18.763  
Year: G (2) 3-0-9

Study of algebraic number fields and function fields, local and global. Ideals, ideles, and adèles; valuation theory. Splitting laws, group of units, class numbers, brief discussion of analytic methods. Cohomology of groups and class field theory for number fields and algebraic curves. *Neukirch*

**18.77 Theory of Numbers**

Prereq.: 18.20 or 18.25; 18.21  
Year: U (1) 3-0-9

Study of primes, congruences, and arithmetic functions and proofs of their asymptotic formulae. Approximations of the real numbers by rationals, Kronecker's theorem, and the introduction of geometry of numbers. Quadratic forms and quadratic number fields. Elementary proof of the prime number theorem. (Not offered 1969-70.) *Ankeny*

**18.78 Topics in the Theory of Numbers (A)**

Prereq.: 18.20 or 18.25; 18.21  
Year: G (2) 3-0-9

**18.79 Topics in the Theory of Numbers (A)**

Prereq.: 18.78  
Year: G (2) 3-0-9

Discussion of the Riemann Zeta function. Proof of the prime number theorem through contour integration, the method of contour integration applied to the divisor problem, the solution of Waring's problem via the circle method of Hardy-Littlewood and Vinogradoff's improvements, other applications of the circle method, the general sieve method of Selberg with application to primes, twin primes. Goldbach's problem. Proofs of certain best possible results of the sieve. Content varying from year to year, so that graduate students may take the subject in successive years. (Not offered 1969-70.) *H. M. Stark*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## MATHEMATICS

- 18.80 Recursion Theory (A)**  
*Prereq.:* 18.20 or 18.25 or 18.886 or 18.89  
*Year:* G (1) 3-0-9  
 Recursive functions, recursively enumerable sets and their complements, fixed-point theorem, Post's problem, priority arguments. Degrees of unsolvability, the jump operator, inclusion relations among recursively enumerable sets. *Rogers*
- 18.802 Higher Recursion Theory (A)**  
*Prereq.:* 18.80  
*Year:* G (2) 3-0-9  
 Arithmetical, hyperarithmetical, and analytical hierarchies. Recursive ordinals, hyperdegrees, hyperjump. Generalized recursive function theory. (*Not offered 1969-70.*) *Rogers*
- 18.81 Topology (A)**  
*Prereq.:* 18.241, 18.25  
*Year:* G (1) 3-0-9
- 18.82 Topology (A)**  
*Prereq.:* 18.81  
*Year:* G (2) 3-0-9  
 Fundamental group, covering spaces, simplicial homology, simplicial approximation, manifolds. Homology and cohomology of topological spaces, universal coefficient theorem, plus additional topics to be chosen by the instructor. *D. W. Anderson (18.81); F. P. Peterson (18.82)*
- 18.821T Graduate Topology Seminar (A)**  
*Prereq.:* 18.82  
*Year:* G (1) *Arr.*  
 Study and discussion of important original papers in the various parts of algebraic and differential topology. *Kan*
- 18.83 Advanced Topology (A)**  
*Prereq.:* 18.82  
*Year:* G (2) 3-0-9  
 Content varying from term to term so that graduate students taking the subject in successive terms may have an introduction to several important phases of topology such as homotopy theory, cohomology theory, fibre spaces, K-theory, combinatorial topology, and/or differential topology. *D. W. Anderson*
- 18.831 Differential Topology (A)**  
*Prereq.:* 18.82  
*Year:* G (2) 3-0-9  
 Introduction to differential topology. Differentiable manifolds, immersion and imbedding theorems, vector bundles, characteristic classes. Other possible topics include surgery, cobordism, piecewise-linear and differentiable structures, Morse theory, Whitehead torsion. *Munkres*
- 18.84 Locally Compact Groups (A)**  
*Prereq.:* 18.35 or 18.37  
*Year:* G (2) 3-0-9  
 Haar measure, group algebras, harmonic analysis on compact and abelian groups, Plancherel theorem, duality theorem. (*Not offered 1969-70.*)
- 18.85 Lie Groups and Lie Algebras (A)**  
*Prereq.:* 18.22, 18.26  
*Year:* G (1) 3-0-9  
 Lie groups and Lie algebras over complete fields; structure and representation theory. *R. W. Goodman*
- 18.86 Lie Groups and Lie Algebras (A)**  
*Prereq.:* 18.85  
*Year:* G (1) 3-0-9  
 Semisimple Lie groups and symmetric spaces. Topics in function theory on symmetric spaces, such as Fourier analysis and Radon transform, invariant differential operators and potential theory. Emphasis on connections with classical analysis and representation theory. (*Not offered 1969-70.*) *Helgason*
- 18.861 Representations of Lie Groups (A)**  
*Prereq.:* 18.85  
*Year:* G (2) 3-0-9  
 Cartan-Weyl finite-dimensional representation theory of semisimple Lie groups. Theory of roots and weights. Weyl character formula. Decomposition of tensor products and reduction to a subgroup. (*Not offered 1969-70.*) *Kostant*
- 18.87 Geometry of Manifolds (A)**  
*Prereq.:* 18.22, 18.81  
*Year:* G (1) 3-0-9
- 18.88 Geometry of Manifolds (A)**  
*Prereq.:* 18.87  
*Year:* G (2) 3-0-9  
 Real and complex manifolds, differential forms, De Rham and Dolbeault theorems, cohomology of sheaves, differential operators on manifolds, resolution of the solution sheaf of a differential equation: formal and analytic theory. *MacKichan (18.87); I. M. Singer (18.88)*
- 18.881 Elliptic Operators (A)**  
*Prereq.:* 18.22, 18.242, 18.81  
*Year:* G (1) 3-0-9
- 18.882 Elliptic Operators (A)**  
*Prereq.:* 18.881  
*Year:* G (2) 3-0-9  
 Local theory of elliptic differential and singular integral operators, extension to vector bundles over manifolds, coercive boundary value problems,  $K(x)$ , index theorem and applications, elliptic complexes, fixed point theorem, Spencer resolution. (*Not offered 1969-70.*) *I. M. Singer*
- 18.886 Introduction to Mathematical Logic**  
*Prereq.:* 18.20 or 18.25  
*Year:* U (2) 3-0-9  
 Formal systems of mathematical logic. Propositional calculus. Quantification theory. Models, validity, and semantic implication. Completeness theorem, Skolem-Löwenheim theory, proof procedures. Axiomatic theories, e.g. set theory. Brief treatment of undecidability and incompleteness of axiomatic theories. *Lerman*
- 18.89 Mathematical Logic (A)**  
*Prereq.:* 18.20 or 18.25  
*Year:* G (1) 3-0-9  
 Classical systems of logic; their use in the formalization of mathematical argument. Algebraic structure in logical systems. Completeness theorem, Skolem-Löwenheim constructions, compactness arguments. Brief study of recursive functions and Gödel incompleteness theorem. *Rota*
- 18.892 Theory of Models (A)**  
*Prereq.:* 18.886 or 18.89  
*Year:* G (2) 3-0-9  
 Elementary equivalence, elementary extensions, saturated models, automorphisms of models, categoricity in power. Element types, model-completeness, elimination of quantifiers. Applications to theories of fields. Non-standard analysis. *H. Rogers*
- 18.893 Set Theory (A)**  
*Prereq.:* 18.886 or 18.89  
*Year:* G (1) 3-0-9  
 Axiomatic set theory. Undecidability of continuum hypothesis and axiom of choice. Consequences of large cardinal hypotheses. *Kleinberg*
- 18.894 Proof Theory (A)**  
*Prereq.:* 18.89  
*Year:* G (2) 3-0-9  
 Consistency and incompleteness. Positive results of Gentzen and his school. Negative results of Gödel. Constructive interpretation of classical results. (*Not offered 1969-70.*)

**18.90 Mathematical Reading (A)**

Prereq.: —  
Year: G (1 or 2)

Arr.

Reading of advanced mathematical treatises under the supervision of some member of the Department. Choice of treatise and allotment of time according to individual cases. For graduate students finding it desirable to do advanced work not provided for in the regular subjects. Open to undergraduates only under exceptional circumstances.

Levinson

## 19. Meteorology

**19.02 Descriptive Meteorology**

Prereq.: —  
Year: U (2)

2-2-5

The general circulation of the earth's atmosphere; the secondary circulations, both tropical and extratropical, including the role of air masses and fronts; the tertiary (local) circulations, including drainage winds, local convection, whirlwinds, showers, thunderstorms, land and sea breeze, large-scale turbulence eddies, föhn winds, etc. Pettersen, *Introduction to Meteorology*, 3rd edition.

J. M. Austin

**19.15 Long-Range Forecasting (A)**

Prereq.: 19.45  
Year: G (1)

3-0-6

Physical and statistical analysis of large-scale changes of the general circulation, with emphasis on the variable solar influences and climatic trends. Review of extended and long-range forecasting techniques.

Willitt

**19.22 Air and Sea Instruments (A)**

Prereq.: 12.21 or 19.83; 19.43  
Year: G (2)

3-2-6

Lectures and laboratory exercises on the design and response characteristics of typical instruments and instrument systems used for measurements in the atmosphere, in the oceans, and in the sea-air interfacial region.

Keily

**19.24 Fluid Dynamics Laboratory (A)**

Prereq.: 1.612 or 2.201 or 16.041 or 18.60 or 19.62  
Year: G (2)

2-4-4

Experiments on processes and phenomena in geophysical fluid mechanics. Design of experiments, similarity, experimental methods, data processing. Laboratory work involving quantitative observation of hydrodynamic instability, transport processes and turbulence.

Mollö-Christensen

**19.34 Statistical Methods in Meteorology**

Prereq.: 18.034  
Year: G (1)

2-0-4

Designed to examine recent developments in statistical weather forecasting and to provide a background for performing and evaluating statistical studies with meteorological data. Statistical forecasting by linear regression, non-linear statistical forecasting, significance of empirical relations, and hypothesis testing.

Lorenz

**19.35 Statistical Problems in Meteorology (A)**

Prereq.: 19.34  
Year: G (2)

2-0-4

Seminar in statistical problems in meteorology, including such topics as power spectrum analysis, properties of stationary time series, and evaluation of linear and non-linear methods of statistical weather forecasting. (Alternate years.)

Lorenz

**19.43T Synoptic Meteorology I**

Prereq.: 8.02, 18.02  
Year: U (1)

2-2-5

The state of the atmosphere including the three-dimensional variation of significant meteorological variables. The heat budget of the atmosphere on a global and local scale. The physical processes associated with the formation of fog, smog, cumulus clouds, thunderstorms, and tornadoes. Introduction to the dynamics of cyclones and hurricanes. World and local climate.

J. M. Austin

**19.45 Synoptic Meteorology II (A)**

Prereq.: 19.43T  
Year: G (2)

3-0-6

Historical development of weather prediction. Application of elementary kinematics and dynamics to patterns of atmospheric flow. Description of structure and behavior of cyclonic and anticyclonic circulations. Simple dynamical prediction models. Pettersen, *Weather Analysis and Forecasting*, 2nd edition, Vol. 1.

Sanders

**19.46 Numerical Weather Prediction (A)**

Prereq.: 18.05  
Year: G (1)

3-0-6

Scale analysis of atmospheric motions and the problem of meteorological noise. The quasi-geostrophic forecast system. Finite difference methods and the analysis of computational stability. Derivation and study of some simple atmospheric models for numerical forecasting.

Phillips

**19.53 Synoptic Laboratory (A)**

Prereq.: 19.43T  
Year: G (2)

0-4-8

Study of atmospheric phenomena in the troposphere and stratosphere by analysis of meteorological data. Consideration of scales ranging from the global general circulation to severe thunderstorm complexes. Data sources include the global network of surface and upper-level balloon sounding stations on land and at sea, aircraft data, rocket soundings in the stratosphere, weather radar, and meteorological satellites. Weather prediction as a probabilistic science. Contemporary operational forecasting as a man-machine system.

Sanders

**19.601 Introduction to Dynamical Meteorology**

Prereq.: 18.034  
Year: U (1)

3-0-6

Thermodynamics of moist air, development of hydrodynamical principles for small-scale atmospheric motion. Convective instability and analysis of simple mode of turbulent convection.

Phillips

**19.62 Dynamic Meteorology I**

Prereq.: 19.601  
Year: U (2)

3-0-6

Hydrodynamic equations of motion. Streamlines and trajectories, circulation and vorticity, theory of atmospheric turbulence, its effects on the vertical distribution of wind and other meteorological elements. Energy transformations in the atmosphere.

Lorenz

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## METEOROLOGY

### 19.64 *Dynamic Meteorology II (A)*

Prereq.: 19.62

Year: G (1) 3-0-9

Large-scale atmospheric motions. Examination of recent theories of the general circulation. Research in the application of fluid mechanics to meteorology and oceanography. *Starr*

### 19.65 *Turbulence and Random Phenomena in Fluid Mechanics (A)*

Prereq.: 1.612 or 2.201 or 16.041 or 18.60

Year: G (2) 3-0-6

Development of descriptions of random fields starting from statistics of ensembles of random functions. Response of systems and fields to random inputs, with examples of filters, dispersive and non-dispersive wave phenomena. Turbulence, descriptors and closure problems. Analogies with kinetic theory. Sources of turbulence, hydrodynamic stability, homogeneous turbulence, equations, spectra, equilibrium and decay. Shear flow turbulence, turbulent boundary layers. The atmospheric boundary layer. Turbulence in a stratified medium. Generation of surface waves by wind. Methods of observation, measurement and analysis. *Mollö-Christensen*

### 19.67 *Planetary Fluid Dynamics (A)*

Prereq.: 18.60

Year: G (1) 3-0-9

Discussion of fluid dynamical problems on the planetary scale with examples drawn from the atmosphere, the oceans and the interior of the earth. Convectively driven circulations in rotating systems and high-speed computational methods for the solution of the governing equations. *Charney*

### 19.70 *Elementary Physics of the Atmosphere*

Prereq.: 8.03, 18.02

Year: U (2) 3-0-6

Treatment of atmospheric radiation, the ozone layer and the upper atmosphere, atmospheric electricity, atmospheric optics, propagation of sound in the atmosphere, and icing of aircraft. *Keily*

### 19.71 *Atmospheric Precipitation Processes (A)*

Prereq.: 8.03, 19.43T

Year: G (1) 2-2-4

Origin and growth of hydrometeors; atmospheric motions of mesoscale and the morphology of convective and stratiform storms. Elementary principles of radar with applications to the observation of precipitation processes on the mesoscale. Laboratory exercises on the evaluation of radar data and on the operation of radar systems. *P. M. Austin*

### 19.72 *Physical Meteorology (A)*

Prereq.: 8.04, 18.02

Year: G (2) 3-0-6

Absorption and scattering of solar radiation in the atmosphere and the spatial and temporal distribution of solar radiation at the surface of the earth. Theory of radiative transfer in the atmosphere, radiation charts, and the radiative heat balance of the atmosphere and earth. Nucleation of water and ice in the atmosphere. Growth of drops and ice particles by condensation and accretion. Mechanisms for the release of precipitation and their interaction with the dynamics of the atmosphere. *Houghton*

### 19.74 *Physics of the Upper Atmosphere (A)*

Prereq.: 8.04, 18.034

Year: G (2) 3-0-6

Structure, composition and properties of the atmosphere above the tropopause. Wind velocity, temperature, pressure, composition and density data obtained with rockets and satellites up to heights of about 1000 km;

discussion of theories which best account for the observations. Interaction between input radiation, both photons and corpuscles, and atmospheric constituents, together with the effects of conduction, convection, radiation and diffusion. Chapman layer theory applied to the ionosphere and to the layer of ozone. Role of the circulation in the transport of trace substances. Dynamic and energetic interaction between the upper and lower atmosphere. Atmospheric tides, noctilucent clouds, and meteors; various aspects of aurorae pertinent to incident energy stream and interaction. *Newell*

### 19.80 *Surface and Internal Waves (A)*

Prereq.: 18.60, 19.83

Year: G (1) 3-0-6

Kinematics and dynamics of small-scale oceanic wave motion. Mathematical development of surface gravity and internal waves, their generation and decay, interaction with other wave modes; comparison with observations. *Beardsley*

### 19.83 *Physical Oceanography I*

Prereq.: 8.02, 18.02

Year: U (1) 3-0-9

Structure and physical properties of the oceans. Methods of measurement and an outline of the observational information. Dynamics of oceanic current systems. Wind currents, waves and tides. Von Arx, *Introduction to Physical Oceanography*. *Houghton*

### 19.84 *Dynamic Oceanography (A)*

Prereq.: 18.05

Year: G (2) 3-0-6

Dynamics of internal gravity waves and rotational waves. Response of the ocean to large-scale mechanical effects from the atmosphere and theories of ocean circulation. *Phillips*

### 19.86 *Oceanic Circulations (A)*

Prereq.: 19.67 or 19.84

Year: G (1 or 2) 3-0-6

Large-scale circulation of the oceans as revealed by the analysis of hydrographic data, direct current measurements and the distribution of properties and tracers. Theories of wind-driven and thermohaline circulation. Emphasis on the relation between observations and recent theories of the main thermocline and the associated thermohaline circulation. *Stommel*

### 19.87 *Seminar in Physical Oceanography (A)*

Prereq.: 19.67 or 19.86

Year: G (1 or 2) 3-0-6

Readings and discussions of current research topics in physical oceanography. Emphasis on circulations of the ocean with choice of topics from most interesting subjects in current literature. *Stommel*

### 19.88 *Oceanic Variability (A)*

Prereq.: 6.571; 12.21 or 19.83

Year: G (1) 3-0-6

Review of oceanographic processes having time or space dependence; the spectrum of oceanic variability. Methods of observation: response scales of instruments and the design of oceanographic time and space series. *Webster*

### 19.89 *Special Problems in Oceanography (A)*

Prereq.: 19.83

Year: G (1, 2) Arr.

Reading, consultation, and original investigation on oceanographic problems. *Staff*

### 19.91 *Meteorological Seminar I (A)*

Prereq.: 19.43T, 19.62

Year: G (1) 2-0-4

Weekly reviews and discussions by staff members and students of recent meteorological contributions in current periodicals and of original research. *Houghton*

- 19.911 Meteorological Seminar I (A)**  
Prereq.: 19.43T, 19.62  
Year: G (1) 1-0-2
- 19.912 Meteorological Seminar II (A)**  
Prereq.: 19.911  
Year: G (2) 1-0-2  
Same as 19.91. Houghton
- 19.93 Special Problems in Oceanography**  
Prereq.: 19.83  
Year: G (1, 2) Arr.  
Reading, consultation, and original investigation on oceanographic problems. Staff
- 19.94 Special Problems in Meteorology**  
Prereq.: 19.02  
Year: G (1 or 2) Arr.  
Reading, consultation, and original investigation on meteorological problems. Staff
- 19.95 Special Problems in Meteorology (A)**  
Prereq.: 19.43T, 19.62  
Year: G (1 or 2) Arr.  
Reading, consultation and original investigation on meteorological problems of more advanced nature than those in 19.94. Staff
- 19.96 Special Subject in Meteorology (A)**  
Prereq.: 19.43T, 19.601  
Year: G (1, 2) Arr.  
Organized lecture or laboratory subject on some aspect of meteorology not normally covered in the regularly scheduled subjects. Staff
- 19.97 Special Subject in Oceanography (A)**  
Prereq.: 19.83  
Year: G (1, 2) Arr.  
Organized lecture or laboratory subject on some aspect of oceanography not normally covered in the regularly scheduled subjects. Staff

## 20.

### Nutrition and Food Science

- 20.02 Nutrition and Food Science Projects Laboratory**  
Prereq.: —  
Year: U (2) 1-8-3  
Laboratory work with faculty guidance but emphasizing independent work, designed to introduce the student to the principles and techniques of design and execution of experimental projects in food science and technology, biochemical engineering, food toxicology, and experimental and human nutrition. A four- to five-week introductory project, followed by the design and execution of one or more specific projects of the student's own choice, utilizing recent research techniques.  
V. R. Young, Labuza, Sinskey, Edozien
- 20.11 Food Science and Technology**  
Prereq.: 5.41T  
Year: U (1) 3-0-5  
Basic principles of food preservation including methods of preservation, changes occurring during processing and storage, and the control of changes in food due to enzymes, microorganisms, and chemical reactions.  
Licciardello

- 20.12 Food Technology Laboratory (A)**  
Prereq.: 20.11  
Year: G (1) 1-6-3  
Laboratory work on a small group basis designed to investigate the chemical, physicochemical and engineering principles of importance to food processing and storage. Areas covered: concentration, dehydration, freezing, thermal processing and packaging. One or two projects for studying the particular effects of the process on the food material and, where applicable, subsequent changes during storage. Labuza, Tannenbaum
- 20.13J Food Engineering**  
(Same subject as 2.642J)  
Prereq.: 2.641  
Year: U (2) 4-0-5  
Quantitative study of selected unit operations of the food industry with consideration of basic principles governing each operation, as well as of important applications. Emphasis on fluid flow, heat transfer, evaporation, distillation, dehydration, filtration and extraction.  
Karel, Wang, Labuza
- 20.15 Advanced Food Engineering (A)**  
Prereq.: 20.11, 20.13J  
Year: G (1) 1-6-3  
Process design problems involving laboratory work, class discussions and plant trips. Detailed consideration of a specific selected food's process, integration engineering and quality factors. Emphasis on analysis of new processes on the basis of information developed through laboratory and pilot plant experiments. (Not offered 1969-70.) Karel
- 20.20 Flavor Chemistry and Flavor Methodology (A)**  
Prereq.: 5.41T, 20.11, 20.32  
Year: G (1 or 2) 2-0-4  
Chemistry of foods with particular reference to the compounds responsible for flavor and odor. Physical and chemical techniques for the separation, purification, and identification of these compounds. Consideration of the behavioral sciences with respect to evaluation of food acceptability. (Alternate years.) Wick
- 20.30 Nutritional Biochemistry and Metabolism**  
Prereq.: 5.41T  
Year: U (2) 4-0-8  
Digestion and absorption, nutritional requirements and interrelationships, metabolic functions of individual nutrients, and influence of physiologic state and environment on nutritional needs and metabolic processes.  
Munro
- 20.301 Experimental Nutrition (A)**  
Prereq.: 20.30  
Year: G (2) 1-6-2  
Discussion and practice of experimental procedures used in nutrition and biochemical research on animals.  
S. A. Miller
- 20.31 Advanced Nutritional Biochemistry and Metabolism (A)**  
Prereq.: 20.30  
Year: G (1) 3-0-6  
Discussion of topics in mammalian metabolism with a bearing on adaptive and other mechanisms that underlie responses to nutritional status. Munro
- (A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

NUTRITION AND FOOD SCIENCE

- 20.32 Techniques in Food and Nutrition Research (A)**  
*Prereq.:* 5.41T, 7.05T  
*Year:* G (1) 2-7-4  
 Lectures and experiments in the principles and use of spectrometric methods, chromatography, and isotope techniques in analysis of food and tissue components. Enzyme isolation and characterization. Major emphasis on advantages and limitations of available analytical techniques and selection of methods for solution of problems in food and nutrition research. Introduction to acquisition and processing of data from analytical instruments. *Wolf, Wick, Issenberg*
- 20.36 Human Nutrition (A)**  
*Prereq.:* 20.39  
*Year:* G (1) 3-0-6  
 Designed for teaching the basic principles of human nutrition and world-wide nature and distribution of nutritional disease. Emphasis on understanding requirements for specific nutrients in individuals and populations, evaluation of food intakes and dietary habits, and on nutritional needs during pregnancy and lactation, growth and maturation, and disease. Analysis of both malnutrition in developing countries and underprivileged populations and the problems of overnutrition in industrialized societies. (*Permission of instructor required for students who have not taken prerequisite.*) *Scrimshaw*
- 20.37 Endocrinology (A)**  
*Prereq.:* 20.63T  
*Year:* G (1) 3-0-6  
 Structure and function of the endocrine glands. Basic nature of abnormalities causing endocrine disease. Biosynthetic mechanisms, hormone transport, molecular basis of hormone action and control systems will be stressed. (*Open to advanced undergraduates. Prerequisite 20.63T Systemic Physiology or permission of instructor. Not offered 1969-70.*) *Bransome*
- 20.38 Factors Determining Food Value**  
*Prereq.:* 5.41T  
*Year:* U (2) 3-0-6  
 Introduction to the chemical and physical basis of food preservation and the impact of processing and storage on the nutritive value of human food supplies. Consideration of Food and Drug Law; stability of vitamins, lipids and proteins; selected food processes which have classically been employed; newer food processes such as irradiation and microwave processing. Discussion on the application of present and future technology to solution of world food problems. *Tannenbaum*
- 20.391 Advanced Nutrition and Physiological Chemistry (A)**  
*Prereq.:* 7.05T, 20.301  
*Year:* G (1 or 2) 2-0-4
- 20.392 Advanced Nutrition and Physiological Chemistry (A)**  
*Prereq.:* 7.05T, 20.301  
*Year:* G (1) 2-0-4
- 20.393 Advanced Nutrition and Physiological Chemistry (A)**  
*Prereq.:* 7.05T, 20.301  
*Year:* G (2) 2-0-4
- 20.394 Advanced Nutrition and Physiological Chemistry (A)**  
*Prereq.:* 7.05T, 20.301  
*Year:* G (1 or 2) 2-0-4
- 20.395 Advanced Nutrition and Physiological Chemistry (A)**  
*Prereq.:* 7.05T, 20.301  
*Year:* G (1 or 2) 2-0-4
- 20.396 Advanced Nutrition and Physiological Chemistry (A)**  
*Prereq.:* 7.05T, 20.301  
*Year:* G (1 or 2) 2-0-4  
 Six-term sequence of lectures and discussions of biochemical aspects of nutrition for advanced graduate students, one section being given each term over a three-year period. (*20.393 and 20.394 offered 1969-70.*) *Staff*
- 20.40 Selected Topics in Nutrition and Food Science (A)**  
*Prereq.:* 20.11, 20.30  
*Year:* G (1 or 2) 3-0-4  
 Detailed discussion of selected topics of current interest. Class work in various fields of nutrition, food science and technology not covered by regular subjects of instruction. *Staff*
- 20.41 Microbiology Laboratory**  
*Prereq.:* 7.05T  
*Year:* U (1 or 2) 2-4-3  
 Techniques necessary for isolation from natural sources of bacteria, yeasts and molds. Morphological and metabolic characterization of microorganisms. *Staff*
- 20.43 Industrial Microbiology (A)**  
*Prereq.:* 7.21T  
*Year:* G (1) 3-6-4  
 Selected topics in the uses of yeasts, bacteria, molds and algae for the production of substances of industrial or food value, such as amino acids, antibiotics, organic acids and vitamins, with emphasis on the biochemistry of fermentations. *Demain*
- 20.45 Epidemiology of Nutritional and Food-Borne Diseases (A)**  
*Prereq.:* 20.36, 20.46  
*Year:* G (2) 2-2-4  
 Principles and practice of field epidemiology, medical ecology and modes of transmission: nutritional diseases such as pellagra and kwashiorkor; dental fluorosis and caries; food- and water-borne infectious diseases such as typhoid fever, bacillary dysentery, amebiasis and cholera; food poisoning from bacterial toxins and heavy metals, and intestinal parasitic infections. Prevention of enteric disease and control of epidemics. Synergism between infection and nutrition. Practical field techniques and research methods. *Rubenstein*
- 20.46 Food Microbiology (A)**  
*Prereq.:* 7.05T, 20.41  
*Year:* G (2) 3-6-6  
 Quantitative aspects of bacteriology and their application to food processing. Mathematical considerations of thermal destruction. Methods of detecting bacteria causing food-borne diseases. *Nickerson, Sinskey*
- 20.47 Biochemical Engineering (A)**  
*Prereq.:* 5.62 or 20.13J; 7.05T or 7.21T  
*Year:* G (2) 3-3-4  
 Interactions of chemical engineering, biochemistry and microbiology. Mathematical representation of microbial systems. Kinetics of growth, death and metabolism. Continuous fermentation. Transfer of gases in fermentation systems. Mixing and the measurement of mixing times. Product recovery. Laboratory experiments involving evaluation of mass transfer coefficients, operation of a pilot plant fermentor, computer simulation of fermentation systems, and other topics. *Wang*
- 20.51 Advanced Food Science (A)**  
*Prereq.:* 5.62, 20.11, 20.30  
*Year:* G (1) 3-0-5  
 Physicochemical properties of foods and their influence on food stability and quality; mechanism and kinetics of

reactions of food components during processing and storage; enzymatic reactions, non-enzymatic browning, lipid oxidation, protein denaturation, and other reactions affecting the acceptability and nutritive value of foods.  
*Issenberg*

**20.52 Advanced Food Technology (A)**

Prereq.: 20.13J, 20.51

Year: G (2) 3-0-6

Detailed consideration of selected food processing methods from the point of view of scientific and engineering principles. Colloidal and surface phenomena in processing of foods. Consideration of transport properties of foods in the design of concentration and dehydration processes. Physical and chemical changes occurring during and after food processing.  
*Karel, Labuza*

**20.57 Food Applications of Ionizing Radiations (A)**

Prereq.: 8.04, 20.11

Year: G (1) 3-0-6

Theory and application of ionizing energy to the preservation of foods. Consideration of the basic effects of radiations on microorganisms and on compounds of biological importance. Dosimetry of intense beams of high-energy radiations. New developments in sources of ionizing energy; consideration of role of legislation from an international point of view as well as the effects of this on the potential uses of ionizing energy. (Alternate years.)  
*Goldblith*

**20.59 Food Toxicology (A)**

Prereq.: 20.11, 20.30

Year: G (2) 3-0-6

Principles and problems in evaluating the wholesomeness and safety of foods, food components, additives, and contaminants. Consideration of selective toxicity, detoxication mechanisms, structure and biological activity; basic concepts and techniques of safety evaluation, and interpretation of biological data. (Not offered 1969-70.)  
*L. Friedman*

**20.59I Food Toxicology Laboratory (A)**

Prereq.: 20.30I, 20.32, 20.59, 20.63T

Year: G (2) 1-6-2

Studies of acute and subacute toxicity; techniques of biological assay; and parameters of biological response. (Not offered 1969-70.)  
*L. Friedman*

**20.61 Seminar in Nutrition and Food Science (A)**

Prereq.: —

Year: G (1) 2-0-2

**20.62 Seminar in Nutrition and Food Science (A)**

Prereq.: —

Year: G (2) 2-0-2

Presentation of recent advances in nutrition, food science and technology.  
*Staff*

**20.63T Systemic Physiology (A)**

Prereq.: —

Year: G (1) 3-0-6

Review of organ and system physiology in mammals, with particular reference to the human. Emphasis on systems and specific organs involved in maintenance of equilibrium with the external environment. Intended for providing a foundation for more specialized subjects in the physiology of higher organisms and in biomedical engineering. (Open to advanced undergraduates and graduates from any department, by permission of instructors.)  
*Wogan, Bransome*

**20.64 Comparative Histology (A)**

Prereq.: 20.63T

Year: G (1) 4-6-6

Study of microscopic and ultramicroscopic structure of cells, tissues and organs of laboratory animals. Relation of structure to function. (Alternate years.)  
*R. Gilmore, Newberne*

**20.65 Nutritional Pathology (A)**

Prereq.: 20.64

Year: G (2) 3-6-6

Comprehensive study of gross and microscopic pathology of nutritional diseases of animals with evaluation and application of selected chemical, histochemical, and cytochemical methods as they apply to localization of enzymes, nucleic acids, amino acids, and other cellular constituents. (Alternate years.)  
*Newberne*

**20.65I Seminar in Comparative Pathology (A)**

Prereq.: 20.65

Year: G (1) 3-0-3

**20.652 Seminar in Comparative Pathology (A)**

Prereq.: 20.65

Year: G (2) 3-0-3

Systematic study of disease problems common to various animal species and caused by viral, bacterial, fungal, and toxicological agents. Emphasis on background knowledge of and current areas of research on selected diseases.  
*Newberne, R. Gilmore*

**20.69 Biological and Cultural Determinants of Food Use (A)**

Prereq.: —

Year: G (1) 3-0-6

Examination of relationships among physiological and cultural determinants of food procurement, preparation, and consumption. Such questions as: What are considered foods in different cultures and how is this affected by the environment? How efficiently do different cultures utilize their food resources? What are the relative influences of physiological and psychological factors on eating behavior? How do the nutritional, technological, and ritual aspects of food preparation differ among cultures? What is the social role of food and eating? Combining of lectures and seminars with project work. (Permission of instructor required.)  
*Zigmond, Diskin*

**20.71 Research Problems (A)**

Prereq.: —

Year: G (1) Arr.

**20.72 Research Problems (A)**

Prereq.: —

Year: G (2) Arr.

Directed research in the field of nutrition and food science.  
*Staff*

**20.73 Undergraduate Research Problems**

Prereq.: —

Year: U (1) Arr.

**20.74 Undergraduate Research Problems**

Prereq.: —

Year: U (2) Arr.

Projects providing undergraduate students with opportunity to conduct original research in areas of mutual interest to students and individual faculty members.  
*Staff*

**20.80 Neuroendocrine Control Mechanisms (A)**

Prereq.: 20.37

Year: G (2) 3-0-6

Study of the interaction of the nervous and endocrine systems, with emphasis on the role of both in the control of metabolism. Topics: components of systems which regulate the extracellular fluid; biologic communication systems; neurotransmitters; catecholamines; the anatomy and physiology of the neuro-endocrine transducers; the hypothalamus; the pineal; the adrenal; the effects of hormones on the brain; and the mechanisms of action of psychotropic drugs. (Permission of instructor required for students who have not taken 20.37.)  
*Wurtman*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## HUMANITIES

### 20.81 *Clinical and Public Health Nutrition (A)*

Prereq.: 20.30

Year: G (S) 8-16-8

Given entirely in Guatemala. Seminar discussions of various nutritional diseases and programs combined with working visits to hospitals, public health clinics and other institutions concerned with nutrition problems. Three weeks of field work in various geographic regions for the nutritional evaluation of different population groups and two weeks of either residence in a rural health district for participation in multidisciplinary applied nutrition programs or completion of a special project. (Restricted to suitably qualified physicians and dentists.) *Scrimshaw*

### 20.84 *Metabolic Aspects in Inherited Disease (A)*

Prereq.: 7.05T

Year: G (1) 3-0-6

Discussion of the genetic and biochemical principles underlying human inherited disease; principles of human genetics as applied to human disease. Systematic survey of the biochemical lesions of inherited disease. Consideration of therapeutic resources. *Stanbury*

### 20.85 *Research Management in the Food and Drug Industries (A)*

Prereq.: —

Year: G (1 or 2) 2-0-2

Lectures devoted to research management problems peculiar to the food and drug industries and to managerial and technological problems encountered in the production of specific foods and food by-products. Governmental regulatory agencies and their relationship to modern food and drug industries. Consideration of research as a dominant force in modern society. Consideration of research audits, research management in small and large companies. *Goldblith*

### 20.871 *Research Approaches to Oral Biology (A)*

Prereq.: 7.21T, 20.30, 20.64

Year: G (1 or 2) 3-0-6

Discussion of recent advances in oral biology and oral pathology in relation to the basic and life sciences (mathematics, physics, chemistry, biochemistry, histology, physiology, bacteriology, nutrition), especially in relation to experimental animals and human beings. New research approaches to the major problems of oral pathology (dental caries, periodontal disease, bone disease, microbial diseases, tumors) will be discussed in terms of choice of experimental animal, laboratory and clinical procedures, modern instrumentation, and experimental design. *R. S. Harris*

### 20.872 *Research Approaches to Oral Biology Laboratory (A)*

Prereq.: 20.871

Year: G (1 or 2) 1-6-1

Animal, chemical, and microbiological laboratory exercises designed to demonstrate the newer approaches to research in oral biology and oral pathology using modern instruments. *R. S. Harris*

### 20.88 *Seminar in Oral Science (A)*

Prereq.: 20.30

Year: G (1) 2-0-4

### 20.89 *Seminar in Oral Science (A)*

Prereq.: 20.30

Year: G (2) 2-0-4

Presentations of recent advances in oral science by staff, guest lecturers and students. *R. S. Harris*

### 20.91 *Experimental Statistics for the Biological Sciences I (A)*

Prereq.: 18.02

Year: G (1) 2-2-4

Designed to give investigators in life sciences a working

knowledge of statistical procedures for interpretation of experimental data. Topics including: variation and statistical measures. Probability, frequency distributions and moments; sampling distributions, point and interval estimation, tests of significance. Basic concepts of statistical models and use of samples. Regression and correlation. Analysis of variance and covariance. *Staff*

### 20.92 *Experimental Statistics for the Biological Sciences II (A)*

Prereq.: 20.91

Year: G (2) 2-2-4

Variance components. Theory of least squares. Elementary experimental design. Individual degrees of freedom, design of experiments repeated over time and place, factorial arrangements and incomplete block designs. *Staff*

## 21.

### Humanities

#### 21.011 *The Western Tradition: The Classical Heritage*

Prereq.: —

Year: U (1) 3-0-6

Reading and discussion of literary and philosophical masterworks central to understanding the ideals and the problems of contemporary Western society. Majority of texts of a literary nature with emphasis on the nature of civilization as the Western tradition has conceived it, its value and cost. Some of the authors to be read: Homer, Aeschylus, Sophocles, Plato, Aristotle, Virgil. *Staff*

#### 21.012 *The Western Tradition: The European Heritage*

Prereq.: 21.011

Year: U (2) 3-0-6

Continuation of 21.011. Representative works from later periods of the Western tradition. Authors to be included: Dante, Shakespeare, Goethe, Dostoevsky, Freud; additional readings constituting a span of topics ranging chronologically from Christian Antiquity through the Renaissance and Enlightenment. *Staff*

#### 21.013 *Identity and Autobiography: The Nineteenth Century*

Prereq.: —

Year: U (1) 3-0-6

Study of the major modes of self-knowledge and self-expression available to modern man. Emphasis on autobiography and literature, with some attention to film, psychology, and philosophy. Reading and discussion of works by Rousseau, Goethe, Wordsworth, Blake, Whitman, Thoreau, Mill, Carlyle, Tennyson, Dostoevsky, Tolstoi, Conrad, and Graves. *Staff*

#### 21.014 *Identity and Autobiography: The Twentieth Century*

Prereq.: 21.013

Year: U (2) 3-0-6

Continuation of 21.013. The re-evaluation of nineteenth century positions during the period between

World War I and World War II, and the attempt since World War II to redefine and interpret the problems of personal identity raised between the wars. Reading and discussion of works by Eliot, Joyce, Pound, Freud, Erikson, Hemingway, Fitzgerald, Steffans, Malraux, Malcolm X, and others. *Staff*

**21.015T Contemporary Moral Issues**

*Prereq.:* —

*Year:* U (1)

3-0-6

Examination of moral controversies arising out of contemporary experience such as the limits of personal responsibility in a mass society, the sanctity of human life and the conditions under which taking it are justified, interference with a person's liberty for his own welfare, and civil disobedience. Readings drawn from contemporary and classical sources alike — philosophers, novelists, theologians and jurists. Works supplemented by lectures and films. *Staff*

**21.016T Contemporary Moral Issues**

*Prereq.:* 21.015T

*Year:* U (2)

3-0-6

Examination of philosophical theories about controversies like those discussed during the first term. Questions to be discussed regarding these theories: Are moral judgments true or false? Is morality relative to a society? Are there universally valid ethical principles? What role should intuition play? Or conscience? Readings from philosophical texts, classical and contemporary, and from relevant studies in cultural anthropology, sociology and jurisprudence. *Staff*

**21.017 Conflict and Community in America**

*Prereq.:* —

*Year:* U (1)

3-0-6

Study of social conflict to reveal how Americans have thought and felt about problems of community and have sought to resolve questions of power, inequality and social injustice. Analysis of the role of different social groups in the process of social change. Consideration of forces and ideas which have led to peaceful change and political violence in American society. Reading of autobiography and fiction along with historical and sociological studies. *Staff*

**21.018 Conflict and Community in America**

*Prereq.:* 21.017

*Year:* U (2)

3-0-6

Analysis of the changing structure of society, the sources of social conflict, and of the social and political imagination in twentieth-century America. Focus on the crises of the 1930's and the 1960's, and on response to these crises in politics, social behavior and literature. Current conceptions of community and reform along with the issues of power, class and race in contemporary America. *Staff*

**21.019 Reason and Revelation: Religious Visions in the West**

*Prereq.:* —

*Year:* U (1)

3-0-6

Introduction to the dominant religious visions of the West as expressed in scripture and in subsequent traditions of literature and philosophy. Beginning with a consideration of the modern religious situation as symbolized by "the death of God," then returning to the sources of Western faith in the "theonomous" cultures of ancient times, both Biblical and pagan. Introduction and application of methods from contemporary philosophy and literary criticism to the problem of apprehending poetry, myth, primitive scientific speculation, and religious testimony. Readings from Kierkegaard, Nietzsche, Luther, Homer, Plato, Virgil and the Bible. *Staff*

**21.020 Reason and Revelation: Religious Visions in the West**

*Prereq.:* 21.019

*Year:* U (2)

3-0-6

Continuation of 21.019. Study of subsequent literary and philosophic masterpieces, created in the effort to interpret, examine, and sustain the spirit of Biblical religion in evolving cultural situations. Arguments for the existence of God, the logical structure of "faith," the idea of a providential pattern in history, and the nature of metaphor in visionary expression. Readings in authors such as Augustine, St. Thomas, Dante, Shakespeare, Milton, Wordsworth, Kant, and Marx. *Staff*

**21.03 Literature: Forms of a Major Theme**

*Prereq.:* One first-year Humanities sequence

*Year:* U (1, 2)

3-0-6

Study of the exercise of the literary imagination on some single major theme (e.g., love, death, guilt) as expressed in a variety of literary forms. Treatment of lyric, epic, drama, fiction, and essay will be concerned with such matters as the relation between forms and substance, the meaning of historical and social contexts, the roles of tradition and individual talent, the relation between the work and its audience. Special attention to the work of some single important writer in his handling of the theme in question. Theme varying from year to year. (*Credit given only for 21.03 or 21.031 or 21.11T.*) *Staff*

**21.031 Literature: Self, Nature and Society**

*Prereq.:* One first-year Humanities sequence

*Year:* U (1, 2)

3-0-6

Reading of literary works considered both as personal acts and public performances. Discussion concentrating on the relation between the author's personal sense of identity and the images of nature and society which help to shape his art. Consideration of the following major problems through study of a wide range of literary forms drawn from the tradition and the modern period: (1) the interaction between the perceived reality and the perceiving self; (2) the means by which drama, as communal art, affects its audience; (3) the significance of literary contributions to the present culture, seen in the context of social values and public response. (*Credit given only for 21.03 or 21.031 or 21.11T.*) *Staff*

**21.04 Philosophy: Classic and Contemporary**

*Prereq.:* One first-year Humanities sequence

*Year:* U (1, 2)

3-0-6

Problems of knowledge, moral choice, reality, and the existence of God. The nature of philosophical inquiry exemplified through the analysis of great texts. *Staff*

**21.05 The Twentieth Century: Revolution and Totalitarianism**

*Prereq.:* One first-year Humanities sequence

*Year:* U (1, 2)

3-0-6

Introduction to history through the analysis of two complex twentieth-century phenomena: revolution (the Russian, Chinese, Cuban and Vietnamese Revolutions) and totalitarianism (Soviet and Chinese Communism, Nazi Germany). Historical analysis of the conditions that breed revolutions, the development of revolutionary ideologies, the roles of radical elites, the dynamics of revolutionary movements, and the characteristics of totalitarian movements and regimes. Study of various theories of revolution, including classical Marxism and its contemporary versions. Readings in primary sources, critical scholarly articles, and works of interpretation. *Staff*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## HUMANITIES

### 21.06 *The Twentieth Century: Consciousness in Industrial Society*

Prereq.: One first-year Humanities sequence  
Year: U (2) 3-0-6

Studies of the impact of mature industrialism and some of its socially influential correlatives (the city, bureaucracy, technology, media, affluence) on human and social life, world views, ideas, values, and sensibilities, mainly in regard to twentieth-century Europe but with occasional reference to other areas such as the United States and Japan. Particular attention to the rise of social scientific consciousness (Freud, Weber, Durkheim, Keynes, and others) and to the accompanying development of new kinds of radically humanistic dissent (Kafka, Sartre, Brecht, Marcuse, and others.) Attention to the social context of intellectual and cultural developments throughout. Staff

### 21.07 *Humanities Seminar*

Prereq.: —  
Year: U (1) 2-0-8

Interdisciplinary seminar on selected topic. (Open only to seniors in Course XXI-A and Course XXI-B, Program 1.) Lamson

### 21.071 *History Seminar*

Prereq.: —  
Year: U (1) 2-0-8

Seminar on selected topic in history. (Open only to juniors or seniors in Course XXI-B, Program 2.) Herzstein

### 21.072T *Philosophy Seminar*

Prereq.: —  
Year: U (1) 2-0-8

Seminar on selected topic in philosophy. (Open only to juniors or seniors in Course XXI-B, Program 2.) Staff

## UNDERGRADUATE ELECTIVES

### 21.091 *Philosophy and Scientific Method*

Prereq.: —  
Year: U (1) 2-0-4

Introduction to questions concerning the principles and methods of scientific activity, and their possible philosophical justifications. Problems of hypothesis formation and testing, induction, and probabilistic reasoning. Nature of scientific concepts, theories, and explanations, and the value of measurements, models, and ideals of natural order. Meanings of causality, determinism and free will, and the unity of science. The role of mathematics in science. Graves

### 21.092 *Introduction to Moral and Social Philosophy*

Prereq.: —  
Year: U (2) 2-0-4

Exploratory study of moral problems as occurring in concrete human situations. Readings from recent work on aggression, love, and in general the spectrum of social feelings. (Limited enrollment.) I. Singer

### 21.094 *Introduction to Contemporary Philosophy*

Prereq.: —  
Year: U (1) 2-0-4

Exploratory study of various trends in present-day philosophy: pragmatism, analytic philosophy, existentialism, psychoanalysis, Marxism, Zen Buddhism. (Not offered 1969-70.) I. Singer, Graubard

### 21.095 *Writing Tutorial*

Prereq.: —  
Year: U (1, 2) Arr.

Non-credit tutorials for students who wish to increase the effectiveness of their writing. Conferences arranged with the instructor. Kaye

### 21.098 *Preliterate Cultures*

Prereq.: —  
Year: U (2) 2-0-4

Sampling of readings about non-Western cultures and societies in an effort to answer three questions: (1) how may an observer come to experience life in the same terms as an individual of a different culture? (2) how does an anthropologist go about studying situations foreign to his life experience? and (3) what is the relevance of anthropology for an understanding of our world? Diskin

## SUBJECTS IN WRITING

### 21.10 *Scientific and Engineering Writing*

Prereq.: —  
Year: U (1, 2) 2-0-4

Instruction basic to all types of communications that scientists and engineers are called upon to write, from abstracts to journal articles. Detailed analysis of the problems of conveying technical information to non-technical as well as to technical audiences. Term project involving a written paper on a technical or semi-technical subject and an oral presentation of the subject in class. Rathbone

### 21.101T *Introduction to the Writing of Fiction*

Prereq.: —  
Year: U (1) 2-0-7

A small number of published stories read as examples of the ways in which writers solve certain technical or strategic problems. Emphasis on the needs and accomplishments of students whose manuscripts will be analyzed in both classroom discussions and individual conferences. (Permission of instructor required.) J. S. Brown

### 21.102T *The Writing of Fiction*

Prereq.: —  
Year: U (2) 2-0-7

Writing of fiction according to individual interests, supplemented by exercises in fictional techniques and critical reading of professional examples. Emphasis on analysis of students' manuscripts. (Permission of instructor required.) Cole

### 21.103T *The Writing of Poetry*

Prereq.: —  
Year: U (1) 2-0-7

Student consideration of the relation of form to content in their own work and that of other poets; also the relation of sonic to visual in the art of poetry. (Permission of instructor required.) Levertov

### 21.104 *Playwriting*

Prereq.: —  
Year: U (2) 2-0-7

Seminar on the writing of plays. Exercises in small scenes, followed by the writing of at least one short play by the individual student. Possible production in some sort of workshop, depending upon merit of work submitted; e.g., Dramashop or a local coffee house. Limited enrollment. (Not offered 1969-70.) Gurney

### 21.105 *The Writing of Prose*

Prereq.: —  
Year: U (1, 2) 2-0-7

Inquiry into, and experimentation with, the sources of material for prose writing, as well as the tactics for communicating the material to the reader. Each student, whether unpracticed or accomplished at prose writing, responsible for a substantial body of writing to be presented on a regular basis during the term. Three meetings with professional writers: one with a novelist, one with a journalist or essayist, and one with a writer having a particular specialty, such as science. Readings

from imaginative literature, the mass media, and several special fields. Tapes, and the comparison of a movie with its script part of the inquiry. (*Limited enrollment.*)  
Kaye

## LITERATURE

For other subjects in literature in addition to those given below, see Special Interdisciplinary Subjects (especially 21.996T American Values of the 1920's, and 21.99T, Origins of Modern and Post Modern), subjects in writing, and subjects offered by the Department of Foreign Literatures and Linguistics.

**21.11T Literary Analysis**

Prereq.: One first-year Humanities sequence  
Year: U (1, 2) 3-0-6

Subject matter of 21.03 or 21.031 presented as an upper-class Humanities elective. (*Open to those who have not taken 21.03 or 21.031.*) Staff

**21.122T Criticism and Culture**

Prereq.: 21.03 or 21.031 or 21.11T  
Year: U (1) 3-0-6

Study of the critical tradition in which the experience of art and literature becomes central for understanding the nature of modern society. Authors to be read include Wordsworth, Carlyle, Ruskin, Pater, Yeats, Nietzsche, Freud, Eliot, Lawrence. (*Not offered 1969-70.*) Kibel

**21.13T The Epic**

Prereq.: 21.03 or 21.031 or 21.11T  
Year: U (1) 3-0-6

Reading and discussion of samples of epic literature, from the tribal to the contemporary, to discover their ritual backgrounds and their services as intellectual and moral centers for their societies. W. C. Greene

**21.15T Shakespeare**

Prereq.: 21.03 or 21.031 or 21.11T  
Year: U (2) 3-0-6

Reading and discussion of ten selected plays of Shakespeare, especially tragedy, in an effort to understand Shakespeare's work as dramatic and poetic expression of Renaissance and Elizabethan views of man. Study of the traditional and innovative qualities of Shakespeare's art and development in their relation to the theater and drama of his time and to later treatments in the modern theater and in films. Independent study of a contemporary of Shakespeare, Marlowe, Dekker, Jonson, or Webster; some exercises in criticism of current performances. Lamson

**21.151 Shakespearean Tragedy**

Prereq.: 21.03 or 21.031 or 21.11T  
Year: U (1) 3-0-6

Study of Shakespeare's tragedies in the contexts of Shakespeare's total performance, the Elizabethan period and the traditions of tragedy from the Greeks to the present. Goodheart

**21.16T Chaucer**

Prereq.: 21.03 or 21.031 or 21.11T  
Year: U (1) 3-0-6

Reading and discussion of *The Canterbury Tales* and *Troilus and Criseyde*. Lamson

**21.17T Literature of the English Renaissance**

Prereq.: 21.03 or 21.031 or 21.11T  
Year: U (1) 3-0-6

Rise and development of English poetry and prose in the sixteenth and early seventeenth centuries, with some attention to the drama. Problems of artistic and social tradition and convention of the Renaissance and their relationship to English innovation and achievement. Reading and discussion of Marlowe, Sidney, Spenser, Shakespeare, Bacon, Jonson, Donne, Browne and other selected writers. (*Not offered 1969-70.*) Lamson

**21.27T Narrative Fiction**

Prereq.: 21.03 or 21.031 or 21.11T  
Year: U (2) 3-0-6

Studies in European Realism: An attempt to define the tradition of psychological realism in the novel as a unique fusion of comic plot and tragic conception of character. Works by Balzac, Stendhal, Flaubert, Dostoevsky, Tolstoy, Kafka, Camus and Malraux. Kibel

**21.271 Utopian Literature**

Prereq.: 21.03 or 21.031 or 21.11T  
Year: U (1) 3-0-6

Study of the imagination of utopia in literature and political thought since the Renaissance. Consideration of modern utopian and anti-utopian fiction. Readings of works by More, Swift, Rousseau, St. Simon, Engels, Morris, Dostoevsky, Orwell, Marcuse. Kibel

**21.272 Narrative and the Novel**

Prereq.: 21.03 or 21.031 or 21.11T  
Year: U (2) 3-0-6

Presentation of varieties of narrative literature between c. 1660 and 1815 for characterization and accounting for the rise of the novel in England. Consideration of certain features of Renaissance writing and view of the major historical interpretations in question necessary for the illumination of the relationship between the evolution of English capitalism and the literature arising from it. Attempt at determining means of modification of artistic tradition by the social experience of industrialization. Authors: Milton, Pope, Fielding, Austen, Wordsworth. Leiken

**21.274 Literature in the Emergence of American World Power**

Prereq.: 21.03 or 21.031 or 21.11T  
Year: U (2) 3-0-6

Study of American literature — mainly fiction — mainly between 1890 and 1930 — and its reflections of and responses to the emergence of this country as a major industrial world power. Cooper, Whitman, Twain, Howells, James, Bellamy, London, Sinclair, Dreiser, *The Masses*, Bourne, Brooks, Hemingway, Dos Passos, Lewis, Faulkner, Fitzgerald. Folsom

**21.276T The Short Story**

Prereq.: 21.03 or 21.031 or 21.11T  
Year: U (2) 3-0-6

The modern short story as a form of literature, approached through a comparative study of various contrasting narrative forms, such as parable, folk legend, fable, Oriental tale, and through a close reading of Chekhov, Joyce, Hemingway and others in the modern canon, in Europe and America. Attention paid to the philosophic and social bases of the short story as a flourishing form in the past century, and to its role as predecessor and competitor to narrative devices being developed in the newer media. Numerous short papers required. (*Not offered 1969-70.*) Cole

**21.28T Theatre Arts: Elementary Stagecraft and Production Studies**

Prereq.: 21.03 or 21.031 or 21.11T  
Year: U (1, 2) 3-0-6

Introduction to the techniques of modern theatre as a means of realizing the thematic content of drama. Tutorial discussions and laboratory exercises in the theatre. Individual study arranged with the instructor in advance, dealing with such subjects as production methods, organizational structure of the theatre, and history of theatre development. Everingham

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## HUMANITIES

### 21.281T *Drama and Community*

Prereq.: 21.03 or 21.031 or 21.11T

Year: U (2) 3-0-6

Examination of drama as a fundamentally communal experience in its inception, production, and final effects; study of local productions and of movies, when relevant; comparison of the political focus of classical Athenian drama with various contemporary attempts to reassert a sense of community in the audience. *Gurney*

### 21.282T *Modern Drama*

Prereq.: 21.03 or 21.031 or 21.11T

Year: U (2) 3-0-6

Close reading of modern dramatists. Plays by Ibsen, Chekhov, Shaw, O'Neill, Wilder, Hellman, Williams, Miller, Ionesco, Beckett, Genet, and others. Approved practical projects in theatrical techniques accepted in lieu of term papers. (Limited enrollment.) *Everingham*

### 21.284T *Comedy*

Prereq.: 21.03 or 21.031 or 21.11T

Year: U (2) 3-0-6

Close reading and discussion of works which have made men laugh, along with various theories which attempt to explain why. (Aristophanes, Plautus, Apuleius, Chaucer, Shakespeare, Molière, Sheridan, Wilde, Shaw, Twain, and various contemporary writers; Aristotle, Cornford, Frye, Kierkegaard, Meredith, Freud, Bergson, Langer, and others.) (Not offered 1969-70.) *Gurney*

### 21.285T *American Folklore*

Prereq.: 21.03 or 21.031 or 21.11T

Year: U (1) 3-0-6

Folklore as popular historical documentation of experiences and beliefs of the American people. Supplementary readings in formal history. Examination of use of folk materials in music, drama, literature, art. (Limited to 25 students.) *T. Wood*

### 21.29T *Dostoevsky, Tolstoi, Chekhov: Russia and the Modern Age*

Prereq.: 21.03 or 21.031 or 21.11T

Year: U (1) 3-0-6

Studies of artistic vision in modernizing Russia. Reading and analysis of *The Brothers Karamazov*, *The Possessed*, *Anna Karenina*, *The Death of Ivan Ilyich*, *The Seagull*, *The Three Sisters*, and shorter works by each of the three authors. Discussion with critical and biographical readings of the relation of artistic works to social and cultural processes. All works in English translation. *MacMaster*

### 21.301T *Non-Western Literature*

Prereq.: 21.03 or 21.031 or 21.11T

Year: U (1) 3-0-6

Reading of major classics and contemporary pieces, largely from India, China, and Japan. Some illustration of attitudes toward life and art of these nations by use of visual art and reference to religious and philosophical systems. (Not offered 1969-70.) *W. C. Greene*

### 21.302T *Chinese Literature*

Prereq.: 21.03 or 21.031 or 21.11T

Year: U (2) 3-0-6

Reflection of Chinese culture in literature from earliest times to the present. Reading to discover the aims of fiction and poetry and how they were realized in China, providing a foundation for a more objective approach to Western literary traditions. Either 21.301T or 21.951T desirable preparation, but not required. (Not offered 1969-70.) *Sivin*

### 21.312T *The Confession in Literature*

Prereq.: 21.03 or 21.031 or 21.11T

Year: U (2) 3-0-6

Study of some of the great confessional works in order to understand changes that have occurred in the conception

of the self during the past 1,500 years. Readings include Augustine's *Confessions*, Montaigne's *Essays*, Rousseau's *Confessions*, fictional confessions like Dostoevsky's *Notes from Underground*, Svevo's *Confessions of Zeno*, and autobiographical poems. (Not offered 1969-70.) *Goodheart*

### 21.313T *Major Authors: Friedrich Nietzsche*

Prereq.: 21.03 or 21.031 or 21.11T

Year: U (1) 3-0-6

Work of a different author each term. May be repeated with permission of instructor in charge. Extensive reading in Nietzsche's translated works. Lecture treatment of his life, the background, development, and effect of his thought, and leading contemporary interpretations. Open discussion weekly. *McNeely*

### 21.314T *Major Authors: T. S. Eliot*

Prereq.: 21.03 or 21.031 or 21.11T

Year: U (2) 3-0-6

Work of a different author each term. May be repeated with permission of instructor in charge. An intensive study of Eliot's poems, plays, and essays. Attention to the influences (nineteenth-century and other) upon his literary behavior; and consideration of the consequences of his career, in critical as well as poetic practice. *Merritt*

### 21.315J *History of the English Language (A)*

(Same subject as 23.733J)

Prereq.: —

Year: G (1) 3-0-9

Selected topics in the history of English syntax, morphology and phonology from Old English to the present, formulated within an attempt at a general theory of linguistic change. Some knowledge of Old and Middle English desirable. (Not offered 1969-70.) *O'Neil*

### 21.317T *Studies in Literature and National Values*

Prereq.: 21.03 or 21.031 or 21.11T

Year: U (1) 3-0-6

Examination of American and Russian self-images as they are embodied in their literary traditions. Use of selected novels and short stories to elucidate and compare the values by which each nation defines itself. *Dworsky*

### 21.35T *Social Vision in Literary Art:*

*Shaw, Lawrence, Faulkner*

Prereq.: 21.03 or 21.031 or 21.11T

Year: U (1) 3-0-6

Reading in depth of three major writers, with emphasis on the varieties of social consciousness which affect dramatic and narrative form. Works to be read include: George Bernard Shaw's *Widower's Houses*, Mrs. Warren's *Profession*, *Man and Superman*, *Heartbreak House*, *Back to Methuselah*; D. H. Lawrence's *Sons and Lovers*, *Women in Love*, *The Plumed Serpent*, *St. Mawr*, *Lady Chatterley's Lover*; William Faulkner's *The Sound and the Fury*, *Absalom! Absalom!*, *Go Down Moses*, *The Hamlet*. (Not offered 1969-70.) *Merritt*

### Special Seminars

(Work in the following subjects will be done in close association with the instructors. Each is open to all students with the permission of its instructor.)

### 21.38T *Sources of Modernism*

Prereq.: 21.03 or 21.031 or 21.11T

Year: U (1) 3-0-6

Some current uses of the concept of literature as self-expression; the impact of its corollary — sincerity as a criterion of artistic excellence — on our experience of works of art. Authors to be read: Genet, D. Lessing, Swift, Sterne, Constant, and some anonymous poets. (Not offered 1969-70.) *Kampf*

**21.381T Literature Today**

Prereq.: 21.03 or 21.031 or 21.11T 3-0-6  
 Year: U (2)

Readings in contemporary poetry. What goes on? Discussion of a wide range of poetic activity — from Robert Lowell to Jackson MacLow, from Daniel Berrigan, S. J., to Ted Berrigan, from Robert Duncan to some of the new Black Poets. Circulation of new "little magazines." Class visits by poets for reading and discussing their work. *Levertov*

**21.384 Linguistics and Literary Study (A)**

Prereq.: — 3-0-9  
 Year: G (2)

Study of the formal properties of the language of literature. Consideration of the insight that linguistic theory gives into the development of a general theory of literature. (Limited to 15 students. Undergraduates admitted only by permission of instructor.) *O'Neil*

**21.385 Lyric and Discourse**

Prereq.: 21.03 or 21.031 or 21.11T 3-0-6  
 Year: U (1)

Study of the relation between lyrical and discursive elements in both prose and verse. Discussion of essays, sermons, poems, letters, public addresses drawn mainly from 1750 to the present. Comparison of expressive and rhetorical functions, for exploration of the properties and capacities of different forms. Student criticism of each other's work as well as the regularly assigned material. (Limited to ten students.) *Merritt*

**21.386T Literature and Interpersonal Relationships**

Prereq.: 21.03 or 21.031 or 21.11T 3-0-6  
 Year: U (2)

Literary works dealing with problems of interpersonal relationships as illustrations of ways of such problems arising in human situations, the sensitive writer's perception of such problems, his fitting them into his own world-view, and his acting them out in his literary works. Influence on the writer of his social environment; relevance to the student's own personal and social attitudes. Readings from Shakespeare, Swift, Ibsen, Dostoevsky, Lawrence, Doris Lessing, and some Romantic poets. *Hawley*

**21.387 Metaphor**

Prereq.: 21.03 or 21.031 or 21.11T 3-0-6  
 Year: U (1)

Attempt to understand metaphor — figurative and tropological language. Exploration and testing of the hypothesis that we can learn about the relationship between thought and language by looking from as many points of view as possible — not merely the literary — at what happens when someone apprehends a metaphor he has not apprehended before. Instructor participation by sharing and arbitrating the task, not imparting a body of knowledge. (Not offered 1969-70.) *Elbow*

**21.391 Special Topics in Literature**

Prereq.: Any two subjects in literature 3-0-6  
 Year: U (1) Arr.

Open to qualified students who wish to pursue special studies or projects with members of the Literature Section. Students electing this subject must consult the Chairman of the Section. *Staff*

**21.392 Special Topics in Literature**

Prereq.: Any two subjects in literature 3-0-6  
 Year: U (2) Arr.

Open to qualified students who wish to pursue special studies or projects with members of the Literature Section. Students electing this subject must consult the Chairman of the Section. *Staff*

**21.393 Independent Study I**

Prereq.: Any two subjects in literature 3-0-6  
 Year: U (1)

**21.394 Independent Study II**

Prereq.: Any two subjects in literature 3-0-6  
 Year: U (2)

For students concentrating in literature in Course XXI-B, Program 2. Designed to fulfill their requirement of independent reading. Decision on reading list by the student in consultation with his advisor on the basis of a general list. *Staff*

## HISTORY

## Economic-Technological

**21.411T History of Engineering**

Prereq.: One first-year Humanities sequence 3-0-6  
 Year: U (1)

History of the techniques and achievements in engineering from ancient times to about 1800. The goals, methods, and status of the engineer in Babylonia, Egypt, Greece, Rome, the Arabic world, the Middle Ages, and the Renaissance set against the background of the political, social, and economic conditions of the times. Study of the development of engineering as an integral part of the life of cultures different from our own to give perspective and background for studying and evaluating the position and contributions of the engineer in modern times. Extensive use of lantern slides. (Not offered 1969-70.) *Woodbury*

**21.412T History of Engineering**

Prereq.: One first-year Humanities sequence 3-0-6  
 Year: U (2)

Study of the development of modern engineering from 1800 to about 1930. Presentation of engineering advance as an important factor among the economic and social changes which center around the Industrial Revolution. Concentration on those key aspects of greatest importance for future engineering development and for economic and social change — coal, steel, textiles, machinery, transportation, electric power, and others. Use of lantern slides. (Not offered 1969-70.) *Woodbury*

**21.414T History of Materials**

Prereq.: One first-year Humanities sequence 2-0-7  
 Year: U (1)

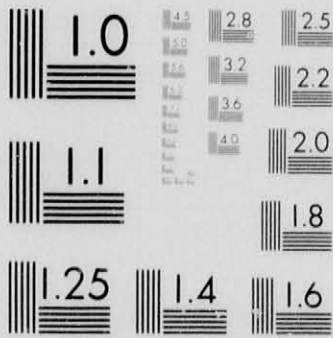
Study of man's knowledge of materials and attitude toward them in all ages from the discovery of ceramics to modern materials science. Materials as a bridge between art, science and engineering. Emphasis on use of original sources and artifacts. (Not offered 1969-70.) *C. S. Smith*

**21.415T Technology and Economic Growth**

Prereq.: One first-year Humanities sequence 3-0-6  
 Year: U (1)

Growth of technology in the modern world in its relationship to economic and social change. Craft technology; industrialization — invention, origins of mass production and interchangeable parts, power sources, transportation, mechanization of agriculture, technology and large-scale enterprises, new industries. (Not offered 1969-70.) *Woodbury*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.



MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

M. I. T. ANNUAL CATALOGUES AND BULLETINS

1969/70

95  
OF  
95

# Descriptions

## HUMANITIES

### 21.421T *Development of American Economic Institutions*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (1) 3-0-6

Topical study of the development of the American economy from 1800 to the present, concentrating on about four of the following topics: Alexander Hamilton; the early New England factory town; the plantation-slave economy; the westward movement; the American farm; the labor union; the automobile industry; the failure of an economy in the 1930's, and the New Deal. *Bryant*

### 21.422T *History of Transportation in the United States*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (2) 3-0-6

Study of new modes of transportation such as the canal, the steamship, the railroad, the automobile, and the airplane — their technical development, their effect on the American economy and society, and the evolution of new institutions for the management and control of the business of transportation. *Bryant*

### 21.424T *The Businessman in American History*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (1) 3-0-6

Study of the changing roles, images, and characterizations of businessmen in America from the colonial period to the present, with special emphasis on tensions between the traditional and innovative in practices, structure, perspectives and values. Readings in history, biography, fiction and critical and popular periodicals. *Hartley*

### 21.426T *History of Technology in the United States*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (2) 3-0-6

An introduction to the development of technology in the United States as interwoven with its economic and social background and influence. Representative topics: cotton, slavery, and Eli Whitney; interchangeable manufacture and the "American system"; McCormick and prairie agriculture; Oliver Evans and automation in grain milling; Samuel Colt and firearms; American machine tools; Howe, Singer, and the sewing machine; American shipbuilding — the clipper ship and the ironclad; petroleum — Drake and Rockefeller; the Wright Brothers and aviation; Ford and the automobile. (*Not offered 1969-70.*) *Woodbury*

#### Social-Cultural

### 21.452T *Introduction to Social Anthropology*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (1) 3-0-6

The organizational aspects of human groups. A cross-cultural approach to the study of kinship, age-grading, caste and class, and their relevance for technology, ideology and economics. Examination of the social and cultural frameworks in anthropological theory through the use of field reports and monographs. *Diskin*

### 21.454T *Near Eastern Archaeology: The Foundations of Civilization*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (1) 3-0-6

A study of the "Urban Revolution" and the achievement of the earliest cities in the ancient Near East. Relationships between political authority, technology, economic structure, myth, and art in Mesopotamia, and Anatolia. Reading combining study of original texts with archaeological reports, and work in local museums. *Steinberg*

### 21.455T *Peasant Society*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (2) 3-0-6

Definition of the peasant as a social type; consideration

of so-called centrifugal-centripetal forces that help shape a given society. Historical factors in the cases of Mexico, Colombia, Jamaica, southern Italy and Malaya. The nature of economic links between the peasant and modern society. Cultural, historical and personality factors in economic development. *Diskin*

### 21.456T *Economic Anthropology*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (1) 3-0-6

Economic aspects of culture and society. Modes of exchange, distribution, and production in non-monetized societies. Consideration of prestation, barter, and peasant markets as mechanisms of social articulation. Examples from New Guinea, Malaya, Mexico, and Africa. The notions of scarcity and maximization examined for their universality. The dual economy debate and economic development discussed. *Diskin*

### 21.459T *Cultures and Societies of Mexico*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (2) 3-0-6

Historical background beginning with the early archeological horizons and the Spanish conquest studied up to present time. Case studies of groups at different levels of development, with emphasis on Mexico and Guatemala. Analysis of social change in the context of historical tradition. (*Not offered 1969-70.*) *Diskin*

### 21.463T *The Emergence of Modern Africa*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (1) 3-0-6

Examination of problems concerning the social and cultural, economic, and political development of tropical Africa from earliest times to the modern period. Interdisciplinary approach, with special emphasis on the findings of archaeology, ethnobotany, linguistics and ethnohistory. Emphasis on indigenous invention as well as the stimulus of contact with Arabia, the Orient, and Europe. The slave trade and the growth of Europe's awareness of Africa. *Rotberg*

### 21.473T *Rome: Reality and Idea*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (1) 3-0-6

Rome from city-state to world-empire. Structure and function of public power in the "classical" republic. Reasons for, and mystique of, Rome's ascendancy; conservatism and improvisation as political ways of life. Revolutionary impact upon, and of, Greek political theory: the captive captor. The Roman revolution and its outcome: world-empire and peace. The unwritten constitution as reality and facade. The question of the "decline and fall": survey and assessment of rival views. The religious, economic, political, and social factors. Byzantium and the Roman legacy. Readings in Roman historians and poets and in secondary works such as Syme, Rostovtzeff, and Gibbon. *Reiche*

### 21.475T *Culture and Society in Medieval Europe*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (2) 3-0-6

Interplay of intellect and society circa 284-1350 A.D. Role of Christian world view in orthodox and heretical manifestations studied against background of social change and political conflict. Topics discussed: continuity from late Roman to early medieval culture; mystic and rational currents in philosophy; Carolingian and Ottonian "rebirths"; idea of a Holy Roman Empire; meaning of scholasticism; and problem of disintegration of medieval life forms. Individuals discussed: Augustine, Bede, Alcuin, John of Salisbury, Aquinas, Eckhardt, and William of Ockham. Romanesque and Gothic art and Latin, Romance, and Germanic literatures surveyed. Concepts of "ancient," "medieval," and "modern" examined. *Herzstein*

**21.476T The Italian Renaissance**

Prereq.: One first-year Humanities sequence  
Year: U (2) 3-0-6

Comparative studies in the development of Italian society and its culture from the generation of Dante to that of Machiavelli, with principal emphasis on Florence and Venice. Reading drawn largely from documents and source materials written by merchants, lawyers and magistrates; artists, scholars and men of letters. (Not offered 1969-70.) Douglas

**21.478T The Northern Renaissance and the Reformation**

Prereq.: One first-year Humanities sequence  
Year: U (2) 3-0-6

Historical change in the structure of society, the economic order and politics, studied in relation to various themes of complaint, protest and reform. Reading in the works of Thomas More, Machiavelli, Luther, Calvin, Rabelais, Montaigne and Cervantes. (Not offered 1969-70.) Douglas

**21.482T Social Criticism in America From Tocqueville to Riesman**

Prereq.: One first-year Humanities sequence  
Year: U (2) 3-0-6

Study of the thought of the following social critics (singling out four or five for detailed scrutiny), and through their work, study of changes and continuities in American values and society since the Colonial period: Tocqueville, Veblen, Brooks Adams, Randolph Bourne, C. Wright Mills, Paul Goodman, David Riesman, Robert Merton, Seymour Lipset, Dwight McDonald, Norman Mailer. (Not offered 1969-70.) Kaledin

**21.483T Dissent and Reform in Twentieth-Century America**

Prereq.: One first-year Humanities sequence  
Year: U (2) 3-0-6

Study of the politics of reform, and of the social, psychological and ideological characteristics of dissenting movements in twentieth-century America. Topics included: the continuing current of "orthodox reform" (the Progressive movement, the New Deal and its latter-day versions); the labor movement and reform; varieties of radical dissent (the failure of socialism in the U.S., the Communist movement in America, dissent on the right from the '30's to the John Birch Society, and on the left from the '30's to the "New Left"); the Negro Revolt of the '50's and '60's. Comparison with social reform movements and dissent in other societies. Kaledin

**21.484T The American Metropolis**

Prereq.: One first-year Humanities sequence  
Year: U (1) 3-0-6

Lectures and readings on the emergence of the American metropolis from about 1880 to the present. Consideration of subjects such as the patterns of foreign and internal migration, the formation of ethnic and racial ghettos, the dispersal and decentralization of the metropolis, the decline of the railways and the triumph of the automobile, the reform of city politics, the transformation of the schools and the police, and the impact of planners and public authorities. Students to read extensively in the social science literature. Fogelson

**21.485 The Black Ghetto**

Prereq.: One first-year Humanities sequence  
Year: U (2) 3-0-6

Lectures and readings on the evolution of the black ghetto from roughly 1880 to the present. Examination of subjects such as the trends in migration, the patterns of economic and social adjustment, the shifts in ideology and protest, and the impact of the depression and the war. In-depth analysis of the 1960's riots and the demand for community control. Primary source reading

and special attention in lectures to the comparative history of minority ghettos and the relevance thereto of the social sciences. Fogelson

**Intellectual-Scientific****21.512T Science and Natural Philosophy in Chinese Tradition**

Prereq.: One first-year Humanities sequence  
Year: U (2) 3-0-6

Foundation, through study of the only major non-Western scientific tradition, of a comparative approach to the origins and development of conceptions and theories. Study of general ideas and disciplinary approaches. Emphasis on both the essential character of science and its culturally conditioned style. Readings in primary sources, including unpublished translations. (21.951 and/or 21.701 desirable as preparation, but not required.) Sivin

**21.515T Intellectual History of Modern Europe**

Prereq.: One first-year Humanities sequence  
Year: U (1) 3-0-6

Intellectual history of the period from 1760 to the present, focusing on political and social thought, but in terms of the interplay of ideas from different fields, and of ideas and events. Consideration of such topics as romanticism, industrialism, and socialism; the increase in awareness of the self; the rise of historicism; the nature of ideology; the concepts of classes, masses, and races; and the nature of imperialist and totalitarian thought. Presentation focused, wherever possible, upon important individuals who epitomize a way of thinking and feeling. (Not offered 1969-70.) Mazlish

**21.517T Russia: Orthodoxy, Autocracy, and Rebellion**

Prereq.: One first-year Humanities sequence  
Year: U (1) 3-0-6

Comparative historical analysis of Russian radical social thought (communist anarchism, populism, socialism, utopianism in general) and action before the advent of Bolshevism. Analysis of social structures, historical experiences, religious and political traditions in Russia, in an effort to discover reasons for the relative prominence of radicalism in modern Russian as compared to modern Western thought. Study of such thinkers as Herzen, Chernyshevsky, Bakunin, Lavrov, Tkachev, Nechaiev and of revolutionary circles and conspiracies inspired by them. MacMaster

**21.518 Anarchism**

Prereq.: One first-year Humanities sequence  
Year: U (2) 3-0-6

Anarchist and Anarcho-Syndicalist movements of the nineteenth and twentieth centuries, their philosophic bases, their opposition to certain societies and governments, their attempts at establishing communities and organizations, their methods of obtaining their goals, their provocation of reactions, within both rural and urban settings. Readings from the classics of anarchism and the histories of anarchist movements in Europe and America. Watson

**21.522T Marx, Darwin, and Freud**

Prereq.: One first-year Humanities sequence  
Year: U (1) 3-0-6

Historical and critical study, in depth, of three attempts to investigate the natural and cultural development of man and society, treated as a problem in intellectual history, history and philosophy of the cultural sciences, and social thought. (Permission of instructor required.) Mazlish

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## HUMANITIES

### 21.524T *History and Psychoanalysis*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (2) 3-0-6

Attempt to inquire into the psychological, especially the psychoanalytic, aspect of historical events and persons. First part: examination of various theories and techniques that have already been employed by historians and psychologists; e.g., readings in Erikson, *Childhood and Society* and *Young Man Luther*. Second part: reports by members of the class on their own attempts to study an event or person in psychohistorical terms. (*Permission of instructor required.*) *Mazlish*

### 21.531T *American Intellectual History*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (2) 3-0-6

Study of important case specimens in the dialogue between "conservatives" and "liberals" from the Founding Fathers to the Radical Right and New Left. Seminar-type discussion of the role of major figures such as Jefferson, Calhoun, Emerson, Sumner and Veblen and of major forces such as industrialization, urbanization and immigration in the shaping of American ideas and values. *Hartley*

### 21.532T *American Ideas and Institutions*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (1) 3-0-6

Historical study of the development of a free, tolerant, and pluralistic society in the United States. Nineteenth-century dissenters and utopians, especially the Transcendentalists and the Mormons. The tradition of civil liberties in America, and the use of the Constitution to promote freedom and tolerance. Pragmatism (Peirce, James, Dewey, and Holmes) as a peculiarly American rationale for individualism, pluralism, and social reform. *Bryant*

### 21.533 *American Constitutional History*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (2) 3-0-6

Historical study of the evolution of constitutional law and institutions in the United States, and their adaptation to social reform in the 1930's and the extension of civil liberties since 1940. *Bryant*

## Political — Diplomatic

### 21.541T *The American Revolution*

*Prereq.:* 17.01 or 21.05 or 21.06  
*Year:* U (1) 3-0-6

Analysis of the social, political and ideological roots of the American Revolution; of the revolutionary movement itself; and of the formation of the new nation and its Constitution. Consideration of the changing image of the Revolution throughout our history, from accounts written by revolutionary partisans to the most recent interpretations. Comparison of the American with other major Revolutions. *Kaledin*

### 21.543T *China, Japan, and the West*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (1) 3-0-6

Relations of the West with China and Japan and the revolutionary ferment set up in the Far East by these contacts. Study of the traditional cultures of China and Japan in their geographic settings. Emphasis on tracing and seeking to explain the processes by which the self-sufficiency and isolation of China and Japan were broken down; development of resulting cultural changes, both planned and spontaneous. *Mahoney*

### 21.544T *France: The Modernization of a Developed Society*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (2) 3-0-6

Examination of the problems of modernization in an already highly advanced society. Emphasis on those factors which since the beginning of the industrial era have contributed to the slowness in the modernization of France as compared to certain of her neighbors. Study of the periodic efforts of the French state since the time of Napoleon to accelerate the process. (*Not offered 1969-70.*) *Ralston*

### 21.545T *War and the Military Institutions of the Modern State*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (2) 3-0-6

Examination of the evolution of military institutions of the modern state in the light of the changing forms and modes of war since the eighteenth century. Stress on the interacting relationship between the military institutions of a state and its political institutions and their effect on civil society. *Ralston*

### 21.547T *Nationalism and Politics in Central Europe from the French Revolution to the Third Reich*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (1) 3-0-6

Awakening of national consciousness among Magyar, Czech, German and Pole, and the meaning of this modern development for the Hapsburg monarchy and Europe. Study of the interplay of nationalism, economic development, international politics, and social traditionalism in this area from 1804 through 1945, treated as a model for comprehension of "contemporary history." (*Not offered 1969-70.*) *Herzstein*

### 21.548T *Vienna and Versailles*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (2) 3-0-6

Two modern attempts to construct an enduring peace for Europe and the world following, respectively, the Wars of the French Revolution and Napoleon and World War I. Comparison of the ideas, institutions, and personalities dominating the architects of Vienna with their counterparts a century later at Versailles. *Mahoney*

### 21.551J *Nationalism in Africa*

(Same subject as 17.65J)  
*Prereq.:* One first-year Humanities sequence  
*Year:* U (2) 3-0-6

Examination of the ideological, political, and economic bases of imperialism, colonialism and nationalism; the partition of Africa, the nature of alien rule, and the response of Africans thereto during the nineteenth and twentieth centuries. *Rotberg*

### 21.552T *The Soviet Union: An Industrial Society in Historical Perspective*

*Prereq.:* One first-year Humanities sequence  
*Year:* U (2) 3-0-6

Comparative historical analysis of the relationships between totalitarianism and modernization in post-revolutionary Russia. Study in depth of the physical and ideological setting, the rise of Stalin, collectivization and industrialization, the terror and the purges, the process of de-Stalinization under Khrushchev and his successors, the transition from developing to industrial society, contemporary movements of dissent among intellectuals, religious groups, and nationalities. Attention to the problem of evaluating the changing Soviet Union in the light of recent developments there and in other Communist regimes, especially the Yugoslav and the Chinese. *MacMaster*

**21.554T Spanish Civil War, 1936-39**

*Prereq.:* 17.01 or 21.05 or 21.06  
*Year:* U (1) 3-0-6

Examination of the eruption of conflicts in Spanish society — between leftist and rightist political groups, civil and military authorities, intellectuals and clerics, workers and capitalists, peasants and landowners — into civil war, almost immediately provoking a worldwide response. Examination of the consequences of the Civil War for Spain and the rest of Europe in light of political, social, and economic issues selected by students and the instructor. *Watson*

**21.556T Soviet-American Diplomacy**

*Prereq.:* One first-year Humanities sequence  
*Year:* U (1) 3-0-6

Study of the foreign policies and diplomatic interaction of the two powers beginning with nineteenth-century patterns of Tsarist and American diplomacy. Case studies which permit detailed examination of the origins of Bolshevik diplomacy with a view toward continuity and change; the formation of America's stance on Soviet Russia; parallels between the two societies during the interwar period: isolationism, messianism, and the drive for security; the themes of conflict and cooperation in World War II, followed by the "Cold War" and the bipolarization of Europe; and the emergence of a new diplomacy. Emphasis on a comparison of the two nations, their parallel problems and instances of direct confrontation. *Clemens*

**21.558T Reconstruction of Europe, 1945-65**

*Prereq.:* One first-year Humanities sequence  
*Year:* U (2) 3-0-6

The Marshall Plan, the Iron Curtain, NATO, the Fourth and Fifth Republics, Italy, Germany, Great Britain. Towards a United States of Europe: the New Technicians; the Common Market; EFTA; Euratom. *Mahoney*

**21.574T Nineteenth Century European Liberalism: Its Decline and Transformation**

*Prereq.:* One first-year Humanities sequence  
*Year:* U (1) 3-0-6

Examination of nineteenth-century European liberalism as it was embodied in the political institutions and political practices of such states as Great Britain, France, Germany, Italy, and Austria-Hungary. Origins of the liberal ideology, and its underlying assumptions about man and society. Forces leading either to its breakdown or transformation in the decades prior to World War I. *Ralston*

**21.576T Varieties of Fascism: Origins and Comparative Development in Germany and France, 1900-1945**

*Prereq.:* One first-year Humanities sequence  
*Year:* U (1) 3-0-6

Study of a major modern theme on both the intellectual and sociopolitical levels, using the comparative method. Fascism in France and Germany as a study in comparative modernization, viewed in part as a response to economic and social change in the period 1870-1945. Focus on the quasi-failure of fascism in France and its success in Germany after 1932, with this central theme posed as a basic question. (*Not offered 1969-70.*) *Herzstein*

**21.591 Special Topics in History**

*Prereq.:* Any two subjects in history  
*Year:* U (1) *Arr.*

Topics in history not included in other subjects. Student electing this subject must consult the Chairman of the Section. *Staff*

**21.592 Special Topics in History**

*Prereq.:* Any two subjects in history  
*Year:* U (2) *Arr.*

Topics in history not included in other subjects. Students electing this subject must consult the Chairman of the Section. *Staff*

PHILOSOPHY

**21.611T History of Philosophy I**

*Prereq.:* 21.04  
*Year:* U (1) 3-0-6

Survey of ancient philosophic thought. Emphasis on Plato and Aristotle. *Brody*

**21.612T History of Philosophy II**

*Prereq.:* 21.04  
*Year:* U (2) 3-0-6

Philosophic thought from the Renaissance through the Enlightenment. Emphasis on Descartes, Locke, and Hume. *Cartwright*

**21.613T Classical Philosophy**

*Prereq.:* One first-year Humanities sequence  
*Year:* U (2) 3-0-6

Selected readings in the pre-Socratics; in Plato and Aristotle; or in Hellenistic and later thought: Stoicism — Lucretius, Epictetus, and Marcus Aurelius; Epicureanism — Epicurus and Lucretius; Neo-Platonism — Plotinus and the critical encounter with early Christianity in theologians like Origen and Augustine; the development of the Logos-concept. *Reiche*

**21.617T Philosophy of History**

*Prereq.:* One first-year Humanities sequence  
*Year:* U (1) 3-0-6

Examination of philosophical questions arising from the critical analysis of historical writing, including the problem of explanation and laws, the nature of narrative, rationality and the explanation of human action, the possibility of substantive theories of history, and the relation of history to the social sciences. Readings from classical and contemporary writers. (*Not offered 1969-70.*) *Graubard*

**21.618T Social Theory from Marx to the Present**

*Prereq.:* One first-year Humanities sequence  
*Year:* U (2) 3-0-6

Investigation of some of the major figures in the development of modern social theory — Marx, Weber, Durkheim, Mannheim, Freud, Parsons, analyzed with respect to certain key substantive questions, the role of ideas in social action (the theory of ideology). Second dimension of inquiry: the investigation of the philosophical and methodological questions related to the social sciences and history. Contemporary extensions within the various social sciences of the theoretical approaches developed by the classical social theorists. (*Not offered 1969-70.*) *Graubard*

**21.639 Aesthetics (A)**

*Prereq.:* —  
*Year:* G (1) 3-0-9

Philosophical problems related to the history and theory of art. Topic this year: Freudian or neo-Freudian aesthetics as a method for analyzing myth and symbolism in literature and the arts. Readings chosen in relation to interests of individual students. (*For graduate students in fields outside of philosophy as well as those within. Qualified undergraduates also welcome.*) *I. Singer*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## HUMANITIES

### 21.641T *Symbolic Logic*

Prereq.: One first-year Humanities sequence  
Year: U (1) 3-0-6

Introduction to the aims and techniques of formal logic. The logic of truth-functions and quantifiers. Formal systems: consistency and completeness. The decision-problem for a formal system. Applications of formal logic, the place of logic in philosophy. *James F. Thomson*

### 21.642 *Philosophy of Logic (A)*

Prereq.: —  
Year: G (1) 3-0-9

Relations between logical operators and their ordinary language counterparts; questions about logical form, logical truth, analyticity, reference, presupposition, and "ontological commitment"; times and tenses; problems about modality and identity. (Primarily for graduate students in philosophy; others admitted only by permission of instructor.) *Bools*

### 21.643 *The Logic of Questions (A)*

Prereq.: —  
Year: G (2) 3-0-9

Discussion of recent literature on erotetic logic (the logic of questions). Examination of problems which arise in the attempt to formalize the logic of questions. Relation of this logic to some problems in the philosophy of science. (Primarily for graduate students in philosophy; undergraduates who have taken 21.04, 21.641 and 21.647 may be admitted by consent of the instructor. Not offered 1969-70.) *Bromberger*

### 21.644T *Ethics*

Prereq.: 21.04  
Year: U (2) 3-0-6

Systematic study of some central problems in ethics, such as the relation between fact and value, the nature of obligation, the relevance to moral evaluation of pleasure, desire, intention, etc. *Judith J. Thomson*

### 21.645T *Phenomenology*

Prereq.: 21.04  
Year: U (1) 3-0-6

A study of Husserl and Heidegger. Their procedure with certain problems of "world" and relevance. Comparison of their procedure with Wittgenstein's. (Enrollment limited.)

### 21.646T *Existentialism*

Prereq.: 21.04  
Year: U (2) 3-0-6

Consideration of certain related problems in the works of Kierkegaard, Nietzsche, Sartre and Merleau-Ponty.

### 21.647T *Theory of Knowledge*

Prereq.: 21.04  
Year: U (1) 3-0-6

Study of problems concerning our concept of knowledge, our knowledge of the past, our knowledge of the thoughts and feelings of ourselves and others, and our knowledge of the existence and properties of physical objects in our immediate environment. *Levensky*

### 21.651 *Moral Philosophy (A)*

Prereq.: —  
Year: G (1) 3-0-9

Systematic study of some problems of moral philosophy. Special attention to the justification of moral evaluation of actions and the relevance to this of intentions, motives, and consequences. Readings chiefly from contemporary sources. (Primarily for graduate students in philosophy; undergraduates may be admitted by consent of the instructor.) *Judith J. Thomson*

### 21.652T *Problems in Ethics*

Prereq.: One first-year Humanities sequence  
Year: U (1) 3-0-6

Study of problems in the theory of value as relevant to both Existentialist and Analytical philosophies; e.g., the nature of choice, the analysis of affective language, the phenomenology of moral judgment. Readings chosen in relation to interests of individual students. (Not offered 1969-70.) *I. Singer*

### 21.653T *Nature and Justification of Liberty*

Prereq.: One first-year Humanities sequence  
Year: U (1) 3-0-6

Problems connected with liberty and coercion in society. The question whether there is a presumption in favor of men being free, and how such a presumption could be justified or rebutted. Examination of such notions as interference, constraint, compulsion, and coercion. (Not offered 1969-70.) *Dworkin*

### 21.654 *Responsibility in Law and Morality (A)*

Prereq.: —  
Year: G (2) 3-0-9

Examination of concepts such as purpose, causation, act and omission and their bearing on issues of responsibility in law and morality. (Primarily for graduate students; undergraduates admitted by permission of instructor.) *Dworkin, Fried*

### 21.655 *Free Will and Moral Responsibility (A)*

Prereq.: —  
Year: G (1) 3-0-9

Examination of the nature and truth of determinism, free will, and their interrelationships. Bearing of these on issues of punishment and blame. Emphasis on current discussions of these topics. (Primarily for graduate students in philosophy; undergraduates may be admitted by consent of the instructor. Not offered 1969-70.) *Dworkin*

### 21.656 *Problems of Explanation and Theory Formation (A)*

Prereq.: —  
Year: G (1) 3-0-9

Problems about the nature of explanation, the evaluation of competing explanations, and the relation of observation to theory. (Primarily for graduate students in philosophy; undergraduates who have taken 21.04 and 21.641T may be admitted by consent of the instructor.) *Bromberger*

### 21.657 *The British Empiricists (A)*

Prereq.: —  
Year: G (2) 3-0-9

Studies in the writings of Locke, Berkeley, and Hume. (Primarily for graduate students in philosophy; undergraduates who have taken 21.04 and 21.647T may be admitted by consent of the instructor.) *Bromberger*

### 21.658 *Kant (A)*

Prereq.: —  
Year: G (2) 3-0-9

Critical examination of the logical, epistemological, and metaphysical doctrines of Kant. Main text: *The Critique of Pure Reason*. Some attention to his views in the *Prolegomena*, the *Inaugural Dissertation*, and some of his early writings. (Primarily for graduate students in philosophy. Undergraduates admitted by permission of instructor. Not offered 1969-70.) *Brody*

### 21.659T *Problems of Knowledge (A)*

Prereq.: —  
Year: G (2) 3-0-9

Study of problems concerning the foundation of knowledge, with special attention to our concepts of evidence, belief, doubt, knowledge, certainty and philosophy.

**21.661T The Continental Rationalists (A)**

Prereq.: —

Year: G (1) 3-0-9

Studies in the writings of Descartes, Spinoza and Leibnitz. (Primarily for graduate students in philosophy; undergraduates admitted by permission of instructor. Not offered 1969-70.) Cartwright

**21.663 Philosophy and the Life Sciences (A)**

Prereq.: —

Year: G (2) 3-0-9

Selected concepts and empirical findings in the life sciences examined for their possible relevance to various problems of philosophy: e.g., current psychiatric and ethological theories about instinct or unlearned behavior studied in their relation to philosophical questions about moral, aesthetic, and religious experience. (Undergraduates admitted by permission of instructor.) I. Singer

**21.664 Analytic Philosophy (A)**

Prereq.: —

Year: G (2) 3-0-9

Examination of some major tendencies in recent and contemporary philosophy such as positivism, the later philosophy of Wittgenstein, and Oxford philosophy. Special reference to theory of knowledge and philosophy of language. (Primarily for graduate students in philosophy; undergraduates admitted by consent of instructor. Not offered 1969-70.) Fodor

**21.665 Background of Contemporary Philosophy (A)**

Prereq.: —

Year: G (1) 3-0-9

Frege; the early philosophies of Moore and Russell, and associated continental movements: logical atomism. (Primarily for graduate students; undergraduates admitted by permission of instructor. Not offered 1969-70.) Cartwright

**21.668T Philosophical Anthropology**

Prereq.: One first-year Humanities sequence

Year: U (1) 3-0-6

Philosophical reflection on the nature of man: meaning of being a human being, living a human life. Cross-cultural perspectives, findings of the behavioral sciences, and insights from the history of philosophy. Laboratory attempts, through encounter group exercises, for affecting the climate of learning and providing experiential bases for themes considered. (Limited enrollment. Advance permission of instructor required. Not offered 1969-70.) H. Smith

**21.669 Probability (A)**

Prereq.: —

Year: G (1) 3-0-9

Philosophical and conceptual questions about probability and the interpretation of probability statements. Relations with notions of "chance," "reason" and "evidence." Discussion of so-called theories of probability (frequency, logical, personalist). No knowledge of mathematical probability theory required, but ability to follow some abstract reasoning necessary. (Primarily for graduate students in philosophy; undergraduates admitted by consent of the instructor.) James F. Thomson

**21.671T Philosophy of the Arts**

Prereq.: One first-year Humanities sequence

Year: U (2) 3-0-6

Examination of questions concerning the identification, interpretation, and evaluation of works of art. Special attention to selected works of literature, music, or film. Essays by philosophers and artists serving as texts. Levensky

**21.672T Philosophy in Literature**

Prereq.: One first-year Humanities sequence

Year: U (1) 3-0-6

Philosophical concepts as an aesthetic component in

literature. Works of Romantic and Existentialist literature analyzed in relation to problems about love, hatred, despair, etc. Kierkegaard, Nietzsche, Schopenhauer, Freud, Sartre, N. O. Brown, etc. studied for their relevance to books such as Proust's *Swann's Way*, Lawrence's *Lady Chatterley's Lover*, Malraux's *The Royal Way*, Beckett's *Endgame*. I. Singer

**21.676J Philosophical Psychology (A)**

(Same subject as 9.595J)

Prereq.: —

Year: G (2) 3-0-9

Place of psychology in the sciences. Nature of psychological explanation. Materialism and behaviorism. Problems concerning simulation of human behavior. Fodor

**21.677 Metaphysics (A)**

Prereq.: —

Year: G (1) 3-0-9

Metaphysical problems centering around concepts such as existence, substance, attribute, relation, identity, and change. Readings from both classical and contemporary sources. (Primarily for graduate students. Qualified undergraduates admitted by consent of instructor.) Cartwright

**21.691T Philosophies and Religions of Asia**

Prereq.: One first-year Humanities sequence

Year: U (2) 3-0-6

Exploration of the distinctive perspectives of India and the Orient on the nature of the universe, the goal of human life, and the means by which this goal is to be achieved. Reading and discussion on the basic texts of Hinduism, Buddhism, Confucianism, Taoism and Japanese Zen; lectures on historical background. (Not offered 1969-70.) H. C. Smith

**21.692T Religious Philosophy in the West**

Prereq.: One first-year Humanities sequence

Year: U (1) 3-0-6

An examination of the conceptual components of Judaism, Christianity, and Islam. Principal historical developments and the contemporary scene.

**21.693T Philosophy of Religion**

Prereq.: One first-year Humanities sequence

Year: U (2) 3-0-6

Object and method of religious philosophy. Relation to theology, phenomenology, and the history, psychology, and sociology of religion. Historic and contemporary meaning of key religious concepts and evaluation of central religious claims. (Not offered 1969-70.) H. C. Smith

**21.701T Science and Philosophy from Antiquity to Copernicus**

Prereq.: One first-year Humanities sequence

Year: U (1) 3-0-6

Development of the philosophy of nature from the earliest Western civilizations through its classical formulations and transformation in the Renaissance. Basic strategies, key conceptions, and taxonomic and quantitative approaches. deSantillana, Sivin

**21.702T Origins of Modern Scientific Thought**

Prereq.: 21.701T

Year: U (2) 3-0-6

Study of the period from the Scientific Revolution and the founding of modern scientific thought to the present. Formation of the main theories and conceptions, their philosophical implications, and the interactions of science and society. (Not offered 1969-70.) deSantillana

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## HUMANITIES

### 21.712T *Philosophy of Science*

Prereq.: One philosophy subject above 21.04  
Year: U (2) 3-0-6

Discussion of philosophical problems arising in the natural sciences: inductive inference; perceptual data and reality; common sense and scientific theories; interrelations among the sciences. *Graves*

### 21.714 *Philosophy of Mathematics (A)*

Prereq.: ——— 3-0-9  
Year: G (2)

Examination of major philosophies of mathematics — logicism, formalism, intuitionism — on the nature of mathematical proof, existence of mathematical entities, and related issues. (For graduate students, and for undergraduates having permission of instructor. It is strongly suggested that students have taken 21.641T or its equivalent.) *James F. Thomson*

### 21.715 *Philosophy of Physics (A)*

Prereq.: ——— 3-0-9  
Year: G (1)

Consideration of philosophical problems concerning the foundations of quantum mechanics and statistical mechanics. (For graduate students, and for undergraduates having permission of instructor. It is strongly suggested that students have taken 8.05 and 8.06 or their equivalents.) (Not offered 1969-70.)

### 21.716 *Philosophy of Mind (A)*

Prereq.: ——— 3-0-9  
Year: G (2)

Some concepts and problems in the philosophy of mind, such as the relations between minds and bodies, sensation and feeling, thinking, and perceiving. (Primarily for graduate students in philosophy; undergraduates who have taken 21.04 and 21.647T may be admitted by consent of the instructor.) *Judith J. Thomson*

### 21.721 *Semantics (A)*

Prereq.: ——— 3-0-9  
Year: G (1)

Characterization of the form of a semantic theory of a natural language. Basic consideration of (1) phenomena falling within the domain of a semantic theory and (2) the descriptive goals of a semantic theory, the kind of theory employed in pursuit of these goals, and the empirical and methodological requirements upon an adequate semantic theory. (Primarily for graduate students; others admitted only by permission of instructor.) *Katz*

### 21.724 *Philosophy of Language (A)*

Prereq.: ——— 3-0-9  
Year: G (2)

Study of recent philosophical movements concerned with the treatment of traditional philosophical problems from a linguistic movement; in particular, logical positivism and ordinary language philosophy. Consideration of the treatment of philosophical problems within the framework of linguistic theory. Some acquaintance with Chomsky's theory of generative grammar desirable. (Primarily for graduate students in philosophy; undergraduates who have taken 21.04 may be admitted by consent of the instructor.) *Katz*

### 21.725 *Seminar: Problems in the Philosophy of Language (A)*

Prereq.: ——— *Arr.*  
Year: G (2)

Study of various problems in the philosophy of language. (Primarily intended for graduate students in philosophy and linguistics. Not offered 1969-70.) *Bromberger*

### 21.781 *Graduate Seminar (A)*

Prereq.: ——— *Arr.*  
Year: G (1)

A graduate proseminar in which students will be pre-

senting original work. (Second- and third-year graduate students in philosophy must attend unless explicitly excused. First-year graduate students in philosophy are invited to participate.) *Staff*

### 21.782 *Graduate Seminar (A)*

Prereq.: ——— *Arr.*  
Year: G (2)

A graduate proseminar in which students will be presenting original work. (Second- and third-year graduate students in philosophy must attend unless explicitly excused. First-year graduate students in philosophy are invited to participate.) *Staff*

### 21.791 *Special Topics in Philosophy*

Prereq.: Any two subjects in philosophy *Arr.*  
Year: U (1)

Open to qualified students who wish to pursue special studies or projects with members of the Philosophy Section. Students electing this subject must consult the Chairman of the Section. *Staff*

### 21.792 *Special Topics in Philosophy*

Prereq.: Any two subjects in philosophy *Arr.*  
Year: U (2)

Open to qualified students who wish to pursue special studies or projects with members of the Philosophy Section. Students electing this subject must consult the Chairman of the Section. *Staff*

### 21.793 *Special Advanced Topics in Philosophy (A)*

Prereq.: ——— *Arr.*  
Year: G (1)

Open to qualified graduate students in philosophy who wish to pursue special studies or projects with members of the Philosophy Section. *Staff*

### 21.794 *Special Advanced Topics in Philosophy (A)*

Prereq.: ——— *Arr.*  
Year: G (2)

Open to qualified graduate students in philosophy who wish to pursue special studies or projects with members of the Philosophy Section. *Staff*

## MUSIC

### 21.81T *Materials of Music*

Prereq.: ——— 3-0-6  
Year: U (1, 2)

Introductory subject in music for students with no formal musical background. Elementary study of musical materials. Exercises in notation, ear training, melodic and harmonic interactions, and their application to the musical literature. Listening to recordings. Written assignments. *Staff*

### 21.82T *Introduction to Music*

Prereq.: 21.81T 3-0-6  
Year: U (1, 2)

Continuation of 21.81T. Formal analysis of representative masterworks through lectures, demonstrations and concerts. Extension of theoretical studies of 21.81. Listening to recordings; exercises; readings; written assignments. *Staff*

### 21.821T *Music Theory I*

Prereq.: 21.82T 3-0-6  
Year: U (1, 2)

Study of harmony and counterpoint as developed in the period of tonal music. Readings, weekly exercises and writing assignments, and analysis of the music of this period. (Permission of instructor required.) *Staff*

**21.822T Music Theory II**

Prereq.: 21.821T

Year: U (1, 2)

3-0-6

Continuation of the work initiated in Music Theory I. Study and the construction of larger musical phrases and forms and the harmonic and contrapuntal principles upon which they depend. Readings, weekly exercises and writing assignments, and analysis of music. (*Permission of instructor required.*) Staff

**21.823T Music Theory III**

Prereq.: 21.822T

Year: U (1)

3-0-6

Study of the techniques of counterpoint and writing of inventions, fugues, and other contrapuntal forms. Readings, weekly exercises and writing assignments. Staff

**21.824T Music Theory IV**

Prereq.: 21.822T

Year: U (2)

3-0-6

Study of the techniques of composition in extending contrapuntal and larger homophonic forms, such as variation and sonata form. Readings, analyses and compositional assignments. Staff

**21.825T Orchestration**

Prereq.: 21.821T

Year: U (1)

3-0-6

An examination of the construction and techniques of orchestral instruments. Graded exercises in instrumentation for strings, woodwinds, brass—separately and subsequently in combination. Deliberate imitative orchestration of selected passages from compositions with the composers' orchestral technique. (*Permission of instructor required.*) J. Cook

**21.826 Problems and Techniques of Music Research**

Prereq.: 21.822T

Year: U (1, 2)

3-0-6

Studies in the structure of music and theories of music, with emphasis upon the use of the computer. Representation of music notation for computer input, appropriate programming languages and data-structures, and the development of relevant models. Readings, papers, discussions, research projects. (*Permission of instructor required. Not offered 1969-70.*)

**21.827T Musical Form and Analysis**

Prereq.: 21.821T

Year: U (2)

3-0-6

Consideration of differing concepts of musical structure and formal organization, viewed in a historical perspective. Study of generalized formal models and the unique formal aspects of specific works. Study of scores, listening to recordings and readings. (*Permission of instructor required.*) Tucker

**21.83T Western Music in the Middle Ages and the Renaissance**

Prereq.: 21.82T

Year: U (1)

3-0-6

Study of representative composers in their historic perspective, with emphasis on outstanding examples of masterworks of the Middle Ages and the Renaissance. Listening to recordings, weekly exercises, and readings required. R. S. Freeman

**21.84T Western Music in the Baroque Era**

Prereq.: 21.82T

Year: U (2)

3-0-6

Study of representative composers in their historic perspective, with emphasis on outstanding examples of masterpieces of the Baroque era. Listening to recordings, weekly exercises, and readings required. Liepmann

**21.85T Western Music in the Classic Era**

Prereq.: 21.82T

Year: U (1)

3-0-6

Study of representative composers in their historic perspective, with emphasis on outstanding examples of masterworks of the Classic era. Listening to recordings, weekly exercises, and readings required. Liepmann

**21.86T Western Music in the Romantic Era**

Prereq.: 21.82T

Year: U (2)

3-0-6

Study of representative composers in their historic perspective, with emphasis on outstanding examples of masterworks of the Romantic era. Listening to recordings, weekly exercises, and readings required. Buttrick

**21.871T Twentieth-Century Music**

Prereq.: 21.82T

Year: U (1)

3-0-6

Study of principal works by masters of the twentieth century. Tradition and innovation as exemplified in the music of Stravinsky, Bartok, Hindemith, Copland, Ives, Prokofieff, and other composers. The interrelationship of art music, folk music, and popular music. Concerts, recordings, and discussion. (*Permission of instructor required.*) Tucker

**21.872T Twentieth-Century Music:****Schoenberg, Berg and Webern**

Prereq.: 21.82T

Year: U (2)

3-0-6

Study of the principal works of Schoenberg, Berg and Webern, and of other dodecaphonic compositions. Concerts of representative solo and chamber music. Study of electronic and other experimental music. (*Permission of instructor required.*) Tucker

**21.88T The Opera**

Prereq.: 21.82T

Year: U (2)

3-0-6

Study of the nature and development of the music drama. Illustrations at the piano as well as from recordings. As far as possible, special attention given to current productions of opera in the Boston area. J. Cook

**21.891T Seminar in Music**

Prereq.: 21.82T

Year: U (1)

3-0-6

Varying topics from year to year. Topic for fall 1969: Studies in composition. (*Permission of instructor required.*) Staff

**21.892T Seminar in Music**

Prereq.: 21.82T

Year: U (2)

3-0-6

Varying topics from year to year. Topic for spring, 1970: a Collegium Musicum on the chamber repertory for woodwind instruments. Careful study of selected works involving both analytic and historical considerations. Performance of compositions studied by members of class. Reading, discussions, papers. (*Permission of instructor required.*) R. S. Freeman

## SPECIAL INTERDISCIPLINARY SUBJECTS

**21.901 Special Topics in Interdisciplinary Studies**

Prereq.: Any two subjects in Humanities

Year: U (1)

Arr.

Special topics involving interdisciplinary study sponsored by members of the Department of Humanities or Institute faculty. Subjects varying from year to year. Staff

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

## HUMANITIES

### 21.902 *Special Topics in Interdisciplinary Studies*

*Prereq.:* Any two subjects in Humanities

*Year:* U (2)

*Arr.*

Special topics involving interdisciplinary study sponsored by members of the Department of Humanities or Institute faculty. Subjects varying from year to year.

*Staff*

### 21.92J *Elements of Urban Evolution*

(Same subject as 4.671J)

*Prereq.:* One first-year Humanities sequence

*Year:* U (1)

3-0-6

Consideration of the forces, in different periods, determining the character and principal functions of cities — military, religious, commercial, political, industrial and utopian. Readings in literary, artistic and historical sources. Independent individual student projects with a wide range of choice, for production of term papers dealing with a particular city over a manageable time span, usually less than a century. Lectures and seminars. (Limited enrollment.)

*Burchard*

### 21.93J *Great Cities: Paris*

(Same subject as 4.672J)

*Prereq.:* One first-year Humanities sequence

*Year:* U (2)

3-0-6

Study of one great city as a non-static environment, relating the history of its physical form to social, economic and cultural forces. Survey of the major building complexes of Paris and the changing character of its environment from its founding to the present but with special emphasis on the time from the founding of Roman Lutetia, first century A.D., to the siege of Paris (1870-1871) and the subsequent Commune. Examination also of the later International Exhibitions, the Metro and the most recent developments. (Limited enrollment. Not offered 1969-70.)

*Burchard*

### 21.95T *Poetic and Scientific Discourse in Classical Literature*

*Prereq.:* 21.03 or 21.031 or 21.11T

*Year:* U (1)

3-0-6

Myth and logic as differential languages for, and perspectives upon, reality. Special emphasis on the transition from one to the other. Readings in Solon, Pindar, Simonides; in philosophical poets like Parmenides, Empedocles, Lucretius; and in Plato and Aristotle on the truth-value of art. (Not offered 1969-70.)

*Reiche*

### 21.951T *Introduction to the Far East*

*Prereq.:* One first-year Humanities sequence

*Year:* U (1)

3-0-6

Interdisciplinary approach to the classical civilizations of China and her immediate neighbors — especially Japan — from earliest times until the mid-nineteenth century. Emphasis on style in art, literature, and science as well as on political and social development. Recommended, but not required, preparation for other subjects concerned with the Far East.

*Sivin*

### 21.958 *Seminar on the American University*

*Prereq.:* One first-year Humanities sequence

*Year:* U (2)

2-0-7

Analysis of the historical development and present condition of the American university (and college), focusing on several current problems: educational reform; the professionalization of intellect and its consequences; student protest; authority and democracy in the university; the role of the university in society; possibilities for the future. (Limited enrollment.)

*Kaledin*

### 21.959 *Education and Society*

*Prereq.:* —

*Year:* U (1, 2)

3-0-6

Selected topics in the politics, economics, and sociology of American education as these intersect with or deter-

mine philosophies of education. Emphasis on the contemporary setting. Precise focus of study to be worked out among the instructors and students. (Enrollment limited to 15.)

*O'Neil, Elbow*

### 21.96T *Contemporary Philosophy and Theology*

*Prereq.:* 21.019, 21.020; or one subject in philosophy

*Year:* U (2)

3-0-6

Study of contemporary theological and philosophical thought concerning the concept of God, the knowledge of God, language about God and the existence of God. Examination of the theology of Paul Tillich (part 1) in the light of selected writings, critical and constructive, of British and American philosophers (part 2) together with a consideration of new directions in contemporary religious thought (part 3).

*W. R. Crout*

### 21.961 *Seminar on Technology and Society*

*Prereq.:* One first-year Humanities sequence

*Year:* U (1)

3-0-6

Examination of some theoretical questions regarding the relation of technology and society, of case studies about the influence of technology on moral and religious values. (Permission of instructor required. It is strongly suggested that students have taken 21.018 or 21.618T.)

*Wertz*

### 21.962 *Morality and the Law*

*Prereq.:* —

*Year:* U (2)

3-0-6

Systematic attempt for discovering and developing moral principles concerning murder, theft, the keeping of promises, etc. Reading exclusively case materials from the criminal and civil law. (Not offered 1969-70.)

*Dworkin*

### 21.963 *Technology, Values and Social Choice*

*Prereq.:* —

*Year:* U (2)

3-2-5

Engineering, economic, psychological and ethical problems of optimizing design of technological systems. Theory of subjective utility and probability as applied to social welfare. Information value. Cooperative and competitive games. Philosophical considerations of justice. Laboratory experiments in quantitative assessment of worth. Possibilities for using computers in pooling individual values and deriving trading relations to determine social choice. (Permission of instructor required.)

*Sheridan*

### 21.964T *Religion and Society in America*

*Prereq.:* One first-year Humanities sequence

*Year:* U (1)

3-0-6

Examination of some historical episodes in which religion shaped and was shaped by social conditions and processes: voluntary religion and the democratic state; exodus and utopia; wilderness and paradise themes; the frontier and revivalism; denominationalism and slavery; evangelism and industrialization; "God is dead" theology and secularization. (Not offered 1969-70.)

*Wertz*

### 21.965T *Seminar on Boston*

*Prereq.:* One first-year Humanities sequence

*Year:* U (2)

3-0-6

Use of historical and contemporary Boston as a laboratory for the study of social change. By means of field trips, visual material, guest lecturers and historical analysis, examination of the dynamics of the city: the social bases of aspiration, conflict and compromise; plans for reordering the physical space of the city; economic and technological influences. Attention to three periods: the founding of Puritan Boston, Yankee-Irish Boston, and the present which will focus on the Boston Redevelopment Authority's plans, the Black Power movement and the attitudes of "suburbia" toward the city. (Not offered 1969-70.)

*Wertz*

- 21.967T Seminar in Urban Education**  
*Prereq.:* One first-year Humanities sequence  
*Year:* U (1) 3-0-6  
 Evaluation of the "Tutoring Plus" program in the light of current general theories of education. Examination of social and political implications of education among different economic groups. (Not offered 1969-70.) *O'Neil*
- 21.968T Seminar in Urban Education**  
*Prereq.:* One first-year Humanities sequence  
*Year:* U (2) 3-0-6  
 Discussion of developing an experimental school in Cambridge involving parents of neighborhood and tutors. (Not offered 1969-70.) *O'Neil*
- 21.97T Biological Bases of Perceptions and Knowledge**  
*Prereq.:* One first-year Humanities sequence  
*Year:* U (1) 3-0-6  
 Inquiry into assumptions underlying physiological and psychological experiments in perception as these reraise the question of whether the study of brain function can avoid metaphysical commitment. The mind-body problem in contemporary guise. (Not offered 1969-70.)  
*deSantillana, Lettvin*
- 21.99T Origins of Modern and Post Modern**  
*Prereq.:* 21.03 or 21.031 or 21.11T  
*Year:* U (2) 3-0-6  
 Investigation into key periods in history of late nineteenth- and twentieth-century literature, art and music. Study of the interrelation of the arts during this period and evolution from modern to post modern as they occur at specific moments in time and place, such as Paris 1886 and 1904, Berlin 1920, New York 1950.  
*Ablov, Goodheart*
- 21.992T Tradition and Innovation in Twentieth-Century Physics**  
*Prereq.:* One first-year Humanities sequence  
*Year:* U (2) 3-0-6  
 Evolution of the new ideas of twentieth-century physics, especially in relativity and quantum mechanics. Value of such notions as paradigm, model, and ideal of natural order in understanding the dynamics of scientific growth and revolutions. Relative importance of individual genius, tradition, and formal methodological rules. Interactions of physics with the philosophy of science. Features unique to the twentieth century. (Not offered 1969-70.)  
*Graves*
- 21.994J Introduction to Film Making**  
 (Same subject as 4.091J)  
*Prereq.:* —  
*Year:* U (1, 2) 4-6-2  
 Workshop exploration of the potentialities of the motion picture as documentary and as a means of personal and political expression. Theories of exercises combining filming, editing, and sound. Viewing and discussion of many films. Ample opportunity for students to experiment with various film techniques.  
*Pincus*
- 21.995T Intellectuals and Social Change**  
*Prereq.:* One first-year Humanities sequence  
*Year:* U (2) 3-0-6  
 The role and responsibility of individuals who challenge the assumptions of the established political and social order, and who are concerned with ideas and their consequences. Discussion of current issues that have given rise to action and protest, in particular: American foreign policy, the problem of poverty, the Negro revolution, the role of university students. Questions of individual commitment, and the available alternatives for action. Historical background, with emphasis on socialist, anarchist, and liberal responses to recurrent problems which have faced the committed individual since the Enlightenment

and Industrial Revolution. Study of the conditioning of these responses by the relation of intellectuals to established institutions such as government and the universities. Individual research on topics of particular current significance.  
*Chomsky, M. V. Miller*

- 21.996T American Values of the 1920's**  
*Prereq.:* 21.03 or 21.031 or 21.11T  
*Year:* U (2) 3-0-6  
*Mencken and The American Mercury, Ross and The New Yorker.* Creative activity in Greenwich Village and Harlem. Work of expatriates — Fitzgerald, Hemingway. The image of America in *Colliers* and *The Saturday Evening Post*. Consideration of some "best sellers."  
*T. Wood*

- 21.997T The Concept of Freedom in Modern Literature**  
*Prereq.:* 21.03 or 21.031 or 21.11T  
*Year:* U (2) 3-0-6  
 Case study in the literature of ideas, exploring not only the various definitions of freedom — political, social, spiritual, sexual — in modern thought but also the special problems and advantages of literature as a form of argument. Readings include some modern novelists, J. S. Mill, Marx, Freud, and other literary, philosophical and political texts. (Not offered 1969-70.) *Hawley*

- 21.998T Literature and Communication**  
*Prereq.:* 21.03 or 21.031 or 21.11T  
*Year:* U (1) 3-0-6  
 Study of the effects of major cultural shifts on literature which examines the development of various modes of literary communication from the oral tradition to the modern period.  
*Zingrone*

## 22.

### Nuclear Engineering

- 22.01 Introduction to Nuclear Reactor Engineering**  
*Prereq.:* 8.01, 18.02  
*Year:* U (1) 3-0-9  
 Introduction to the basic scientific and engineering principles underlying the production of useful energy from nuclear fission. Neutron diffusion in, and interaction with, materials. Characteristics of the fission process and their influence upon the reactor physics and engineering design of an integrated nuclear power plant.  
*Clikeman*
- 22.10 Elementary Nuclear Physics**  
*Prereq.:* 8.02, 18.034  
*Year:* G (1) 2-0-4  
 Introduction to aspects of modern physics important in nuclear engineering; atomic structure, atomic radiations and X rays; nuclear structure, radioactivity, nuclear reactions, and the fission process. Primarily for students without prior knowledge of nuclear physics who wish background as preparation for 22.21. Students planning to take graduate work in nuclear engineering should take 8.051.  
*Yip*
- (A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

NUCLEAR ENGINEERING

## 22.21 Nuclear Reactor Physics I (A)

Prereq.: 8.272 or 22.10; 18.06

Year: G (1, 2)

3-0-9

Introduction to problems of fission reactor physics; nuclear reactions induced by neutrons; nuclear fission; diffusion and slowing-down of neutrons; elementary diffusion, age-diffusion and multigroup treatment of unreflected homogeneous reactors; reflected thermal reactors; heterogeneous reactors; reactor design parameters. Emphasis on the nuclear physical bases of reactor design and their relation to reactor engineering problems.

Kaplan, Henry

## 22.22 Nuclear Reactor Physics II (A)

Prereq.: 22.21

Year: G (2)

3-0-9

Problems relating to the operation of a nuclear reactor at power; poisoning effects of fission products; effect of temperature on reactor design parameters; excess reactivity; elements of reactor kinetics, perturbation theory, transport theory and control rod theory. Emphasis on applying reactor theory to actual reactor systems.

Kaplan

## 22.231 Nuclear Reactor Engineering (A)

Prereq.: 2.50, 22.21

Year: G (1)

3-0-9

Engineering principles of nuclear reactors with emphasis on applications in central station power reactors. Power plant thermodynamics; energy production and distribution; heat transfer by conduction, convection by incompressible fluids, boiling; thermal stress analysis; reactor types.

E. A. Mason

## 22.232 Nuclear Engineering for Space Applications (A)

Prereq.: 22.231

Year: G (2)

3-0-9

Continuation of nuclear engineering principles with emphasis on applications in space nuclear power sources. Nuclear rocket and auxiliary space power systems; flow and heat transfer of compressible gases; radiant heat transfer; thermoelectric and thermionic energy conversion; shielding; design and optimization of reactor systems.

E. A. Mason

## 22.241 Principles of Control Systems (A)

Prereq.: 18.06

Year: G (1)

3-0-6

Problem of control of dynamical systems and its implications, Fourier and Laplace transforms, transfer functions, feedback systems, flow graphs, block diagrams, transient and steady-state response of feedback systems, stability criteria. Correlation techniques used in linear systems. Discussion of non-linear problems. (Alternate years.)

Gyftopoulos

## 22.242 Nuclear Plant Dynamics (A)

Prereq.: 6.214 or 6.601 or 22.241; 22.21

Year: G (2)

3-0-9

Nuclear reactor kinetics, thermal dynamics, inherent feedback loops, external control loops, transient and steady-state performance of nuclear reactors. Pile statistics, pile oscillation tests. Dynamics of nuclear plants, analog and digital methods of analysis of nuclear systems. Analysis of non-linear nuclear plant dynamics, development of boundedness and stability criteria for non-linear systems. Synthesis of control systems. (Alternate years.)

Gyftopoulos

## 22.243 Space-Time Reactor Kinetics (A)

Prereq.: 22.22

Year: G (2)

3-0-9

Development of methods for predicting dynamic behavior when space and time are not separable. Application of the point kinetics formalism, the adiabatic

method, direct finite space-time difference approach; nodal methods and the application of orthogonal and non-orthogonal modes; flux synthesis schemes based on variational and weighted residual techniques. (Not offered 1969-70.)

Henry

## 22.25 Advanced Reactor Physics (A)

Prereq.: 22.22

Year: G (1)

3-0-9

Review of current methods for predicting neutron behavior in complex geometrical and material configurations. Systematic few-group procedures; blackness theory for control rods; the  $S_n$  method; cell theory; flux synthesis techniques; the use of variational and weighted residual techniques to derive approximation methods in a systematic manner.

Henry

## 22.26 Nuclear Reactor Design (A)

Prereq.: 22.22 or 22.242; 22.231

Year: G (2)

2-4-6

Systems analysis and design of nuclear reactors, integrating the requirements of reactor physics, control, heat transfer, safety, materials, power production, and fuel cycle management; economic optimization; computer applications; group design project.

Driscoll

## 22.27 Economics of Nuclear Power (A)

Prereq.: 22.21, 22.231

Year: G (2)

2-0-6

Projected growth of nuclear power; fuel cycle performance of typical reactors; reactor uranium requirements; uranium resources and costs; fuel cycle costs; nuclear plant costs; power cost accounting; interrelation between costs of nuclear power and conventional power.

Benedict

## 22.28T Fast Power Reactors (A)

Prereq.: 22.21, 22.231

Year: G (1)

3-0-9

Unified system design of fast power reactors, coupling of engineering and physics considerations. Current status; design, construction and operational experience; safety considerations; future large fast breeder reactors. Competitive reactor design project. Two lectures, one design discussion group per week. (Alternate years. Not offered 1969-70.)

T. J. Thompson

## 22.29T Thermal Power Reactors (A)

Prereq.: 22.21, 22.231

Year: G (1)

3-0-9

A survey of the reactor engineering and reactor physics aspects of large nuclear power reactors operating principally by thermal neutron fission. Current status; design and operational problems; safety considerations; future plant designs. Students will conduct a competitive survey of several promising designs. (Alternate years.)

T. J. Thompson

## 22.31 Nuclear Chemical Engineering (A)

Prereq.: 10.12

Year: G (1)

3-0-9

Applications of chemical engineering to the processing of materials for and from nuclear reactors. Fuel cycles for nuclear reactors; chemistry of uranium, plutonium and fission products; refining of uranium; production of materials for nuclear reactors; separation of products of nuclear reactors; inorganic solvent extraction as applied to nuclear reactor materials; disposal of radioactive wastes; processes for isotope separation; and theory of isotope separation. (Not offered 1969-70.)

E. A. Mason

## 22.41 Nuclear Reactor Physics Laboratory (A)

Prereq.: 22.21

Year: G (1, 2)

2-6-4

Properties of the particles and radiations resulting from

the fission process. Use of scintillation counters, ionization chambers, proportional counters, Geiger counters, health physics instruments, and other detection devices employed in reactor technology. Experimental methods for determining the macroscopic properties of nuclear reactors, including cross section measurements, cadmium ratios, diffusion lengths, albedoes, Fermi age, and neutron multiplication of the subcritical assembly. Radioactive chemical separation methods. *Olson, Clikeman*

**22.42 Nuclear Reactor Operations (A)**

*Prereq.:* 22.21, 22.41  
*Year:* G (2) 2-6-4

Techniques of nuclear reactor operation, initial fuel loading, criticality considerations, startup reactivity effect measurements, measurements at power; operating experience at power reactor facilities including hazards evaluation and accident experience; group and individual participation in startup and operations at the M.I.T. Nuclear Reactor, investigation of M.I.T. Reactor operational problems. *T. J. Thompson*

**22.44 Basic Electronic Instrumentation Laboratory**

*Prereq.:* —  
*Year:* G (S) 1-5-2

For engineering research students with little or no background in electronics, who need a working knowledge of electronic devices and circuits. Basic laws and electronic principles, basic circuits and components, servo systems, operational amplifiers, feedback control, digital circuits and logic and other devices, using both tube and transistor circuitry. *Olson*

**22.51 Neutral Particle Transport (A)**

*Prereq.:* 8.341; or 18.15 and 22.21; or 18.28  
*Year:* G (2) 3-0-9

Boltzmann and integral transport equations. Infinite space and Milne problems. Spherical harmonic and variational methods. Corrections to diffusion theory. Slowing down theory. Special methods of solving transport equations. Adjoint functions. *Yip*

**22.531T Numerical Methods of Reactor Analysis (A)**

*Prereq.:* 22.21  
*Year:* G (1) 3-0-9

Applications of digital computers to nuclear engineering topics. Review of specific mathematical techniques for solving engineering problems including matrix algebra, finite difference equations, and numerical solution of equations. Special topics such as multigroup diffusion methods and Monte Carlo techniques. *K. F. Hansen*

**22.532 Advanced Methods of Reactor Analysis (A)**

*Prereq.:* 22.531T  
*Year:* G (2) 3-0-9

Advanced numerical treatment of problems in reactor criticality and transient behavior. Transport analysis by spherical harmonic and discrete ordinates methods. Reactor kinetics analysis by direct numerical integration and approximate techniques such as modal and nodal methods. (*Alternate years.*) *K. F. Hansen*

**22.54 Radiation Shielding (A)**

*Prereq.:* 8.272 or 8.722 or 22.10; 22.21  
*Year:* G (1) 3-0-6

Shielding of nuclear reactors, accelerators and space vehicles. Interaction of  $\gamma$ -rays, neutrons and charged particles with matter. Energy range from thermal through cosmic rays. Application of particle transport theory to penetration of shields. (*Not offered 1969-70.*) *K. F. Hansen, Rasmussen*

**22.55 Neutron Physics and Applications (A)**

*Prereq.:* 8.721  
*Year:* G (2) 3-0-6

Basic principles of neutron interaction with nuclei in matter. Applications to cross section calculation for reactor design and to scattering experiments for the study of material properties. Fast neutron cross sections, resonance absorption, neutron thermalization, general properties of inelastic scattering of thermal and cold neutrons in liquids and solids, and analysis of current experiments. *Chen*

**22.56 Fast Reactor Physics (A)**

*Prereq.:* 22.21  
*Year:* G (1) 2-0-6

Characteristics of the neutron balance in the large fast breeder reactors proposed for central station power generation. Methods for and results of calculation of core and blanket neutronics. Comparison of the effects of various fissile and fertile materials, structural materials and coolants on criticality and the breeding ratio. Doppler and coolant void reactivity coefficients. Time-dependent behavior: kinetics, burnup, and reactivity transients. Experimental fast reactor physics: critical assemblies, spectral indices, reactivity coefficient measurements. *Driscoll*

**22.61 Plasmas and Controlled Fusion I (A)**

*Prereq.:* 8.03; 8.05 or 22.10  
*Year:* G (1) 3-0-9

Survey of the means of obtaining energy from fusion reactions. Energy resources. Atomic and electronic collision phenomena, and transport and electromagnetic theory applicable to confined plasmas. Methods of producing and heating plasmas. Electromagnetic methods of confinement. Material and energy loss processes. Energy balances. Recent experiments. Diagnostics. *Lidsky*

**22.62 Plasmas and Controlled Fusion II (A)**

*Prereq.:* 8.261 or 22.61; 8.311  
*Year:* G (2) 3-0-9

Topics in plasma dynamics of current interest in thermonuclear research, such as: conductivity of highly ionized plasma; radiation losses; wave propagation; magnetic field structures; instabilities; dynamics of a thermonuclear system; critical review of confinement schemes; advanced diagnostic techniques; recent experiments. *Lidsky*

**22.63 Engineering Physics of Plasma and Particle Devices (A)**

*Prereq.:* 6.03T or 22.61  
*Year:* G (1) 3-0-6

Principles of accelerators and thermonuclear research devices, including vacuum systems, magnets, acceleration methods, ion sources, targets, lasers, and laser diagnostics. Examples from recent practice. *Blanken*

**22.65 Plasma Laboratory (A)**

*Prereq.:* 8.261 or 22.61 or 22.63  
*Year:* G (2) 1-4-4

Introduction to the advanced experimental techniques needed for research in plasma physics and useful in experimental atomic and nuclear physics. Laboratory work on vacuum systems, plasma generation and diagnostics, physics of ionized gases, ion sources and beam optics, cryogenics, magnetic field generation, and other topics of current interest; brief lectures and literature references to elucidate the physical bases of the laboratory work. *Blanken*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

FOREIGN LITERATURES AND LINGUISTICS

## 22.68J Plasma Kinetic Theory (A)

(Same subject as 8.621J)

Prereq.: 8.611 or 8.622 or 16.59

Year: G (1)

3-0-9

Content varying from year to year. Typical subjects: the linearized Vlasov equation, Fokker-Planck and diffusion approximations for the average distribution function, autocorrelation functions, resonant and non-resonant diffusion, free energy, energy and momentum conservation, resonant wave coupling, non-linear Landau damping, strong turbulence theories. Selected applications to enhanced diffusion, stochastic acceleration, turbulent resistivity, shock waves, radio emission. *Dupree*

## 22.69J Advanced Topics in Plasma Kinetic Theory (A)

(Same subject as 16.581J)

Prereq.: 22.68J

Year: G (2)

3-0-9

Varying content including topics of current interest. Typical subjects: theories of non-linear phenomena in plasma, particularly in the regime described by the Vlasov equation. General normal mode analysis, Van Kampen modes, radiation, limitations of the linear theory, resonance and trapping, continuum modes. Multiple length-and-time-scale formulations. Non-linear stationary wave solutions, shock waves. Unstable plasmas, phase space and statistical considerations, entropy. Computer experiments. Perturbation methods, quasi-linear theory, mode coupling. N-momentum space description, master equation, general H-theorem, equilibrium. *Dupree, McCune*

## 22.71 Metallurgy for Nuclear Engineers (A)

Prereq.: —

Year: G (2)

3-0-9

Crystallography and microstructure of engineering materials. Elastic and plastic properties of metals and relation of mechanical properties to metallurgical structure. Phase relations in metals; phase transformations and diffusion kinetics. Corrosion and oxidation. Effects of radiation on mechanical properties. Emphasis throughout is on materials used in nuclear reactor systems — structural alloys, fuels, moderators, and control materials. *Ziebold*

## 22.72J Nuclear Fuels (A)

(Same subject as 3.72J)

Prereq.: 3.13 or 3.14 or 22.71

Year: G (1)

2-0-6

Behavior of nuclear fuels and fuel element cladding materials in reactor cores. Experimental observations and theory of radiation damage to metals and ceramics of practical interest. Processes for fabricating fuel elements and fuel assemblies; fuel fabrication costs. Recent developments of advanced reactor core materials. (*Alternate years.*) *Ziebold*

## 22.721J Radiation Damage in Crystalline Solids (A)

(Same subject as 3.721J)

Prereq.: 3.13 or 3.14 or 22.71

Year: G (1)

2-0-6

Theory of atomic displacements, cascades, and spike phenomena produced in metals and ceramics by high energy radiation bombardment. Recovery of damage related to mobility and structure of crystalline imperfections. Discussion of radiation damage experiments of technological importance and basic experiments designed to test the theory of damage production and recovery. Consideration of special problems associated with damage in fissionable materials. Brief outline of the role of materials in nuclear reactor design. (*Not offered 1969-70.*) *Ziebold*

## 22.81 Radiation and Radioisotope Applications (A)

Prereq.: 8.272 or 22.10

Year: G (2)

3-0-6

Basic topics include production of radiation and radioisotopes, interaction of radiation with matter, detection, dosimetry, radiation chemistry and biology. Various topics such as radiation preservation and synthesis, radiation modification of materials, radiation gauging, and use of radioisotopes as terrestrial and space power sources explored in depth. Emphasis on student participation. (*Not offered 1969-70.*) *Brownell*

## 22.82 Biological Effects of Nuclear Radiation (A)

Prereq.: 8.272 or 22.10

Year: G (1)

3-0-6

Review of interactions of nuclear radiations with matter and the effects of energy absorbed from nuclear radiation on simple and complex chemical systems, various organisms, and living tissue. Theories of the action of radiations on living matter, and considerations of various factors which affect the biological response, such as time and type of radiation. Theory and practice of radiation dosimetry with special reference to practical applications. Discussion of biological and physical bases for safety standards. (*Alternate years.*) *Brownell*

## 22.90 Special Problems in Nuclear Engineering (A)

Prereq.: —

Year: G (1, 2)

Arr.

For graduate and advanced undergraduate students who wish to carry out a one-term project of a theoretical or experimental nature in the nuclear engineering field in close cooperation with individual staff members. Arrangement of topic and hours to fit student requirements. *Benedict*

## 22.91 Seminar in Nuclear Engineering (A)

Prereq.: —

Year: G (1)

2-0-1

## 22.92 Seminar in Nuclear Engineering (A)

Prereq.: —

Year: G (2)

2-0-1

For graduate students engaged on doctoral theses. *Benedict*

## 23.

### Foreign Literatures and Linguistics

#### 23.011 The Greek Tradition

Prereq.: —

Year: U (1)

3-0-6

Study of the foundations of Western civilization through selected masterworks of Greek literature (*The Iliad*, *The Oresteia*), history (*The Peloponnesian War*), and philosophy (*The Apology*, *Phaedo*, *The Republic*). Readings, lectures, and discussion in French. Tests and essays in English. (*Restricted to students with an adequate background in French.*) *Bottiglia*

#### 23.021 The Judaeo-Christian Tradition

Prereq.: 23.011

Year: U (2)

3-0-6

Study of the foundations of Western civilization through selected works of the Hebrew and Christian Bibles: e.g., Genesis, Job, various of the historical and prophetic books, the Gospels, and various epistles. Readings,

lectures, and discussion in French. Tests and essays in English. (*Restricted to students with an adequate background in French.*) Bottiglia

**23.032 The European Tradition: Goethe Era**  
Prereq.: 21.011  
Year: U (2) 3-0-6  
Introduction to literature and thought in the era of Goethe. Reading and discussion of works by Lessing, Goethe, Schiller, Novalis, Tieck, Eichendorff, and Kleist. The major movements of the period: Aufklärung, Sturm und Drang, Klassik, Romantik. Some attention to such thinkers as Kant and Fichte. Instruction in German. Discussion in German and English. Papers, exercises, and examination in English. (*Restricted to students with an adequate background in German.*) Dyck

**23.031 The Nature of Literature**  
Prereq.: 23.051  
Year: U (2) 3-0-6  
Training in background, internal, and comparative analysis of modern poems (by Eliot, Yeats, St. John Perse), plays (by Giraudoux, Sartre, O'Neill), and novels (by Camus, Malraux, Faulkner). Readings in French and English. Lectures and discussion in French. Tests and essays in English. (*Restricted to students with an adequate background in French.*) R. E. Jones

**23.032 The Nature of Literature**  
Prereq.: 23.022  
Year: U (1) 3-0-6  
Introduction to the analysis of poetry, drama, and fiction. An examination of the various strata, and of their interrelations, in the total experience of reading a literary work. Structure, sound, style; idea, meaning, substance; the metaphoric spectrum. Examples drawn chiefly from modern German poetry (George, Rilke, Hofmannsthal, and others), drama (Hauptmann, Brecht, Dürrenmatt, and others), and fiction (Thomas Mann, Kafka, and others). Instruction in German. Discussion in German and English. Papers, exercises, and examination in English. (*Restricted to students with an adequate background in German.*) Exner

**23.051 The French Enlightenment**  
Prereq.: 23.021  
Year: U (1) 3-0-6  
Training in the elements of historical method through analysis of major developments in the French Enlightenment. Focus on political, economic, and social phenomena. Some attention to cultural manifestations as well. Readings in primary sources and works of interpretation. Lectures, discussion, and readings in French. Tests and essays in English. (*Restricted to students with an adequate background in French.*) R. E. Jones

**23.052 The Twentieth Century: Revolution, War, and "Totalism"**  
Prereq.: 23.032  
Year: U (2) 3-0-6  
Training in the elements of historical method through analysis of some major developments in today's world. Focus on political, economic, and social phenomena, with special attention to Germany. Readings in primary sources and works of interpretation. Readings and lectures in German. Discussion and tests in German and English. Essays in English. (*Restricted to students with an adequate background in German. Not offered 1969-70.*) Dyck

**23.11 Elementary German**  
Prereq.: —  
Year: U (1, 2) 4-0-8  
Basic principles of the German language. Fundamentals of pronunciation, intonation, and grammar. Acquisition of basic vocabulary. Laboratory exercises to further comprehension and oral expression. Reading of simple texts, practice in writing. Staff

**23.12 Elementary German**  
Prereq.: 23.11  
Year: U (1, 2) 4-0-8  
Continued practice in pronunciation and intonation. Extension of vocabulary for both conversational and literary purposes. Review and extension of basic grammar. Practice in writing short essays. Introduction to the history and culture of German-speaking countries. Conducted partly in German. Staff

**23.13 Intermediate German**  
Prereq.: 23.12  
Year: U (1, 2) 4-0-8  
Intensive review of general linguistic forms and idiomatic structures, with emphasis on literary usage. Readings designed to broaden acquaintance with German thought and culture. Class discussion and essays on the reading material. Conducted in German. Nelson

**23.14 Advanced German**  
Prereq.: 23.13  
Year: U (1, 2) 4-0-8  
Extensive practice in reading, writing, and speaking German. Readings in narrative prose, drama, and poetry as an introduction to German literature and in relation to historical and cultural developments. Oral and written analyses of texts. Conducted in German. Nelson

**23.15T Goethe's Poetry**  
Prereq.: 23.14  
Year: U (2) 3-0-6  
An intensive analysis of representative poems from Goethe's entire career. Supplementary readings in Goethe's thought. Instruction in German. Discussion and papers in English or German. Dyck

**23.16T German Romanticism**  
Prereq.: 23.14  
Year: U (2) 3-0-6  
A critical study of literary works of the German Romantic movement, with emphasis on Novalis, Friedrich Schlegel, Tieck, Brentano, Eichendorff, and Hoffmann. Some attention to the manifestations of Romanticism in extraliterary domains: music and painting, science and religion, philosophy and political thought. Instruction in German. Discussion and papers in English or German. (*Not offered 1969-70.*) Dyck

**23.171 Spoken German I**  
Prereq.: —  
Year: G (1) 4-0-8  
Introduction to speaking and understanding German. No previous knowledge of German required. Primary emphasis on rapid acquisition of essentials for effective communication in practical situations. Practice in reading. Full use made of language laboratory. (*Open to graduate students only. No credit given.*) Staff

**23.172 Spoken German II**  
Prereq.: 23.171  
Year: G (2) 4-0-8  
Continued training in speaking and understanding German. Increased practice in reading. Continued use of language laboratory. (*Open to graduate students only. No credit given.*) Staff

**23.173 German Reading I**  
Prereq.: —  
Year: G (1) 4-0-8  
Introduction to the reading of German. No previous knowledge of German required. Intensive study of grammar. Practice in reading simple materials. (*Open to graduate students only. No credit given.*) Staff

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

FOREIGN LITERATURES AND LINGUISTICS

- 23.174 German Reading II**  
*Prereq.:* 23.173  
*Year:* G (2) 4-0-8  
 Reading of varied materials of intermediate difficulty, both general and technical. Continued study of grammar. (*Open to graduate students only. No credit given.*)  
*Staff*
- 23.19T Goethe's "Faust"**  
*Prereq.:* 23.14  
*Year:* U (1) 3-0-6  
 An intensive analysis of both parts of *Faust*. Instruction in German. Discussion and papers in English or German. (*Not offered 1969-70.*)  
*Dyck*
- 23.20T Seminar in German Poetry**  
*Prereq.:* 23.14  
*Year:* U (2) 3-0-6  
 Introduction to various methods of analysis, intrinsic and extrinsic, and to the major phases of German poetry, through detailed analysis of some two dozen representative poems written since 1600. Followed by concentration on one poet, e.g., Hölderlin, Schiller, Brentano, Eichendorff, Heine, Mörike, Droste-Hülshoff, C. F. Meyer, George, Rilke, Hofmannsthal, Trakl, Heym, Benn, or a more recent one. Instruction in German. Discussion and papers in English or German. (*Limited enrollment. Not offered 1969-70.*)  
*Dyck*
- 23.21T Modern German Drama**  
*Prereq.:* 23.14  
*Year:* U (1) 3-0-6  
 An intensive analysis of representative German plays written since 1880. The evolution of themes and techniques from naturalism and expressionism to more recent times. Major authors: Hauptmann, Hofmannsthal, Kaiser, Brecht, Frisch, Dürrenmatt. Instruction in German. Discussion and papers in English or German. (*Not offered 1969-70.*)  
*Dyck*
- 23.22T Modern German Fiction**  
*Prereq.:* 23.14  
*Year:* U (1) 3-0-6  
 Critical reading and discussion of examples of modern German prose fiction, with emphasis on Mann and Kafka. Instruction in German. Discussion and papers in English or German.  
*Exner*
- 23.24T\* The Modern German Novel**  
*Prereq.:* 21.03 or 21.031 or 21.11T or 23.031 or 23.032  
*Year:* U (2) 3-0-6  
 Close study of novels by such writers as Raabe, Mann, Döblin, Kafka, Jünger, Broch, Musil, Böll, and Grass. Readings in translation. Conducted in English. (*Not offered 1969-70.*)  
*Dyck*
- 23.26T\* Modern German Drama**  
*Prereq.:* 21.03 or 21.031 or 21.11T or 23.031 or 23.032  
*Year:* U (2) 3-0-6  
 Close study of plays by Lessing, Kleist, Büchner, Hebbel, Wedekind, Schnitzler, Brecht, Frisch, Dürrenmatt, and others. Readings in translation. Conducted in English. (*Not offered 1969-70.*)  
*Dyck*
- 23.35T Spanish Drama**  
*Prereq.:* 23.41T  
*Year:* U (1) 3-0-6  
 Reading and discussion of works by Lope de Vega, Cervantes, Tirso de Molina, Ruiz de Alarcón, Calderón de la Barca, Rojas Zorilla, Moratín, Duque de Rivas. Conducted in Spanish. (*Limited enrollment. Not offered 1969-70.*)  
*J. W. Harris*
- 23.36T Twentieth-Century Spanish Literature**  
*Prereq.:* 23.41T  
*Year:* U (2) 3-0-6  
 Study of philosophical works by Unamuno, Ortega y Gasset. Reading and discussion of literary prose works by Azorín, Pío Baroja, Valle-Inclán, and others. Conducted in Spanish. (*Limited enrollment. Not offered 1969-70.*)  
*J. W. Harris*
- 23.371 Spoken Spanish I**  
*Prereq.:* —  
*Year:* G (1) 4-0-8  
 Introduction to speaking and understanding Spanish. No previous knowledge of Spanish required. Primary emphasis on rapid acquisition of essentials for effective communication in practical situations. Practice in reading. Full use made of language laboratory. (*Open to graduate students only. No credit given.*)  
*J. W. Harris*
- 23.372 Spoken Spanish II**  
*Prereq.:* 23.371  
*Year:* G (2) 4-0-8  
 Continued training in speaking and understanding Spanish. Increased practice in reading. Continued use of language laboratory. (*Open to graduate students only. No credit given.*)  
*J. W. Harris*
- 23.373 Spanish Reading I**  
*Prereq.:* —  
*Year:* G (1) 4-0-8  
 Introduction to the reading of Spanish. No previous knowledge of Spanish required. Intensive study of grammar. Practice in reading simple materials. (*Open to graduate students only. No credit given.*)  
*Staff*
- 23.374 Spanish Reading II**  
*Prereq.:* 23.373  
*Year:* G (2) 4-0-8  
 Reading of varied materials of intermediate difficulty, both general and technical. Continued study of grammar. (*Open to graduate students only. No credit given.*)  
*Staff*
- 23.41T Introduction to Spanish Literature**  
*Prereq.:* —  
*Year:* U (1) 3-0-6  
 Detailed study of poems, plays, and prose works by such writers as Arceola, Baroja, Casona, Guzmán, and Neruda. Emphasis on control of grammar and rapid acquisition of vocabulary, leading to the ability to read standard works with immediate comprehension and pleasure. Conducted largely in Spanish.  
*J. W. Harris*
- 23.42T Masterpieces of Spanish Literature**  
*Prereq.:* 23.41T  
*Year:* U (2) 3-0-6  
 Careful study of unabridged works of recognized masters in various genres, largely contemporary and largely Latin American, such as Arciniegas, Borges, García Lorca, Mistral, Romero, and Paz. Conducted in Spanish.  
*J. W. Harris*
- 23.51 Elementary French**  
*Prereq.:* —  
*Year:* U (1, 2) 4-0-8  
 Necessary foundation for French language and literature. Training in pronunciation and intonation with the aid of mechanical devices, and in elementary grammar; practice in hearing and speaking French; acquisition of useful vocabulary; reading of varied matter.  
*Greenfield*

\*Readings in English, conducted in English.

**23.52 Elementary French**

Prereq.: 23.51

Year: U (1, 2)

4-0-8

Continued training in the speaking and listening skills with the aid of mechanical devices. Completion of elementary grammar. Practice in reading to increase vocabulary and to develop some appreciation of French literature and civilization. *Kramsch*

**23.53 Intermediate French**

Prereq.: 23.52

Year: U (1, 2)

4-0-8

Practice in spoken French to develop fluency in everyday conversation; also in written French to increase accuracy. Grammar review; reading of varied matter. Mechanical devices used for improving pronunciation and intonation. Appropriate for Fulbright candidates. *Ricardo*

**23.54 Conversational French**

Prereq.: 23.53

Year: U (1, 2)

4-0-8

Practice in spoken French to develop fluency in cultural conversation; also in written French to increase accuracy. Reading of varied matter. Appropriate for Fulbright candidates. *Ricardo*

**23.571 Spoken French I**

Prereq.: —

Year: G (1)

4-0-8

Introduction to speaking and understanding French. No previous knowledge of French required. Primary emphasis on rapid acquisition of essentials for effective communication in practical situations. Practice in reading. Full use made of language laboratory. (*Open to graduate students only. No credit given.*) *Staff*

**23.572 Spoken French II**

Prereq.: 23.571

Year: G (2)

4-0-8

Continued training in speaking and understanding French. Increased practice in reading. Continued use of language laboratory. (*Open to graduate students only. No credit given.*) *Staff*

**23.573 French Reading I**

Prereq.: —

Year: G (1)

4-0-8

Introduction to the reading of French. No previous knowledge of French required. Intensive study of grammar. Practice in reading simple materials. (*Open to graduate students only. No credit given.*) *Staff*

**23.574 French Reading II**

Prereq.: 23.573

Year: G (2)

4-0-8

Reading of varied materials of intermediate difficulty, both general and technical. Continued study of grammar. (*Open to graduate students only. No credit given.*) *Staff*

**23.61T Contemporary French Drama**

Prereq.: 23.54

Year: U (1)

3-0-6

Study of major authors and movements in French drama since 1920: Lenormand, Giraudoux, Anouilh, Montherlant, Claudel, Artaud, Ionesco, Beckett, Genet, Surrealism, Existentialism, etc. Conducted in French. (*Not offered 1969-70.*) *R. E. Jones*

**23.62T French Romanticism**

Prereq.: 23.54

Year: U (2)

3-0-6

Inclusive study of French literature from 1800 to 1860, with emphasis on the poetry of Hugo, Vigny, Musset, Lamartine, Nerval, and Gautier, the novels of Stendhal and Balzac, and the Romantic theatre. Also, examination of the allied arts of music and painting. Conducted in French. (*Not offered 1969-70.*) *R. E. Jones*

**23.63T French Prose Fiction**

Prereq.: 23.54

Year: U (1)

3-0-6

Analysis of various types and techniques of fiction. Readings selected from several periods of French literature, but emphasis on such nineteenth and twentieth century authors as Flaubert, Zola, Proust, Gide, Malraux, Camus, Bernanos, Céline, and Robbe-Grillet. Conducted in French. *R. E. Jones*

**23.64T Seminar in French Literature**

Prereq.: 23.54

Year: U (2)

3-0-6

Detailed study of some aspect of modern French literature. Conducted in French. *R. E. Jones*

**23.65T Classical French Drama**

Prereq.: 23.54

Year: U (1)

3-0-6

Concentrated study of selected plays by Corneille, Racine, and Molière, and of Boileau's *Art poétique*. Conducted in French. (*Not offered 1969-70.*) *R. E. Jones*

**23.66T Modern French Poetry**

Prereq.: 23.54

Year: U (2)

3-0-6

Detailed analyses of poetry by Nerval, Baudelaire, Rimbaud, Mallarmé, Apollinaire, and the Surrealists. Special attention to the prose poem. Conducted in French. (*Not offered 1969-70.*) *R. E. Jones*

**23.701 Crucial Problems in Linguistics**

Prereq.: —

Year: G (1)

2-0-7

The Moscow school — Fortunatov, Trubetzkoy, further stages — and its place in world linguistics. (*Not offered 1969-70.*) *Jakobson*

**23.702 Seminar in Language Acquisition**

Prereq.: —

Year: G (1)

Arr.

Discussion of the theoretical and factual basis for a model of language learning. Treatment of philosophical, psychological, and linguistic issues concerning language learning as well as the recent evidence from studies on children's language skills. (*Not offered 1969-70.*) *Staff*

**23.703 Linguistics and Poetics**

Prereq.: —

Year: G (1)

2-0-7

Poetic function of language; linguistic analysis of poems; verse, rime, parallelism; phonemic, morphologic and syntactic texture; tropes and figures. (*Not offered 1969-70.*) *Jakobson*

**23.705 Seminar on Poetic Form**

Prereq.: —

Year: G (1)

Arr.

Study of the organization of linguistic elements in metrical verse. (*Not offered 1969-70.*) *Halle*

**23.707 Studies in Comparative and Russian Poetics**

Prereq.: —

Year: G (1)

2-0-7

Language and poetry; comparative approach to Russian verse, rime, and parallelism. Brief historical survey of Russian poetry oral and written. Reading and analysis of Russian poems and folklore texts; their rhythm, sound texture, grammatical pattern, imagery, and composition, with special reference to the relation between Russian poetic devices and linguistic structure. Conducted in English. *Jakobson*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

FOREIGN LITERATURES AND LINGUISTICS

- 23.71 Special Problems in Language and Literature**  
*Prereq.:* —  
*Year:* G (1) Arr.
- 23.72 Special Problems in Language and Literature**  
*Prereq.:* —  
*Year:* G (2) Arr.  
 Advanced work in literature or linguistics for unusually well-prepared students. Offered by members of staff in their special fields. Staff
- 23.731 Structure of English I (A)**  
*Prereq.:* 23.751T  
*Year:* G (2) 3-0-9  
 Introduction to the grammatical devices of English. The interrelation of syntactic, morphological and phonological phenomena in the English language. The phonological system and the structure of phonemes. Special reference to current interpretations by leading structuralists.  
*Kiparsky, J. R. Ross*
- 23.732 Structure of English II: Advanced Syntax (A)**  
*Prereq.:* 23.751T  
*Year:* G (1) 3-0-9  
 Selected topics in the syntax of English. *J. R. Ross*
- 23.733J History of the English Language**  
*(Same subject as 21.315J)*  
*Prereq.:* —  
*Year:* G (1) 3-0-9  
 Selected topics in the history of English syntax, morphology and phonology from Old English to the present, formulated within an attempt at a general theory of linguistic change. Some knowledge of Old and Middle English desirable. *(Not offered 1969-70.)* O'Neil
- 23.734 Structure of Russian (A)**  
*Prereq.:* 23.731, 23.762  
*Year:* G (2) 2-0-10  
 Survey of the syntax, morphology and phonology of contemporary literary Russian, with emphasis on the application of modern theory to classical problems of Slavic linguistics. Consideration of the relevant dialectological and historical evidence. *(Adequate knowledge of Russian required. Not offered 1969-70.)* Halle
- 23.736 Structure of German (A)**  
*Prereq.:* 23.731, 23.762  
*Year:* G (2) 2-0-10  
 Survey of the syntax, morphology and phonology of contemporary literary German, with emphasis on the application of modern theory to classical problems of Germanic linguistics. Consideration of the relevant historical evidence. *(Adequate knowledge of German required.)* Kiparsky, J. R. Ross
- 23.737T Introduction to Sanskrit**  
*Prereq.:* —  
*Year:* G (1) 3-0-9  
 Brief review of writing system, phonology, morphology, and syntax of the language. Kiparsky
- 23.738 Seminar on English Syntax (A)**  
*Prereq.:* 23.732  
*Year:* G (2) 3-0-9  
 Continuation of 23.732. *(Not offered 1969-70.)* J. R. Ross
- 23.742 Structure of Spanish (A)**  
*Prereq.:* 23.731, 23.762  
*Year:* G (2) 3-0-9  
 Survey of the syntax, morphology and phonology of contemporary literary Spanish, with emphasis on the application of modern theory to classical problems of Spanish linguistics. *(Adequate knowledge of Spanish required. Not offered 1969-70.)* Halle, J. W. Harris
- 23.744 Structure of Arabic**  
*Prereq.:* 23.751T  
*Year:* G (2) 3-0-9  
 Selected topics of current theoretical interest in the phonology, morphology, and syntax of modern literary Arabic. Discussion of controversial questions, such as the existence of a morphological component, the existence of a naturalness condition in phonology, and the existence of performative verbs or abstract predicates in syntax. Offering of some evidence which bears directly on the resolution of the question of certain controversial rules and base structures in syntax, such as conjunct movement, embedded conjunctions, etc. Examination of issues internal to Semitic, such as the source of gemination and infixation in phonology, and the underlying order of constituents in syntax. Particular attention to the question of a morphological component and its location in the grammar, i.e., post-transformational or lexical.  
Brame
- 23.751T Introduction to Linguistics I: Syntax**  
*Prereq.:* —  
*Year:* G (1) 6-0-18  
 Deep and surface structure. Phrase structure and transformational rules. Recursive mechanisms: relative clauses, complements, conjunctions. Types of ordering. Exception mechanisms and pruning. Universality of deep structure. Halle, J. R. Ross
- 23.752T Linguistic Structure**  
*Prereq.:* 23.751T  
*Year:* G (1) 3-0-9  
 The empirical requirements for a theory of linguistic structure that will encompass and account for linguistic competence and the ability to use and acquire it. Study of aspects of English syntax, semantics, and phonology insofar as they furnish critical tests for such a theory. Systematic presentation of a theory of linguistic structure, its abstract properties and range of empirical adequacy. Explanatory models in linguistics; their implications concerning the nature of cognitive processes.  
Chomsky
- 23.754 Field Methods**  
*Prereq.:* 23.751T  
*Year:* G (2) 2-0-7  
 Survey of means for eliciting linguistically relevant data about a language from a native speaker; for obtaining correct phonetic representations, the basic phonological system, and basic grammatical structure. Suggestions for dealing with informants, elicitation, and data organization. Halle
- 23.756 Indo-European (A)**  
*Prereq.:* 23.785T  
*Year:* G (2) 3-0-9  
 Selected topics in the grammar of Indo-European. Kiparsky
- 23.758 Introduction to Linguistics III: Theory of Grammar**  
*Prereq.:* 23.751T  
*Year:* G (2) 3-0-9  
 Elementary transformations and derived constituent structure. Rule government. Variables. Identity. Indexing. The abstract nature of underlying structures. J. R. Ross
- 23.762 Introduction to Linguistics II: Phonology**  
*Prereq.:* 23.751T  
*Year:* G (2) 3-0-5  
 Aims and principles of a scientific description of the phonic aspect of language. The mechanism and acoustics of speech. Distinctive features as the descriptive framework. The phoneme. The phonemic system of a language. The interrelations between phonology and other linguistic levels. Some problems of historical phonology. Practical exercises. Halle

**23.768J Speech Communication (A)**

(Same subject as 6.691J)

Prereq.: —

Year: G (2)

3-0-9

Survey of structural properties of natural languages with special emphasis on the sound pattern. Survey of physiology of speech production, articulatory phonetics. Acoustical theory of speech production; the vocal tract as a generator of acoustical signals; acoustical correlates of vocal-tract configurations, both stationary and dynamic; acoustical and articulatory descriptions of phonetic features. Perception of speech: the auditory capabilities of man; evidence for perceptual correlates of phonetic categories. Mechanical recognition and generation of speech. Speech transmission and compression; the concept of intelligibility; effects of distortion on intelligibility. Recommended prerequisites: engineering and science students, 6.36; linguistics students, mathematical background equivalent to 6.05 or 18.05. Others admitted by permission of instructor. (Not offered 1969-70.) Halle, Stevens

**23.771 Mathematical Backgrounds for Communication Sciences**

Prereq.: —

Year: G (1)

3-0-9

Fundamentals of discrete mathematics for non-mathematicians. Introduction to various topics in set theory and foundations, logic and formal systems, modern algebra, theory of automata and computability. Mattheus

**23.772 Mathematical Models in Linguistics**

Prereq.: 23.771

Year: G (2)

3-0-9

Study of mathematical models that relate to linguistic competence and performance. Formal properties of grammatical systems. Grammars of natural and artificial languages. Models for the speaker and hearer that incorporate representations of his knowledge of the language. Probabilistic models for the user. Stress on interconnections of theory of grammar and theory of automata, and implications for the study of human cognitive processes wherever possible. Mattheus

**23.781T Survey of General Linguistics I (A)**

Prereq.: 23.751T

Year: G (1)

3-0-9

An expository and critical survey of modern structural linguistics. The work of Boas, Sapir, Bloomfield, the Prague Circle, and other developments in general linguistics during the past half-century. Contemporary trends and their immediate backgrounds. Mattheus

**23.782 Survey of General Linguistics II (A)**

Prereq.: 23.781T

Year: G (1)

3-0-9

Concepts of language as they have arisen in linguistics, psychology, and philosophy studied against the background of developments in science and philosophy. Emphasis on the nineteenth and twentieth centuries, with stress on contemporary relevance. Chomsky, Bromberger

**23.783T Topics in the Grammar of Non-Indo-European Languages (A)**

Prereq.: 23.751T, 23.754

Year: G (1)

3-0-9

Detailed examination of the grammar of a non-Indo-European language with special emphasis on problems of interest to general linguistics. Hale

**23.784 Seminar on Universal Grammar (A)**

Prereq.: 23.752T, 23.783T

Year: G (1)

3-0-9

Study of grammatical problems in several languages

with a view towards achieving a sharper characterization of certain universal features of grammatical structure. Mattheus

**23.785T Linguistic Change (A)**

Prereq.: 23.751T

Year: G (1)

3-0-9

Review of instances of change in phonology, morphology, and syntax. Examples to be drawn from various language families, Indo-European as well as others. An attempt to develop a general theory of linguistic change. Mattheus, Hale

**23.786 Seminar on Linguistic Change (A)**

Prereq.: 23.785T

Year: G (2)

2-0-10

Continuation of 23.785T. (Not offered 1969-70.) Hale, Mattheus

**23.789 Seminar on the Linguist in Society**

Prereq.: —

Year: G (2)

1-0-5

Discussion of role and responsibility of the linguist qua linguist. Nature of linguistics as a tool and as a discipline in modern society. Moral decisions the linguist must be prepared to make concerning how his special knowledge and research is to be used both by himself and by others. Kinds of situations that arise which call upon him to make such decisions, and the relationship between these decisions and his responsibility as a member of society. Mattheus

**23.87T Dante I**

Prereq.: —

Year: U (1)

3-0-6

Intensive literary analysis of the *Inferno* in the original, after preliminary training in fundamentals of Italian grammar and pronunciation. Designed for students with no previous knowledge of Italian. (Not offered 1969-70.) Bottiglia

**23.88T Dante II**

Prereq.: 23.87T

Year: U (2)

3-0-6

Continuation of 23.87T. Intensive literary analysis of the *Purgatorio* and the *Paradiso* in the original. (Not offered 1969-70.) Bottiglia

**23.91 Elementary Russian**

Prereq.: —

Year: U (1, 2)

4-0-8

Basic grammar. Extensive use of language laboratory. Emphasis on learning to speak as prerequisite for effective reading. Staff

**23.92 Elementary Russian**

Prereq.: 23.91

Year: U (1, 2)

4-0-8

Continued practice in speaking. Selected readings with a dictionary. Conducted in Russian. Chvany

**23.93 Intermediate Russian**

Prereq.: 23.92

Year: U (1, 2)

4-0-8

Review of Russian grammar, with the aid of oral and written exercises built around the vocabulary of literary reading material. Work on reading and aural comprehension in the classroom and in the language laboratory. Chvany

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

FOREIGN LITERATURES AND LINGUISTICS

- 23.94 Advanced Russian**  
*Prereq.:* 23.93  
*Year:* U (1, 2) 4-0-8  
 Conversation, reading, and written composition centered on topics of Russian history and culture from the beginning to the present. Use of mechanical devices for improving pronunciation and comprehension.  
*M. Z. Freeman*
- 23.941T Introduction to Russian Literature**  
*Prereq.:* 23.94  
*Year:* U (1) 3-0-6  
 Intensive study of selected masterpieces, combined with introduction to literary terminology and critical method. Conducted in Russian.  
*Pomorska*
- 23.95T Puškin and Russian Romanticism**  
*Prereq.:* 23.941T  
*Year:* U (2) 3-0-6  
 Reading and analysis of Puškin's poems and prose works in relation to major problems of European and Russian Romanticism. Readings in Russian. Conducted in Russian or English, depending on individual student needs and abilities.  
*Pomorska*
- 23.951T\* Soviet Russian Literature**  
*Prereq.:* 21.03 or 21.031 or 21.11T or 23.94  
*Year:* U (1) 3-0-6  
 Study of the processes which led from the "Golden Age" of Soviet literature to the proclamation of Socialist Realism by the First Congress of Soviet Writers in 1934. Effects of this proclamation on the current situation considered. Authors to be read: I. Babel, B. Pilnjak, I. Ehrenburg, Ilf and Petrov, Sholokov. Readings in English, conducted in English. (Not offered 1969-70.)  
*Pomorska*
- 23.96T Seminar in Modern Russian Poetry**  
*Prereq.:* 23.941T  
*Year:* U (1) 3-0-6  
 Intensive analysis of Russian Symbolist and post-Symbolist poetry up to the Revolution. Conducted in English or Russian, depending on individual student needs and abilities. (Not offered 1969-70.)  
*Pomorska*
- 23.961T\* Gogol and Literary Methodology in Russia**  
*Prereq.:* 21.03 or 21.031 or 21.11T or 23.94  
*Year:* U (2) 3-0-6  
 Gogol's writings as approached by sociological criticism (Belinsky, Chernyshevsky), by the symbolists, by the Formalist school; the biographical and psychological approach; the impact of Husserl's phenomenology in Russia at the beginning of the twentieth century. Readings in English, conducted in English. (Not offered 1969-70.)  
*Pomorska*
- 23.971 Spoken Russian I**  
*Prereq.:* —  
*Year:* G (1) 4-0-8  
 Introduction to speaking and understanding Russian. No previous knowledge of Russian required. Primary emphasis on rapid acquisition of essentials for effective communication in practical situations. Practice in reading. Full use made of language laboratory. (Open to graduate students only. No credit given.)  
*Staff*
- 23.972 Spoken Russian II**  
*Prereq.:* 23.971  
*Year:* G (2) 4-0-8  
 Continued training in speaking and understanding Russian. Increased practice in reading. Continued use of language laboratory. (Open to graduate students only. No credit given.)  
*Staff*
- 23.973 Russian Reading I**  
*Prereq.:* —  
*Year:* G (1) 4-0-8  
 Introduction to the reading of Russian. No previous knowledge of Russian required. Intensive study of grammar. Practice in reading simple materials. (Open to graduate students only. No credit given.)  
*Staff*
- 23.974 Russian Reading II**  
*Prereq.:* 23.973  
*Year:* G (2) 4-0-8  
 Reading of varied materials of intermediate difficulty, both general and technical. Continued study of grammar. (Open to graduate students only. No credit given.)  
*Staff*
- 23.98T Selected Problems in Soviet Literature**  
*Prereq.:* 23.941T  
*Year:* U (2) 3-0-6  
 Intensive study of prose works from the twenties, the "golden age" of Soviet literature, by writers such as young Pasternak, Pilnjak, Babel, Zamyatin, Zoshchenko. Followed by readings in prose and poetry of the post-Stalin period, drawn from the works of such writers as Ehrenburg, Panova, Solzhenitsyn, Voznesenskij, Yevtushenko, Okudzhava. Conducted in English or Russian, depending on individual student needs and abilities. (Not offered 1969-70.)  
*Pomorska*
- 23.981T\* Mayakovsky and Pasternak**  
*Prereq.:* 21.03 or 21.031 or 21.11T or 23.94  
*Year:* U (2) 3-0-6  
 Consideration of twentieth-century literary movements, like Futurism and Constructivism, through a study of both the poetry and prose of Russia's greatest contemporary poets. Readings in English, conducted in English. (Not offered 1969-70.)  
*Pomorska*
- 23.99T Seminar in Russian Prose**  
*Prereq.:* 23.941T  
*Year:* U (1) 3-0-6  
 Concentrated study of one of the following authors: Gogol, Tolstoy, Dostoevski, Chekhov. Conducted in English or Russian, depending on individual student needs and abilities. (Not offered 1969-70.)  
*Pomorska*
- 23.991T\* Tolstói's "War and Peace"**  
*Prereq.:* 21.03 or 21.031 or 21.11T or 23.94  
*Year:* U (1) 3-0-6  
 Intensive study of *War and Peace* both as an historical novel and as a literary structure. Readings in English, conducted in English.  
*Pomorska*
- 23.993T\* Contemporary Soviet Literature**  
*Prereq.:* 21.03 or 21.031 or 21.11T or 23.94  
*Year:* U (1) 3-0-6  
 Intensive study of prose and poetry of the post-Stalin period up to the present, based on the works of such writers as Ehrenburg, Panova, Solzhenitsyn, Yevtushenko, Voznesenskij, Okudzhava, Kazakoj, and Ak-syonov. Readings in English, conducted in English. (Not offered 1969-70.)  
*Pomorska*
- 23.995\* The Russian Short Story**  
*Prereq.:* 21.03 or 21.031 or 21.11T or 23.94  
*Year:* U (2) 3-0-6  
 Tradition and novelty in Russian short story of the nineteenth century. Intensive analysis of works by Karamzin, Puškin, Lermontov, Gogol, Turgenyev, Tolstói, Dostoevski, and Chekhov. Readings in English, conducted in English.  
*Pomorska*

(See also 21.641 SYMBOLIC LOGIC; 9.59 PSYCHOLOGY OF LANGUAGE AND COMMUNICATION; and 6.574 TRANSMISSION OF INFORMATION.)

\*Readings in English, conducted in English.

## AS

## Aerospace Studies

AS11T *World Military Systems*

Prereq.: —  
Year: U (1) 3-0-3

Study of historical development of warfare and the causes of present world conflict with emphasis on the role and relationship of military power to the present world situation; concepts and principles of war from which differing political philosophies have evolved; past military policy and its relationship to national power; individual military systems and strategies of all types of warfare, with emphasis upon the U.S. Department of Defense and the U.S. Air Force. (Restricted to students selected for A.F.R.O.T.C.) Grenier

AS111 *Corps Training*

Prereq.: —  
Year: U (1) 0-1-0

AS121 *Corps Training*

Prereq.: AS111  
Year: U (2) 0-1-0

Introduction to customs and traditions, courtesies, and drill procedures as they apply to the Air Force. Introduction to life in the Air Force through seminars and guest speakers. Drill procedures under the supervision of advanced class members. (Restricted to students selected for A.F.R.O.T.C.) Staff

AS12T *Airpower and the World Military Systems*

Prereq.: AS11T  
Year: U (2) 3-0-3

Continuation of AS11. Political-military issues surrounding the existence of present-day forces; organization, mission, and doctrine of the United States Army, United States Navy, NATO, CENTO, SEATO, and their role in the security of the free world; military forces of the U.S.S.R., the Soviet satellite armies, and the Chinese Communist Army; and effects of the above on military concepts and the world political situation. (Restricted to students selected for A.F.R.O.T.C.) Grenier

AS121 *See above following AS111.*AS21 *Air Force Environment I*

Prereq.: AS121  
Year: U (1) 0-1-0

AS22 *Air Force Environment II*

Prereq.: AS21  
Year: U (2) 0-1-0

Lecture series on current concepts for using Air Force aircraft and missiles; discussion of opportunities and environment in Air Force life; development of ability to give information and directions during Corps Training periods. (Restricted to students selected for A.F.R.O.T.C.) Staff

AS31T *Seminar in Growth and Development of Aerospace Power*

Prereq.: AS22  
Year: U (1) 3-0-1

AS32T *Seminar in Space Operations*

Prereq.: AS31T  
Year: U (2) 3-0-1

Seminar in the development of aerospace power and its relation to the military posture of the United States. Primarily concerned with Air Force concepts, doctrine, and employment, related to astronautical and space operations, with emphasis on future development of aerospace power, both military and civilian. Specific U.S. space programs concerning development of propulsion systems, guidance systems, vehicles and other problems related to space exploration; emphasis on current and

projected technology with an introduction into the history of the aerospace power. (Six weeks of field training is an acceptable prerequisite for AS31 in lieu of AS22. Restricted to students selected for A.F.R.O.T.C.) Staff

AS311 *Leadership Practice*

Prereq.: AS22  
Year: U (1) 0-1-0

AS321 *Leadership Practice*

Prereq.: AS311  
Year: U (2) 0-1-0

Supervisory practice and exercise of leadership functions in controlling and improving upon the activities of the cadet corps. Preparation for attendance at Field Training. (Restricted to students selected for A.F.R.O.T.C.) Staff

AS41T *The Professional Officer, Principles and Techniques of Leadership*

Prereq.: AS32T  
Year: U (1) 3-0-6

Thorough investigation of the communicative process both oral and written, with special emphasis on improving each student's ability to express himself and to impart information or directions. A study of professionalism and leadership. Includes the meaning of professionalism; professional responsibilities; the military justice system; leadership theory, functions, and practices. (Restricted to students selected for A.F.R.O.T.C.) Perselay

AS411 *Management Experiences*

Prereq.: AS321  
Year: U (1) 0-1-0

AS421 *Management Experiences*

Prereq.: AS411  
Year: U (2) 0-1-0

Exercise of management functions in planning, supervising and directing cadet corps activities. Preparation for active duty in the Air Force. (Restricted to students selected for A.F.R.O.T.C.) Staff

AS42T *Principles of Management*

Prereq.: AS41T  
Year: U (2) 3-0-6

Study of the fundamental principles of management and of a framework which joins them systematically. The functions of management — planning, organizing, coordinating, directing and controlling — as context for discussing management tools and concepts. Special application to the management of complex military organizations. (Required of students selected for A.F.R.O.T.C.) Perselay

AS421 *See above following AS411.*

## MS

## Military Science

MS11T *World Military History*

Prereq.: —  
Year: U (1) 3-0-4

Analysis of fundamental concepts of land, sea, and air war in historical perspective, examining the relation of strategy and tactics to geography, economics, sociology, technology, and political objectives. Historical examination of relationship between culture and military policy. Survey of the main developments in the history of warfare and applications to current national defense problems. Staff

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

# Descriptions

NAVAL SCIENCE

## MS21T *Leadership Development*

*Prereq.:* —  
*Year:* U (1) 0-1-0  
 Laboratory emphasizing development of leadership abilities. *Staff*

## MS22T *Concepts of General and Limited War Systems*

*Prereq.:* 17.51T 3-0-5  
*Year:* U (2)  
 Examination of general and limited war systems and strategies in postwar period. Comparison of nuclear and non-nuclear forces for the deterrence and conduct of war. Emphasis on technological, strategic, political, budgetary, resource, and environmental parameters. *Staff*

## MS22I *Leadership Development*

*Prereq.:* MS21T 0-1-0  
*Year:* U (2)  
 Continuation of MS21T. *Staff*

## MS31T *Military Tactics and Communications*

*Prereq.:* — 2-1-0  
*Year:* U (1)  
 Introduction to tactical military operations and communications systems; development of leadership abilities. *Staff*

## MS32T *Principles of Military Teaching and Leadership*

*Prereq.:* MS31T 2-1-0  
*Year:* U (2)  
 Application of teaching principles and a study of military leadership; development of leadership abilities. *Staff*

## MS41T *Principles and Applications of Military Law and Administration*

*Prereq.:* MS32T 2-1-0  
*Year:* U (1)  
 Study and application of junior officer's leadership role in the military environment; professional instruction in military law and administration; development of leadership abilities. *Staff*

## MS42T *Principles of Military Management and Logistics*

*Prereq.:* MS41T 2-1-0  
*Year:* U (2)  
 Principles and techniques of military management and organization emphasizing effective and economical utilization of men and materiel; logistics and maintenance; professional seminar on service life and customs of the service; development of leadership abilities. *Staff*

## NS111 *Naval Orientation and Leadership*

*Prereq.:* — 0-1-0  
*Year:* U (1)  
 Laboratory sessions in Naval Science. *Staff*

## NS12 *Orientation and Sea Power*

*Prereq.:* — 0-1-0  
*Year:* U (2)  
 Fundamentals of naval knowledge. Concepts of use of sea power and naval tactics. *Staff*

## NS21 *Naval Guided Missiles*

*Prereq.:* — 1-0-0  
*Year:* U (1)

## NS22 *Naval Guided Missiles*

*Prereq.:* — 1-0-0  
*Year:* U (2)  
 Lecture series on technological fundamentals of present-day naval guided missiles. *Staff*

## NS31 *Naval Engineering*

*Prereq.:* — 1-0-0  
*Year:* U (1)

## NS32 *Naval Engineering*

*Prereq.:* — 1-0-0  
*Year:* U (2)  
 Lecture series on technological fundamentals of applied and planned naval engineering. *Staff*

## NS41T *Naval Industrial Management and Leadership*

*Prereq.:* — 3-0-6  
*Year:* U (1)

## NS42T *Naval Industrial Management and Leadership*

*Prereq.:* 17.31T 3-0-6  
*Year:* U (2)  
 Study of the principles and applications of industrial management as applied to naval situations. Topics covered: organization theory, planning and production control, PERT and EPS, time and motion study, personnel and financial management, principles and problems of naval leadership, administration of naval organizations, and related case studies. *Staff*

## NS41I *Naval Orientation and Leadership*

*Prereq.:* — 0-1-0  
*Year:* U (1)  
 Laboratory sessions in Naval Science. *Staff*

NS42T See above following NS41T.

## NS42I *Naval Orientation and Leadership*

*Prereq.:* — 0-1-0  
*Year:* U (2)  
 Laboratory sessions in Naval Science. *Staff*

## NS

### Naval Science

#### NS11T *Naval Organization and Management*

*Prereq.:* — 3-0-6  
*Year:* U (1)  
 Introduction to basic principles of management in the Navy. Organization and operation of the Navy Department, naval ships, and the naval shore establishment. Consideration of basic planning organization and controlling principles and the application to naval organizations. Brief discussion of personnel administration, financial management and material management as implemented within the Navy. *Staff*

## SEM

### Undergraduate Seminar

#### SEM11 *Undergraduate Seminar*

*Prereq.:* — 0-6-0  
*Year:* U (1, 2)

#### SEM12 *Undergraduate Seminar*

*Prereq.:* — 0-6-0  
*Year:* U (1, 2)  
 Seminar and/or research work for undergraduates in a

small group under leadership of a staff member. A description of seminars and research projects offered is published each term. Application for all seminars is made to the Undergraduate Seminar Office. Enrollment may be limited; selection of participants is made by the staff member offering the seminar. *Gilliland*

**SEM211 Undergraduate Teaching Seminar**

*Prereq.:* —

*Year:* U (1)

2-5-5

Teaching assistant program in cooperation with the Cambridge School System providing opportunity to teach at the high school level in the areas of science, mathematics, English, or social studies. Concurrent seminars at M.I.T. allowing discussion of situations arising from the teaching experience and providing a systematic review of educational theories. Outside lecturers participating. Acceptance to the program at the discretion of the M.I.T. faculty member in charge of the particular area and the headmaster of the Cambridge high school involved. *Menand*

**SEM212 Undergraduate Teaching Seminar**

*Prereq.:* —

*Year:* U (1, 2)

2-0-10

Seminar oriented towards research in particular issues arising from SEM211 but without simultaneous teaching. Topics ranging from preparation for SEM211 to analysis of particular issues arising from work in SEM211. *Menand*

## CORPORATION STANDING, AUDITING, AND VISITING COMMITTEES

### Standing Committees, 1969-70

#### EXECUTIVE COMMITTEE

HOWARD W. JOHNSON, *Ex officio*  
 JAMES R. KILLIAN, JR., *Ex officio*  
 JOSEPH J. SNYDER, *Ex officio*  
 MALCOLM G. KISPERT, *Secretary*  
 ROBERT B. SEMPLE 1970  
 DAVID A. SHEPARD 1970  
 WILLIAM B. MURPHY 1971  
 GEORGE W. THORN 1971  
 EDWARD J. HANLEY 1972  
 WILLIAM A. COOLIDGE 1973  
 JAMES B. FISK 1974

#### DEVELOPMENT COMMITTEE

JAMES R. KILLIAN, JR., *Chairman*  
 HOWARD W. JOHNSON, *Ex officio*  
 JOSEPH J. SNYDER, *Ex officio*  
 VINCENT A. FULMER,  
*Executive Officer*

#### Term Expiring in 1970

W. GARDNER BARKER  
 WILLIAM B. BERGEN  
 EARL L. BIMSON  
 BENJAMIN H. BRISTOL  
 HOMER A. BURNELL  
 MARSHALL B. DALTON  
 CHARLES DIEBOLD III  
 JAMES A. DRAIN  
 CARBON C. DUBBS  
 JAMES M. EWELL  
 WALTER H. GALE  
 ARTHUR R. HARVEY  
 DONALD A. HENDERSON  
 WAYNE J. HOLMAN, JR.  
 JAMES T. HOLMES  
 I. AUSTIN KELLY III  
 PAUL V. KEYSER, JR.  
 JOHN R. KIMBERLY  
 WILLIAM H. LANG  
 JOHN LAWRENCE  
 SAMUEL E. LUNDEN  
 HAROLD E. MACDONALD  
 WILFRED D. MACDONNELL  
 THEODORE A. MANGELSDORF  
 JAMES G. MCCURDY  
 THOMAS K. MELOY  
 WILLIAM C. MENTZER, JR.  
 ROBERT W. MILLER  
 LEWIS W. MOORE  
 DAVID B. NICHINSON  
 GOFF SMITH  
 ROGER P. SONNABEND  
 HOYT P. STEELE  
 RICHARD M. STEWART  
 KARL R. VAN TASSEL  
 LAURENCE L. WAITE  
 CHARLES E. WAMPLER  
 D. REID WEEDON, JR.  
 THORNTON A. WILSON

ROBERT E. WORDEN  
 FRANK S. WYLE

#### Terms Expiring in 1971

WILLIAM L. ABRAMOWITZ  
 ARTHUR R. ANDERSON  
 A. RUFUS APPELGARTH, JR.  
 OLIVER BARDES  
 CARL W. BLANCHARD  
 CHARLES P. BOWEN, JR.  
 JOSEPH S. BOWMAN  
 MARION W. BOYER  
 GEORGE M. BUNKER  
 JAMES M. W. CHAMBERLAIN  
 WILLIAM VAN ALAN CLARK, JR.  
 ARCHIBALD P. COCHRAN  
 THOMAS F. CREAMER  
 DONALD W. DOUGLAS  
 LUIS A. FERRÉ  
 ROBERT L. GIBSON, JR.  
 ELLIOTT M. GORDON  
 ELISHA GRAY II  
 RUDOLF E. GRUBER  
 WILLIAM E. HARTMANN  
 RUDOLPH HURWICH  
 HENRI P. JUNOD  
 BREENE M. KERR  
 LEO LOEB  
 ANGUS N. MACDONALD  
 JOSEPH R. MARES  
 WILLIAM H. MILLS  
 CARL M. MUELLER  
 CLINT W. MURCHISON, JR.  
 THORNTON W. OWEN  
 PHILIP H. PETERS  
 JOHN L. RIEGEL  
 DONALD G. ROBBINS  
 WILLARD F. ROCKWELL  
 CORNELIUS VAN S. ROOSEVELT  
 HOWARD J. SAMUELS  
 ARCH C. SCURLOCK  
 WILLIAM C. SESSIONS  
 WILLIAM J. SHERRY  
 HAROLD E. THAYER  
 L. G. LEE THOMAS  
 GEORGE R. VILA  
 JEPHTHA H. WADE  
 TEDDY F. WALKOWICZ  
 HOWARD D. WILLIAMS

#### Terms Expiring in 1972

BENNETT ARCHAMBAULT  
 DAVID BAKALAR  
 LEO M. BECKWITH  
 SAMUEL BERKE  
 PHILIP L. COLEMAN  
 EMILIO G. COLLADO  
 PAUL M. COOK  
 WILLIAM E. P. DOELGER  
 HERBERT H. DOW  
 BRADFORD M. ENDICOTT  
 FRED C. FISCHER

W. KROME GEORGE  
 KENNETH J. GERMESHAUSEN  
 MORTON E. GOULDER  
 EDWIN W. HIAM  
 HALL L. HIBBARD  
 DONALD A. HOLDEN  
 CUTHBERT HURD  
 IRVING D. JAKOBSON  
 FRANKLIN M. JARMAN  
 ANDREW P. KELLOGG  
 RALPH LANDAU  
 CARL M. LOEB  
 JAMES MCCORMACK  
 DENMAN MCNEAR  
 THEODORE T. MILLER  
 MYLES MORGAN  
 THOMAS F. MORROW  
 JOHN W. NORRIS  
 FRANKLIN E. PENN  
 PAUL D. SHEELINE  
 DAVID W. SKINNER  
 S. JOSEPH TANKOOS  
 PAUL TISHMAN  
 THOMAS H. WEST

#### Terms Expiring in 1973

CRAWFORD H. GREENEWALT  
 JOHN K. JAMIESON

#### Terms Expiring in 1974

GEORGE P. EDMONDS  
 ROBERT C. GUNNESS  
 MERVIN J. KELLY  
 SEMON E. KNUDSEN

#### INVESTMENT COMMITTEE

JOSEPH J. SNYDER, *Chairman*  
 JAMES R. KILLIAN, JR., *Ex Officio*  
 SEMON E. KNUDSEN 1970  
 DAVID A. SHEPARD 1970  
 GEORGE J. LENESS 1971  
 FRANK R. MILLIKEN 1971  
 EDWARD J. HANLEY 1972  
 GEORGE P. GARDNER, JR. 1973  
 CARL M. MUELLER 1974

#### MEMBERSHIP COMMITTEE

JAMES R. KILLIAN, JR., *Chairman*  
 HOWARD W. JOHNSON, *Ex officio*  
 DONALD F. CARPENTER 1970  
 WILLIAM WEBSTER 1971  
 MARSHALL B. DALTON 1972  
 GEORGE P. GARDNER, JR. 1973  
 GILBERT M. RODDY 1974

### Auditing Committee, 1968-69

DAVID A. SHEPARD, *Chairman*  
 FRANK R. MILLIKEN  
 GILBERT M. RODDY

**JOINT ADVISORY COMMITTEE ON  
INSTITUTE-WIDE AFFAIRS,  
1969-1970**

GREGORY SMITH, *Chairman*  
MICHAEL A. ALBERT, *Ex officio*  
RALPH M. DAVISON, *Ex officio*  
WILLIAM T. MARTIN, *Ex officio*  
PHILIP H. PETERS, *Ex officio*  
THEODORE H. BENTTINEN, JR. 1970  
JAY W. FORRESTER 1970  
RANDOLPH G. HAWTHORNE 1970  
DONLYN LYNDON 1970  
MARVIN A. SIRBU, JR. 1970  
KAREN H. WATTEL 1970  
STEVEN WEINBERG 1971  
HAYWARD R. ALKER 1972  
VANNEVAR BUSH 1972  
JAMES A. CHAMPY 1972  
HERMANN A. HAUS 1972  
DAVID A. SHEPARD 1972  
JEPHTHA H. WADE III 1972

**Visiting Committees,  
1968-69<sup>1</sup>**

**DEPARTMENT OF AERONAUTICS  
AND ASTRONAUTICS**

RUSSELL DE YOUNG, *Chairman*  
WILLIAM B. BERGEN\*  
WILLIAM H. COOK, JR.\*  
HOWARD W. EMMONS†  
IVAN A. GETTING  
WILLIS M. HAWKINS†  
IRA G. HEDRICK†  
THORNTON A. WILSON  
JOHN R. WILEY\*

**SCHOOL OF ARCHITECTURE  
AND PLANNING**

THOMAS D. CABOT, *Chairman*  
ANTHONY DOWNS†  
IRÉNÉE DU PONT, JR.  
DAVID A. GROSSMAN\*  
JOHN C. HAAS  
WILLIAM E. HARTMANN  
GEORGE E. KOSTRITSKY\*  
RALPH LAZARUS†  
JOHN G. RAUMA\*  
BURTON ROCKWELL\*  
GEORGE I. TABER†

**DEPARTMENT OF BIOLOGY**

VANNEVAR BUSH, *Chairman*  
W. GERALD AUSTEN\*  
MAX DELBRUCK†  
RICHARD S. GORDON\*  
IRWIN C. GUNSALUS†  
MERVIN J. KELLY  
KARL PFISTER III\*  
UNCAS A. WHITAKER

**CENTER FOR  
INTERNATIONAL STUDIES**

ROBERT A. LOVETT, *Chairman*  
KINGMAN BREWSTER, JR.†  
JOHN COWLES†  
HAROLD W. FISHER\*

<sup>1</sup> Names without notations indicate  
nominees by the Corporation  
\*Nominees by the Alumni Council  
†Nominees by the President

CARL KAYSEN†  
GEORGE J. LENESE  
HENRY S. ROWEN\*  
JULIUS A. STRATTON  
D. REID WEEDON, JR.\*

**DEPARTMENT OF CHEMICAL  
ENGINEERING**

JOHN K. JAMIESON, *Chairman*  
ROBERT F. FLOOD\*  
M. WREN GABEL  
ALBERT J. GRACIA†  
ROBERT L. HERSHEY†  
RALPH LANDAU\*  
ROBERT L. PIGFORD†  
CHARLES E. REED\*  
CHARLES A. THOMAS

**DEPARTMENT OF CHEMISTRY**

JOHN C. HAAS, *Chairman*  
ROBERT T. ARMSTRONG\*  
THOMAS W. CARMODY\*  
JACK HALPERN†  
WALTER KAUFMANN†  
GERALD D. LAUBACH\*  
WALTER H. STOCKMAYER†  
GEORGE R. VILA  
ROBERT B. WOODWARD

**DEPARTMENT OF CIVIL  
ENGINEERING**

LUIS A. FERRÉ, *Chairman*  
ARTHUR R. ANDERSON\*  
NICHOLAS L. BARBAROSSA\*  
WALTER S. DOUGLAS†  
RALPH E. FADUM†  
RALPH F. GOW  
NORMAN B. LEVENTHAL\*  
RALPH M. PARSONS†  
ALFRED E. PERLMAN

**EARTH AND PLANETARY SCIENCES**

CECIL H. GREEN, *Chairman*  
THOMAS C. DESMOND  
ROBERT A. FROSCH†  
W. BARCLAY KAMB\*  
BREENE M. KERR\*  
JOHN LAWRENCE  
FRANK R. MILLIKEN  
WALTER H. MUNK†  
ROBERT M. WHITE\*  
HATTEN S. YODER, JR.\*

**DEPARTMENT OF ECONOMICS**

EMILIO G. COLLADO, *Chairman*  
JOHN R. COLEMAN†  
WILLIAM S. EDGERLY\*  
KERMIT GORDON†  
ROBERT A. GORDON†  
CRAWFORD H. GREENEWALT  
WILLIAM E. HARTMANN  
CARL M. MUELLER\*  
GEORGE P. SHULTZ\*

**DEPARTMENT OF ELECTRICAL  
ENGINEERING**

ROBERT C. SPRAGUE, *Chairman*  
JAMES J. LING†

BERNARD M. OLIVER†  
KENNETH H. OLSEN\*  
H. I. ROMNES  
DONALD B. SINCLAIR\*  
HENRY E. SINGLETON  
PHILIP SPORN†  
JOHN G. TRUXAL\*  
JOHN R. WHINNERY†

**DEPARTMENT OF FOREIGN  
LITERATURES AND LINGUISTICS**

SAMUEL A. GROVES, *Chairman*  
JEAN BOORSCH†  
LUIS A. FERRÉ  
RUDOLF E. GRUBER\*  
HENRY M. HOENIGSWALD†  
GILBERT W. KING\*  
CORNELIUS VAN S. ROOSEVELT\*  
IRA O. WADE†  
ROBERT H. WINTERS

**DEPARTMENT OF HUMANITIES**

DONALD F. CARPENTER, *Chairman*  
LLOYD D. BRACE  
ALFRED D. CHANDLER, JR.†  
CARL G. HEMPEL†  
WILLIAM R. KEAST†  
I. AUSTIN KELLY III\*  
NORMAN LLOYD†  
ANGUS N. MACDONALD\*  
WALTER A. NETSCH\*  
JULIUS A. STRATTON

**LIBRARIES**

ROBERT C. GUNNESS, *Chairman*  
NATHAN COHN\*  
ROBERT C. COWEN\*  
EDWARD G. FREEHAFFER†  
DOUGLAS M. KNIGHT  
NATHANIEL ROCHESTER\*  
DON R. SWANSON†  
ROBERT G. VOSPER†

**ALFRED P. SLOAN SCHOOL  
OF MANAGEMENT**

GEORGE R. VILA, *Chairman*  
WILLIAM BLACKIE†  
CHARLES P. BOWEN, JR.\*  
WILLIAM S. BREWSTER  
DONALD C. COOK†  
HUGH S. FERGUSON\*  
GROVER M. HERMANN†  
RICHARD D. HILL†  
BRYAN F. SMITH\*  
ROGER P. SONNABEND\*

**DEPARTMENT OF MATHEMATICS**

ALBERT H. BOWKER, *Chairman*  
VANNEVAR BUSH  
FELIX HAAS\*  
GILBERT A. HUNT, JR.\*  
IRVING KAPLANSKY†  
CHARLES B. MORREY, JR.†  
JACOB T. SCHWARTZ†  
DONALD C. SPENCER\*  
ROBERT B. WOODWARD

## VISITING COMMITTEES

### DEPARTMENT OF MECHANICAL ENGINEERING

WILLIAM S. BREWSTER, *Chairman*  
MAC C. ADAMS†  
PETER BOLAN\*  
JOHN T. BURWELL, JR.\*  
PAUL F. CHENEAE†  
NORMAN A. COPELAND\*  
SAMUEL A. GROVES  
GEORGE J. MASLACH†  
HORACE W. MCCURDY

### MEDICAL DEPARTMENT

UNCAS A. WHITAKER, *Chairman*  
IRÉNÉE DU PONT, JR.  
RITA M. KELLEY\*  
SIDNEY KIBRICK\*  
JOHN H. KNOWLES†  
R. VINCENT KRON\*  
EDWARD P. RADFORD†  
DAVID D. RUTSTEIN†  
GREGORY SMITH  
DOUGLASS S. THOMPSON†

### DEPARTMENT OF METALLURGY AND MATERIALS SCIENCE

FRANK R. MILLIKEN, *Chairman*  
BRUCE CHALMERS†  
KARL L. FETTERS\*  
RALPH F. GOW  
FRANCIS B. HERLIHY\*  
PAUL QUENEAU†  
REINHARDT SCHUHMAN, JR.\*  
ROBERT C. SPRAGUE  
MORRIS TANENBAUM†

### DEPARTMENT OF NAVAL ARCHITECTURE AND MARINE ENGINEERING

JOHN J. WILSON, *Chairman*  
HENRY A. ARNOLD\*  
WILLIAM A. BROCKETT†  
EDWARD J. FAHY†  
GEORGE P. GARDNER, JR.  
GEORGE C. HALSTEAD\*  
EDWARD H. HEINEMANN†  
DONALD A. HOLDEN  
HORACE W. MCCURDY  
OLIN J. STEPHENS II\*

### DEPARTMENT OF NUCLEAR ENGINEERING

WILLIAM WEBSTER, *Chairman*  
SOLOMON J. BUCHSBAUM\*  
ROBERT A. CHARPIE†  
DAYTON H. CLEWELL  
GEORGE M. KAVANAGH\*  
MERVIN J. KELLY  
W. BENNETT LEWIS†  
KENNETH G. MCKAY\*  
RICHARD F. POST†

### DEPARTMENT OF NUTRITION AND FOOD SCIENCE

GEORGE W. THORN, *Chairman*  
ROBERT H. COTTON\*  
JOHN T. DORRANCE, JR.†  
JAMES F. HALE\*  
JOHN K. JAMIESON  
MAYNARD A. JOSLYN†  
EUGENE MCDERMOTT  
ROBERT E. OLSEN†  
SAMUEL RABINOWITZ\*  
W. H. SEBRELL, JR.†

### DEPARTMENT OF PHYSICS

IVAN A. GETTING, *Chairman*  
THOMAS D. CABOT  
THOMAS C. DESMOND  
RICHARD L. GARWIN†  
MARVIN L. GOLDBERGER†  
CLARK GOODMAN\*  
CECIL H. GREEN  
CHARLES KITTEL†  
DAVID L. MACADAM\*  
LEONARD I. SCHIFF\*

### DEPARTMENT OF POLITICAL SCIENCE

ROBERT H. WINTERS, *Chairman*  
VIRGILIO BARCO-VARGAS\*  
FRANCIS M. BATOR\*  
PENDLETON HERRING†  
DOUGLAS M. KNIGHT  
JOHN A. LUNN\*  
ALFRED E. PERLMAN  
DAVID B. TRUMAN†

### DEPARTMENT OF PSYCHOLOGY

CRAWFORD H. GREENEWALT,  
*Chairman*  
A. RUFUS APPLLEGARTH, JR.\*  
LLOYD D. BRACE  
RICHARD S. CRUTCHFIELD†  
ALLEN LATHAM, JR.\*  
DONALD B. LINDSLEY†  
EUGENE MCDERMOTT  
JULIUS P. MOLNAR\*  
VERNON B. MOUNTCASTLE†  
GEORGE W. THORN

### SPONSORED RESEARCH

GILBERT M. RODDY, *Chairman*  
DAYTON H. CLEWELL  
FREDERIC A. L. HOLLOWAY†  
LAWRENCE LEVY\*  
HOWARD O. MCMAHON\*  
HOWARD L. RICHARDSON\*  
GEORGE S. SCHAIRER†  
HENRY E. SINGLETON  
TEDDY F. WALKOWICZ†

### STUDENT AFFAIRS

GREGORY SMITH, *Chairman*  
GERALD A. BERLIN

DONALD F. CARPENTER  
RICHARD W. DAY†  
GEORGE P. EDMONDS  
LOUIS H. FRITZEMEIER†  
VIRGINIA F. HILDEBRAND\*  
JEROME H. HOLLAND†  
HENRY W. JONES\*  
THEODORE A. MANGELSDORF, JR.\*

## ADMINISTRATION

### Office of the President

HOWARD WESLEY JOHNSON, LL.D., D.H.L., SC.D.  
*President*

CONSTANTINE B. SIMONIDES, A.B., M.B.A.  
*Assistant to the President*

ELIZABETH JANE WHITTAKER, A.B.  
*Administrative Assistant*

### Office of the Provost

JEROME BERT WIESNER, PH.D.  
*Provost*

WALTER ALTER ROSENBLITH, ING. RAD.  
*Associate Provost*

PAUL EDWARD GRAY, SC.D.  
*Associate Provost*

LOUIS MENAND, III, PH.D.  
*Assistant to the Provost*

LUCY NEDZEL, PH.D.  
*Special Assistant to the Provost*

KENNETH EDWARD SCHOMAN, JR., S.B.  
*Special Assistant to the Provost*

RICHARD PHILIP ADELSTEIN, S.B., M.A.T.  
*Special Assistant to the Provost*

### Institute Relations

BENSON ROWELL SNYDER, M.D.  
*Dean for Institute Relations*

### STUDENT AFFAIRS

JOHN DANIEL NYHART, A.B., LL.B.  
*Dean for Student Affairs*

WILLIAM SPEER, A.B.  
*Associate Dean for Student Counseling*

ROBERT JOHNSON HOLDEN, A.B., S.T.B.  
*Associate Dean for Student Affairs*

EMILY LIPPINCOTT WICK, PH.D.  
*Associate Dean for Student Affairs*

JAY CURTIS HAMMERNESS, S.B.  
*Assistant Dean for Student Affairs*

RICHARD ARTHUR SORENSON B.S.  
*Assistant Dean for Student Affairs*

HAROLD LOCKE HAZEN, SC.D.  
*Dean of the Graduate School, Emeritus;  
Foreign Study Adviser*

PETER BÜTTNER, S.B.  
*Assistant to the Dean for Student Affairs*

AMY JILL BLUE METCALFE, M.A.  
*Assistant to the Dean for Student Affairs*

JAMES JOSEPH BISHOP, B.S.  
*Assistant to the Dean for Student Affairs*

DOROTHY ELIZABETH BOWE  
*Assistant to the Dean for Student Affairs*

### FACULTY IN RESIDENCE

JOHN WITHERS IRVINE, JR., PH.D., SC.D.  
*Master of Ashdown House*

MEHMET NAFI TOKSÖZ, PH.D.  
*Master of Baker House*

PRESCOTT ARTHUR SMITH, S.B.  
*Master of Bexley Hall*

HERBERT HORACE WOODSON, SC.D.  
*Master of Burton-Conner*

ALVIN WILLIAM DRAKE, SC.D.  
*Master of East Campus*

KLAUS BIEMANN, PH.D.  
*Master of McCormick Hall*

RONALD ALAN WALTER, S.M.  
*Faculty Resident, Pandom Hall*

MURRAY EDEN, PH.D.  
*Master of Senior House*

### ATHLETIC DEPARTMENT

ROSS HAROLD SMITH, B.S., M.ED.  
*Professor of Physical Education;  
Director of Athletics; Head of the Department*

JOHN GALE BARRY, M.S.  
*Associate Professor of Physical Education;  
Assistant Director of Athletics;  
Varsity Basketball Coach*

CHARLES BATTERMAN, B.S., M.A.  
*Associate Professor of Physical Education;  
Varsity Swimming Coach*

WILFRED RAYMOND CHASSEY, M.S.  
*Associate Professor of Physical Education;  
Varsity Wrestling and Freshman Lacrosse Coach*

EDWARD ARTHUR CROCKER, B.S.  
*Associate Professor of Physical Education;  
Director of Physical Education;  
Varsity Squash and Varsity Tennis Coach*

ARTHUR EDWIN FARNHAM, JR., B.S.  
*Associate Professor of Physical Education;  
Head Track Coach*

PETER ANDERSON HOLLAND, M.A.  
*Assistant Professor of Physical Education;  
Head Rowing Coach*

GORDON VICTOR KELLY, B.S., M.ED.  
*Assistant Professor of Physical Education;  
Assistant Track Coach*

BENJAMIN ROBINSON MARTIN, JR., B.S.  
*Assistant Professor of Physical Education;  
Varsity Hockey and Varsity Lacrosse Coach*

FRANCIS CHARLES O'BRIEN, JR., M.ED.  
*Assistant Professor of Physical Education;  
Assistant Basketball and Varsity Baseball Coach*

SILVIO NAPOLEON VITALE, M.F.A.  
*Assistant Professor of Physical Education;  
Fencing Master and Coordinator of Women's Athletics*

## ADMINISTRATION

### Instructors

HAROLD BROWN, JR., B.S.  
*Associate Director of Sailing Program;  
Varsity Sailing Coach*

PETER MICHAEL CLOSE, B.A.  
*Sports Information Director*

JAMES ERNEST LESTER, B.S.  
*Physiotherapist and Trainer*

ROBERT F. LILLY, B.S.  
*Varsity Gymnastics Coach*

DAVID MICHAEL, B.S.  
*Physical Education Swimming Program Director;  
Supervisor of Intramurals*

WILLIAM STANLEY MORRISON, B.S., M.ED.  
*Varsity Ski and Varsity Soccer Coach*

JAY D. MOXLEY, B.A.  
*Freshman Swimming Coach*

R. KIRK RANDALL, M.S.  
*Freshman Tennis and Freshman Squash Coach*

GERALD MELVILLE REED, JR.  
*Sailing Master*

PAUL CARROLL WILSON

### Other Staff

THOMAS PATRICK McLENNAN  
*Pistol-Rifle Range Officer*

RODERICK R. ARTHUR  
*Business Manager; Assistant to the Director of Athletics*

### Academic Administration and Personnel

MALCOLM GORDON KISPERT, SC.D.  
*Vice President, Academic Administration*

### OFFICE OF ADMISSIONS

ROLAND BRADFORD GREELEY, M.C.P.  
*Director of Admissions*

EUGENE RANDOLPH CHAMBERLAIN, A.B.  
*Associate Director of Admissions;  
Adviser to Foreign Students*

MATTHEW BRYCE LEGGETT, A.B., S.M.  
*Associate Director of Admissions*

PETER HUGHES RICHARDSON, M.S.  
*Associate Director of Admissions*

ROBERT A. SCHUITEMAN, PH.D.  
*Associate Director of Admissions;  
Associate Adviser to Foreign Students*

PETER DUNCAN LEAVITT, A.B.  
*Associate Director of Admissions;  
Associate Adviser to Foreign Students*

WILLIAM JOHN HECHT, S.B.  
*Associate Director of Admissions;  
Director of the Educational Council*

JOHN ALLEN MIMS, B.S.  
*Assistant Director of Admissions*

JULIA CATHERINE McLELLAN  
*Assistant to the Director of Admissions*

JUANITA LOUISE STULLER, S.B.  
*Statistical Analyst*

### OFFICE OF STUDENT AID

JACK HENRY FRAILEY, AER.E.  
*Director of Student Aid*

EDWARD JOHN CAREY, JR., A.B.  
*Associate Director of Student Aid;  
Director of Student Employment*

LEONARD VINCENT GALLAGHER, S.B.  
*Associate Director of Student Aid*

JAMES SAMUEL JONES, A.M.  
*Associate Director of Student Aid*

DANIEL THOMAS LANGDALE, A.B.  
*Assistant Director of Student Aid*

### OFFICE OF THE REGISTRAR

WARREN DAVIS WELLS, S.B.  
*Registrar*

ROBERT HOWARD COOK, B.A.  
*Associate Registrar*

RONALD PAUL SMITH  
*Assistant Registrar*

MARJORIE ALBERTA BUTLER  
*Assistant to the Registrar*

BESSIE HOWLAND GROGGETT, A.B.  
*Recorder*

ELSA NABER, A.B.  
*Assistant to the Registrar*

### PLACEMENT OFFICE

ROBERT KAREL WEATHERALL, M.A.  
*Director of Placement*

EVELYN BARTLETT YATES, A.B.  
*Alumni Placement Officer*

BONNIE LINANE STOWELL, B.A.  
*Assistant to the Alumni Placement Officer*

### MEDICAL DEPARTMENT

ALBERT OTTO SEELER, M.D.  
*Professor of Medicine; Medical Director;  
Head of the Department*

SAMUEL DRURY CLARK, M.D. (Absent)  
*Associate Medical Director; Physician*

MELVIN HERBERT RODMAN, M.D.  
*Associate Medical Director; Physician*

HARRIET LOUISE HARDY, M.D.  
*Assistant Medical Director;  
in Charge of the Occupational Medical Service*

SAMUEL WOLF STEIN, M.D.  
*Assistant Medical Director; Physician*

JOHN VERNON PIKULA, M.D.  
*Surgeon in Chief*

MERTON JEROME KAHNE, M.D.  
*Professor of Social Psychiatry; Psychiatrist in Chief*

BENSON ROWELL SNYDER, M.D.  
*Professor of Psychiatry; Dean for Institute Relations*

FREDERICK GARFIELD WORDEN, M.D.  
*Professor of Psychiatry*

DOROTHY BROWN BROOKS, R.N., B.S.  
*Director of Nursing*

JACQUELINE ALICE BUCK, M.S.S.  
*Social Worker*

LEO DAVID CAPLICE, A.B.  
*Administrative Officer*

**Physicians**

MELVIN HOWARD CHALFEN, M.D.  
 GEORGE GOLDMAN, M.D.  
 ELMER ERNEST HINTON, M.D.  
 JOHN HOMANS, M.D.  
 HENRY WALTER JONES, JR. M.D.  
 DUDLEY MERRILL, M.D.  
 WALTER WARREN POINT, M.D.  
 WILLARD SAMUEL PUTNAM, M.D.  
 GORDON DUFOUR WINCHELL, M.D.

**Associate Physicians**

LEWIS EDWARD BRAVERMAN, M.D.  
 CHARLES SAMUEL KEEVIL, JR., M.D.  
 MELVIN JOEL KRANT, M.D.  
 JUNF WISE PRYOR, M.D.  
 ROBERT CARLYSLE STEWART, M.D.

**Assistant Physicians**

GARO HARUTUNE GARABEDIAN, M.D.  
 ARTHUR JOEL NEITERMAN, M.D.  
 GLORIA ANNA RUDISCH, M.D.  
 RUTH ANN JORDAN RUNYON, M.D.  
 DUNCAN PORTER THOMAS, M.D.

**Surgeons**

GEORGE TAYLOR BOTTOMLEY, M.D.  
 HENRY BROWN, M.D.  
 RALPH CLEMENT DARLING, M.D.  
 JULIUS ELI GOLDBLATT, M.D.  
 ISAAC O. MEHREZ, M.D.  
 JOHN LORING ROWBOTHAM, M.D.

**Associate Surgeons**

FREDERICK WILLIAM ACKROYD, M.D.  
 MENELAOS ANASTASIOS ALIAPPOULIS, M.D.  
 CARL JOSEPH CANZANELLI, M.D.  
 RENÉE BENNETT O'SULLIVAN, M.D.  
 ALAN ROBERT SPIEVACK, M.D.

**Assistant Surgeons**

HARRY AZADIAN, M.D.  
 DONALD ENGLUND BUTTERFIELD, M.D.  
 LAWRENCE THEODORE GEOGHEGAN, M.D.  
 WINSLOW WARREN CHILTON GREEN, M.D.

**Consultant in Surgery**

JOHN WINSLOW CHAMBERLAIN, M.D.

**Orthopedic Surgeons**

JAMES GAVIN MANSON, M.D.  
 ROBERT CHASE RUNYON, M.D.

**Psychiatrists**

JOSEPH HYMAN BRENNER, M.D.  
 THOMAS FRANCIS DWYER, M.D.  
 CAROLA B. EISENBERG, M.D.  
 PETER BORIE JENNEY, M.D.  
 ALFRED JAN KOUMANS, M.D.  
 DONALD PALMER, M.D.

**Associate Psychiatrists**

RICHARD EARL CUTLER, M.D.  
 ALBERT HILLEL FEINGOLD, M.D.  
 WADE ROCKWOOD, M.D.

HELEN DAVIDOFF WALLACH, M.D.  
 OLGA SPERANZA WERMER, M.D.

**Psychologist**

LORA HEIMS TESSMAN, PH.D.

**Research Sociologist**

CHARLOTTE GREEN SCHWARTZ, M.A.

**Consultant in Psychiatry**

LYDIA GIBSON DAWES, M.D.

**Director of Dental Service**

HAROLD ARTHUR CARNES, D.M.D.

**Dentists**

BURTON JORDAN GOVE, D.M.D.  
 GILMAN WARD HAVEN, D.D.S.  
 OWEN WILLIAM KITE, D.M.D.

**Neurologists**

ALBERT CHARLES ENGLAND, JR., M.D.  
 HOWARD DIXON MCINTYRE, JR., M.D.  
 DONALD HAROLD OSTERBERG, M.D.

**Dermatologist**

ROBERT FREDERICK TILLEY, M.D.

**Associate Dermatologists**

WILLIAM LYNCH CURWEN, M.D.  
 MILTON ELLIOT HELMAN, M.D.  
 MYRON HAROLD MATZ, M.D.  
 ELIZABETH COLE SPIVACK, M.D.

**Gynecologists**

CHARLES FLETCHER EADES, M.D.  
 LAWRENCE JOSEPH MALONE, M.D.

**Ophthalmologist**

JACOB RICE, M.D.

**Associate Ophthalmologists**

GEORGE ELIAS GHAREEB, M.D.  
 EDWARD FRANKLIN GOODMAN, M.D.  
 ROLAND EUGENE HOULE, M.D.  
 ALEXANDER LEVINE, M.D.  
 HARVEY JULIAN LEWIS, M.D.  
 MICHAEL SELIG WIEDMAN, M.D.

**Otolaryngologist**

JOHN CHRISTOS TRAKAS, M.D.

**Associate Otolaryngologist**

DONALD GEORGE KEAMY, M.D.

**Radiologists**

JOHN EVERETT GARY, M.D.  
 EARL DAVID NORDBERG, M.D.  
 RICHARD SCHATZKI, M.D.  
 STEFAN CONRAD SCHATZKI, M.D.

**Veterinarian**

RAYMOND RUSSO, D.V.M.

**Sanitary Engineer**

FRED EMERY SMITH, M.S.

**Consultant in Hospital Management**

JOHN STANLEY KOWAL, B.B.A., M.S.

## ADMINISTRATION

SAMUEL LEVIN, S.B.

*Radiation Protection Officer;  
Executive Officer for the Occupational Medical Service*

### **Associate Radiation Protection Officers**

RICHARD LAWRENCE LEHMAN, PH.D.

FRANCIS XAVIER MASSE, B.S.

### **Assistant Radiation Protection Officer**

EDWARD KARAIAAN, B.B.A.E.M.

### **Radiation Protection Chemist**

MURRAY MCKEE BOLTON, JR., B.S.

### **Radiation Protection Biochemist**

EDWIN DECKER FLACK, M.S.

### **Industrial Hygiene Officer**

RICHARD IRVING CHAMBERLIN, B.S.

### **Associate Industrial Hygiene Officer**

GEORGE WILLIAM BOYLEN, JR., B.S.

### **Industrial Hygiene Engineers**

JOSEPH EDWARD LEAHY, B.S.

STEPHEN KENNETH PICCOLO, B.B.A.

### **Consultant in Industrial Hygiene**

FREDERICK JAMES VILES, JR., S.M.

## PERSONNEL

ROBERT JONES DAVIS, B.S.

*Director of the Office of Personnel Relations*

ALBERT FLEETFORD SISE

*Associate Director of the Office of Personnel Relations*

JAMES JOSEPH FANDEL, B.A., M.S.

*Assistant Director of the Office of Personnel Relations*

DOROTHY ANNE BLAIR, A.B.

*Personnel Officer for Office Personnel*

JOHN ALEXANDER CARLEY, A.B.

*Personnel Officer for Training and Information*

HAROLD EMIL DREYER, PH.D., LL.D.

*Personnel Officer for Benefits*

RICHARD FRANCIS HUGHES, B.S., LL.B.

*Professional Personnel Officer*

KERRY BECKLES WILSON, A.B.

*Personnel Officer for Hourly Personnel*

ROBERT JAMES NELSON, B.S.

*Manager, Personnel Information Systems and Records*

VIRGINIA ANNE BISHOP, A.B.

*Personnel Representative*

SALLY BOYD HOWES, B.A.

*Personnel Representative*

SUSAN ALICE LESTER, B.A.

*Personnel Representative*

JOHN ARTHUR McDONNELL

*Personnel Representative*

PRISCILLA ESTELLE MEAD, B.A.

*Personnel Representative*

JOHN EDWARD NEWCOMB, JR.

*Personnel Representative*

MARGARET EMMA SCHMIDT, B.A.

*Personnel Representative*

RICHARD EDWARD HIGHAM, A.B.

*Special Assistant to the Director*

## OFFICE OF OPPORTUNITY DEVELOPMENT

JAMES COLLINS ALLISON, JR.

*Opportunity Development Officer*

JOSEPH FITZGERALD LYNCH

*Assistant Opportunity Development Officer*

## PUBLIC RELATIONS

FRANCIS ERNEST WYLIE, A.B.

*Director of Public Relations*

WILLIAM THORNTON STRUBLE, A.B.

*Director of Publications*

ROBERT MARTIN BYERS, B.A.

*Associate Director of Public Relations*

PAUL EDWARD JOHNSON, A.B., M.F.D.

*Associate Director of Public Relations;*

*Director of Campus Information Services*

WILLIAM KIRK STUCKEY, B.S.

*Associate Director of Public Relations*

JOHN GORDON NEIL RUSHBROOK, M.S.

*Assistant Director of Public Relations*

JOANNE S. MILLER

*Assistant to the Director of Public Relations*

JACQUELINE SHEPHARD CASEY, B.F.A.

*Graphic Designer, Office of Publications*

RALPH M. H. COBURN

*Graphic Designer, Office of Publications*

DIETMAR RAINER WINKLER, A.B.

*Graphic Designer, Office of Publications*

## Financial and Business Administration

### OFFICE OF THE TREASURER

JOSEPH JULIEN SNYDER, B.S., M.B.A.

*Vice President and Treasurer*

PAUL VINCENT CUSICK

*Comptroller*

FREDERIC WHITNEY WATRISS, S.B.

*Assistant Treasurer; Recording Secretary*

KIMBALL VALENTINE, JR., B.A., J.D.

*Assistant to the Treasurer*

ELIZABETH JANE GRIFFIN, B.A.

*Administrative Assistant*

WINIFRED THERESA McDONOUGH, B.A.

*Assistant Recording Secretary*

ANTONY HERREY, A.B., S.M.

*Institute Real Estate Officer*

SHEILA BROWN BEYER, B.S.B.A., ED.M.

*Assistant to the Institute Real Estate Officer*

JOHN D. O'CONNOR, B.S., B.A.

*Real Estate Accountant*

RALPH J. DEVIR, JR., B.S.

*Project Manager*

CHARLES D. O'NEAL, B.A.

*Project Manager*

LEIGH S. WOODWARD, B. ARCH.

*Project Manager*

PAUL VINCENT CUSICK

*Comptroller*

## DIVISION OF SPONSORED RESEARCH

STUART HAMMOND COWEN, S.B., M.B.A.  
*Administrative Director*

GEORGE HUTCHINSON DUMMER, S.B., LL.B.  
*Associate Director*

FRANK RAYMOND STEVENS, M.B.A.  
*Associate Director*

DAVID CHARLES DRISCOLL, J.D.  
*Assistant Director*

WILLIAM BRADFORD GOVE, B.S.  
*Assistant Director*

RICHARD CHANEST HODGSON, B.S.  
*Assistant Director*

FRANCIS HUGH McGRORY, LL.B.  
*Assistant Director*

PAUL HENRY QUINN  
*Assistant Director*

JOHN ADAM SEEGER, S.B.  
*Assistant Director*

CAROL ELLEN VANAKEN, S.B.  
*Assistant Director*

JOHN WILLIAM VITT, JR.  
*Assistant Director*

ROGER PEARSON WEBBER, B.B.A.  
*Assistant Director*

ALFRED PEET ROGERS, A.B., M.B.A.  
*Property Officer*

WENDELL ALDEN DERRY  
*Assistant Property Officer*

DAVID JOSEPH HARRIGAN, B.S., LL.B.  
*Assistant to the Director*

MICHAEL THOMAS LEONARD, M.B.A.  
*Assistant to the Director*

LAWRENCE EDWARD MAGUIRE, B.A.  
*Assistant to the Director*

DOUGLAS GENE MILLER  
*Assistant to the Director*

THOMAS JOSEPH CRANE, PH.B., M.B.A.  
*Fiscal Officer*

ROBERT MICHAEL DANKESE, B.S.  
*Assistant Fiscal Officer*

ROBERTA FRANCES BURNS  
*Assistant Fiscal Officer*

EDWIN FORREST BUTTERS, B.S.  
*Assistant to the Fiscal Officer*

**ACCOUNTING OFFICE**

JOHN ALBERT LITTLE, A.B., M.C.S.  
*Associate Comptroller*

PHILIP JOHN KEOHAN, B.S., M.B.A.  
*Assistant Comptroller*

WILLIAM EDWIN KELLEY, M.B.A.  
*Assistant Comptroller*

JOSEPH MARTIN PATTEN, A.B.  
*Assistant to the Comptroller*

JAMES LEWIS MACLARY  
*Accounting Officer for Budgets*

ROBERT WILLIAM McQUILLAN  
*Accounting Officer for Benefits*

ROBERT ERNEST LEE, S.B.  
*Accounting Officer for Investments*

DAVID SHERMAN COHEN, B.S., M.B.A.  
*Investment Accountant*

CARL TOWNE CAREY, JR.  
*Bursar*

JOHN ROBERT ROGERS, B.B.A.  
*Assistant Bursar*

RUTH LILLIAN DAWSON  
*Assistant Bursar*

WILLIAM JOSEPH DUGGAN, B.S.E.A.  
*Manager of Data Processing*

STANLEY MILLER, B.S., M.B.A.  
*Manager for Systems Programming*

ROBERT NOEL CLARK, B.S.  
*Manager for Computer Operations*

PETER GEORGE BRONCHUK, B.S., B.A.  
*Assistant Manager for Computer Operations*

RICHARD EARLE YAPLE  
*Assistant Manager for Systems Programming*

WILLIAM JOSEPH FITZGERALD  
*Systems Analyst*

EDWARD THOMAS HESTER, B.S.  
*Systems Analyst*

DONALD EVERETT STONE, B.A.  
*Systems Analyst*

ROBERT ULRICH CYR  
*Staff Programmer*

SALLY ANGELA DECICCO, B.A.  
*Staff Programmer*

PAULINE SHENG SHIH, B.A., M.S.  
*Staff Programmer*

THADDEUS WALTER KOWILCIK  
*Accounting Officer for Contracts*

JOHN JOSEPH HYNES, B.S.  
*Accounting Officer for Grants*

JOSEPH ROBERT CULLINAN  
*Accounting Officer for Payrolls*

JOHN COLEMAN SEARS  
*Accounting Officer*

PAULINE JEANNE BOULARD  
*Staff Accountant*

JAMES BARRY ENOS  
*Staff Accountant*

DAVID HUSTON HENSHAW, B.S.  
*Staff Accountant*

JOHN STEPHEN LAVALLE, B.S.  
*Staff Accountant*

OLIVE HELEN LIBITZ  
*Staff Accountant*

ROBERT JOSEPH LONG  
*Staff Accountant*

RICHARD ALDEN MAY, B.B.A.  
*Staff Accountant*

ROBERT ARTHUR OLINTO, B.S.A.  
*Staff Accountant*

JOHN DAVID O'SULLIVAN, B.S.  
*Staff Accountant*

PAUL CHESTER POWELL, B.S.  
*Staff Accountant*

**ADMINISTRATION**

GEORGE FRANCIS PRENDERGAST, B.S.  
*Staff Accountant*

OWEN THOMAS SWEENEY, B.S.  
*Staff Accountant*

GARY BAINBRIDGE WALKER, B.S.B.A.  
*Staff Accountant*

**AUDIT DIVISION**

EDWARD LAURENCE McCORMACK, B.S., M.B.A.  
*Auditor*

RAYMOND SYLVESTER O'CONNOR, M.B.A.  
*Associate Auditor*

ROBERT R. BABB, JR., M.B.A.  
*Assistant Auditor*

GRANT A. EMRICK, B.B.A.  
*Assistant Auditor*

KENNETH FRANCIS LEVIE  
*Assistant Auditor*

JOHN JOSEPH SILVASY, B.S.B.A.  
*Assistant Auditor*

EDWARD GREGORY MARCATO, B.B.A.  
*Assistant to the Auditor*

RICHARD VINCENT McDEVITT, B.S.  
*Assistant to the Auditor*

MICHAEL G. PETRUZZIELLO, B.S.  
*Assistant to the Auditor*

**FISCAL PLANNING OFFICE**

STUART HAMMOND COWEN, S.B., M.B.A.  
*Director of Fiscal Planning*

**INSTRUMENTATION LABORATORY FISCAL OFFICE**

JOHN PHILIP LEONARD, B.S.B.A.  
*Manager*

RAYMOND HENRY GAGNON, M.S.  
*Assistant Manager*

JOHN LUCIEN MATARESE, B.S.  
*Staff Accountant*

ROBERT MICHAEL SULLIVAN, B.S.  
*Staff Accountant*

**LINCOLN LABORATORY FISCAL OFFICE**

ROBERT VINCENT DODD, B.B.A.  
*Manager*

MITCHELL ANTHONY KLOZA  
*Accounting Supervisor*

THOMAS SAXON, JR.  
*Disbursing Supervisor*

BRUCE KENYON WILLARD, B.S.  
*Subcontract Administrator*

**PURCHASING**

GEORGE EDWARD NEALAND, S.B.  
*Director of Purchasing*

ARTHUR BERNARD WHITE  
*Manager of the Office of Laboratory Supplies*

GLENN THOMAS CURTIS  
*Buyer*

ROBERT EARLE DURLAND  
*Buyer*

GERALD ALASTAIR GREENHOW  
*Buyer*

ARTHUR HIRAM LITCHFIELD  
*Buyer*

HENRY JOSEPH PRITCHARD, JR., B.S.  
*Buyer*

STANLEY NORMAN ROACH, B.B.A.  
*Buyer*

DANTI JOSEPH SCARPONI  
*Buyer*

**Operations**

PHILIP ARNOLD STODDARD, S.B.  
*Vice President, Operations*

JOHN ALAN CURRIE, S.M.  
*Assistant to the Vice President, Operations*

**PHYSICAL PLANT**

CARL MAGNUS FRITHIOF PETERSON, S.M.  
*Director of the Physical Plant*

DONALD WHISTON, S.B.  
*Associate Director of the Physical Plant*

WILLIAM ROBERT DICKSON, S.B.  
*Assistant Director of the Physical Plant*

JEROME HAZELTON BARRAFORD, B.S.  
*General Superintendent of Power and Utilities*

PAUL FRANK BARRETT, B.S.  
*Construction Manager*

MORTON BERLAN, B.A., M.B.A.  
*Communications Officer*

JAMES FRANCIS BRADY  
*Administrative Services Officer*

RICHARD EUGENE COLLINS  
*Technical Assistant*

WILLIAM HOBART COMBS, S.B.  
*Superintendent of Building Maintenance*

MILES PAYNE COWEN  
*Superintendent of Building Services*

THEODORE MULFORD DOAN, JR.  
*Assistant Superintendent of Building Services*

ALFRED EDWARD ENNIS  
*Senior Manager of the Auditorium and Student Center*

EARL MINERS HARVEY, M. ARCH.  
*Staff Architect*

CHARLES ROSS JOHNSON, B.S.  
*Project Engineer*

MICHAEL JOHN KARAFFA, B.ARCH.  
*Project Engineer*

HENRY JOSEPH LEONARD  
*Personnel Officer*

RICHARD FREEMAN McKAY, S.B.  
*Mechanical Engineer*

HOWARD FRANCIS MILLER, B.A., M.S.  
*Design Coordinator — Construction*

AGNES NIVEN MORRICE  
*Administrative Assistant*

HORACE STANLEY PALMER, S.B.  
*Superintendent of Mechanical Services*

GEORGE NIKOLA PETIEVICH, B.S., M.B.A.  
*Administrative Officer*

JOSEPH MARIO SALVATORE  
*Design Coordinator — Design Services*

KENNETH GEORGE SCHULT, B.S.  
*Superintendent of Grounds*  
 ROBERT FAY SCOFIELD  
*Construction Coordinator*  
 THOMAS ELWELL SHEPHERD, JR., B.S.  
*Staff Engineer — Electrical*  
 GEORGE EDWARD WEST, JR., B.S.  
*Assistant to the Superintendent of Mechanical Services*

**SAFETY**

MARK JOHN DONDERO, B.S.  
*Safety Engineer*  
 RAYMOND MICHAEL DIFFLEY, B.S.  
*Assistant Safety Engineer*  
 JOHN MICHAEL FRESINA, B.S.  
*Assistant Safety Engineer*  
 JOSEPH FRANCIS KUCHTA, B.S.  
*Assistant Safety Engineer*

**HOUSING AND DINING**

LAURENCE HERBERT BISHOFF, S.B.  
*Director of Housing and Dining Services*  
 DANIEL GRAHAM WEBSTER  
*Manager of Campus Housing*  
 KENNETH CRAIG BROWNING, S.M.  
*Assistant to the Director of Housing and Dining Services*  
 JAMES EDWARD GROSS  
*Administrative Assistant*  
 SALVATORE LAURICELLA  
*Manager, Student Center Dining Service*  
 ROBERT JAMES RADOCCCHIA  
*Manager, Walker Memorial Dining Service*  
 ROBERT EDGAR SHAW  
*Administrative Assistant*

**GRAPHIC ARTS**

FRANK HERBERT CONANT  
*Director of the Graphic Arts Service*  
 JEROME HARRY ADLER  
*Manager of the Audio-Visual Service*  
 JAMES WILLIAM COLEMAN  
*Production Manager*  
 VERNON ALBERT RAINE  
*Financial Manager*  
 EDWARD NORRIS WEST  
*Graphic Arts Representative*

**CAMPUS PATROL**

NORMAN STEPHEN SIDNEY  
*Chief*  
 JAMES OLIVIERI  
*Captain*

**ENDICOTT HOUSE**

AIMEE PIERSON, B.A.  
*Manager*

**Special Laboratories**

JACK PHILIP RUINA, D.E.E.  
*Vice President for Special Laboratories*  
 MILTON URE CLAUSER, PH.D.  
*Director, Lincoln Laboratory*

GERALD PAUL DINNEEN, PH.D.  
*Associate Director, Lincoln Laboratory*  
 CHARLES STARK DRAPER, SC.D.  
*Director, Instrumentation Laboratory*  
 JOSEPH FRANCIS O'CONNOR, A.B.  
*Administrative Assistant to the Vice President for Special Laboratories*

**Special Projects**

KENNETH ROBERT WADLEIGH, SC.D.  
*Vice President*  
 ALICE MARIE SEELINGER, S.B.  
*Administrative Assistant*

**Organization Systems**

JOHN MACDONALD WYNNE, A.B., S.M.  
*Vice President, Organization Systems*

**OFFICE OF ADMINISTRATIVE SYSTEMS**

DEAN LOUIS JACOBY, S.B.  
*Director*  
 JAMES AUGUSTINE CARRIG, B.S.  
*Assistant Director, Project Coordination*  
 JAMES LONDON LINDERMAN, S.M.  
*Assistant Director, Programming and Systems Development*  
 DAVID MICHAEL CARNEY  
*Manager, Computer Operations*  
 JOSEPH FRANCIS CONNOLLY  
*Project Coordinator*  
 FREDERICK PETER FINNERAN  
*Systems Analyst*  
 VINCENT LAWRENCE FOXWORTHY  
*Systems Programmer*  
 MARY MOORE FUREY, A.B.  
*Systems Analyst*  
 BERNARD WILLIAM GLEASON, JR., B.S.  
*Systems Analyst*  
 RUTH SELMA GOODWIN, A.B.  
*Administrative Assistant*  
 MIN-YI LIANG, B.A.  
*Documentation Analyst*  
 ROBERT FREDERICK MATSON, A.B.  
*Systems Analyst*  
 JAMES HENRY SUSSBAUER  
*Programmer*

**ANALYTICAL STUDIES GROUP**

PAUL WEST COOK, JR., PH.D.  
*Director*  
 DANIEL FREDRICK CREASEY, B.S., M.B.A.  
*Associate*  
 ROBERT HUGH SCOTT, S.B.  
*Associate*  
 PAUL VICTOR TEPLITZ, D.B.A.  
*Associate*  
 WAYNE ANDREW STUART, S.B., M.B.A.  
*Assistant for Studies of Undergraduate Education*

## ADMINISTRATION

### PLANNING OFFICE

OVADIA ROBERT SIMHA, B.A., M.C.P.  
*Planning Officer*

HARRY PHILLIP PORTNOY, B.ARCH.  
*Senior Architect*

ROBERT BERNARD CAVANAUGH, B.A.  
*Assistant Planning Officer*

GEORGE NOEL KURILKO, PH.D.  
*Assistant Planning Officer*

KREON LOUIS CYROS, S.M.  
*Project Director*

RICHARD J. CALOGGERO  
*Project Administrator*

LALITA DAS, B.ARCH.  
*Architect-Programmer*

PAUL H. DUDEK, M.ARCH.  
*Architect-Planner*

JOHN ALBERT LANGELL, S.B.  
*Project Programmer*

PAUL STEVENSON OLES, JR., M.ARCH.  
*Architect-Programmer*

PETER EDWARD SORANT, S.B.  
*Planning Assistant*

### Secretary

VINCENT ANTHONY FULMER, A.B., S.M.  
*Vice President and Secretary of the Institute*

DOW HUGH DARDEN, LL.B., A.M.  
*Institute Estate Secretary*

DAVID JEROME TOBIN, S.M.  
*Institute Secretary for Charitable Trusts*

CHARLES WARREN SMALZEL, S.M.  
*Institute Secretary for Corporations*

PAUL HOWARD BURR, S.B.  
*Institute Secretary for Foundations*

ARNOLD HERBERT SINGAL, A.B., LL.B., S.M.  
*Staff Associate to the Institute Estate Secretary*

### INDUSTRIAL LIAISON OFFICE

JACK WARNER CHRISTENSEN, S.B.  
*Director*

J. PETER BARTL, S.B., B.A.  
*Industrial Liaison Officer*

LESLIE MILTON BORING, JR., S.M.  
*Industrial Liaison Officer*

PETER CRAIG FARRELL, S.M.  
*Industrial Liaison Officer*

HARRY CRANE MOSER, S.M.  
*Industrial Liaison Officer*

CARL HERBERT NEU, JR., S.B., M.B.A.  
*Industrial Liaison Officer*

RONALD STEWART STONE, S.M.  
*Industrial Liaison Officer*

GEORGE WILLIAM ULLRICH, S.M.  
*Industrial Liaison Officer*

### M.I.T. ASSOCIATES

DAVID HADDON ROBBINS, S.M.  
*Director*

### REGISTRY OF GUESTS

CAROLYN BRADBURY COX  
*Director*

### DEVELOPMENT OFFICE

NELSON COOPER LEES, S.B., M.A.  
*Director*

JAMES WILLIAM LAMBERT, A.B.  
*Assistant Director*

### Other Administrative Departments and Offices

#### RESIDENT STAFF OF THE ALUMNI ASSOCIATION

DONALD PORTER SEVERANCE, S.M.  
*Executive Vice President and Treasurer*

FREDERICK GLIESSMANN LEHMANN, S.B.  
*Secretary*

GARNET PETER GRANT, JR., S.B.  
*Director for Clubs*

JOHN SIMON PFEIL, JR., A.B.  
*Business Manager*

PANAYIOTIS DIMITRIOS SPILIAKOS, S.B.  
*Assistant Secretary*

JOHN ISHAM MATTILL, M.A.  
*Editor of "Technology Review"*

FRED WHEELER, B.S.C.  
*Managing Editor of "Technology Review"*

RICHARD FRANKLIN WRIGHT  
*Advertising Manager of "Technology Review"*

KENNETH SUMNER BROCK, S.B.  
*Director of the Alumni Fund*

ROBERT HAGOPIAN  
*Associate Director of the Alumni Fund*

JACQUELYN MACLEAN FINDLAY, S.B.  
*Assistant to the Director of the Alumni Fund*

JAMES NORVAL PHINNEY, B.A.  
*Executive Secretary of the M.I.T. Alumni Center of New York*

### LIBRARIES

WILLIAM NASH LOCKE, PH.D.  
*Director of Libraries*

NATALIE NEILL NICHOLSON, S.B.  
*Associate Director of Libraries*

MYER MICHAEL KESSLER, PH.D.  
*Associate Director of Libraries*

JOSEPH MARTOCCI DAGNESE, M.A., M.S.L.S.  
*Assistant Director for Technical Services*

EDWARD NEAL HARTLEY, A.M.  
*Institute Archivist*

ELEANOR LOUISE BARTLETT  
*Archives Librarian*

EVA MARKOVITS BONIS, M.S.L.S.  
*Assistant Science Librarian*

KARL SEIBERT BYNOE, A.B., M.L.S.  
*Humanities Librarian; Head, Extramural Services*

LAURA MARGARET CARCHIA, B.S., M.S.L.S.  
*Industrial Relations Librarian*

CHING-CHIH CHEN, B.A., A.M.L.S.  
*Associate Science Librarian*

JACQUELINE ZELDIN COLBY, B.S.  
*Assistant Head, Catalog Department*

- ZELDA WAEFE COLODNER, A.B., M.S.L.S.  
*Cataloger*
- ELIZABETH GOODRIDGE FLEMINGS, B.A., M.S.L.S.  
*Assistant Science Librarian*
- MARY REAY HOWIE FREVE (*Absent*)  
*Rotch Librarian*
- ROBERT LEWIS HADLOCK, A.B., M.L.S.  
*Head, Acquisitions Department*
- FRANCES ELAINE HASLETT, B.S., M.S.L.S.  
*Student Center Librarian*
- JESSIE ELIZABETH HOWES, A.B., S.B.  
*Cataloger*
- IRMA YARBROUGH JOHNSON, B.S., M.A. (*Absent*)  
*Science Librarian*
- BARBARA JONES, A.B., M.S.L.S.  
*Cataloger*
- FREDERICK SCHEETZ JONES, II, A.B., M.S.L.S.  
*Head, Administrative Services*
- FLORENCE VIRGINIA KELL, B.A., M.L.S.  
*Assistant Rotch Librarian*
- EILEEN RUTH KIBRICK, B.S., A.M., M.S.L.S.  
*Cataloger*
- BARBARA KLINGENHAGEN, A.B.  
*Dewey Librarian*
- KAREN KUGELL, B.S., M.S.L.S.  
*Exchange and Gifts Librarian*
- JOSE BETTY LEONE, B.A., M.S.L.S.  
*Cataloger*
- MURIEL JOSEPHINE LEWIS, A.B., S.B.  
*Cataloger*
- ALEKSANDER LEYFELL, M.A.  
*Social Science Literature Specialist*
- MAUREEN JULIA MALONE, A.B., M.L.S.  
*Assistant Humanities Librarian*
- SYLVIA ANN McDOWELL, M.S.L.S.  
*Head, Serials and Journals Section, Catalog Department*
- ARTHUREE ROSEMILLE McLAUGHLIN, A.B., M.L.S.  
*Assistant Science Librarian*
- RALPH REGINALD McNAY, B.E., A.B.  
*Librarian*
- JUDITH WHITMEN MOORE, B.A., M.L.S.  
*Assistant Humanities Librarian*
- SUANNE WILSON MUEHLNER, M.S.L.S.  
*Acting Lindgren Librarian*
- FRANCES LUBOVITZ NEEDLEMAN, B.A., M.S.  
*Head, Catalog Department*
- LIGIJA ILSE NEIBERGS  
*Cataloger*
- MARGARET AMELIA OTTO, B.A., M.S.  
*Acting Science Librarian*
- PATRICIA BRADDELL PIER, B.S., B.L.S.  
*Acting Rotch Librarian*
- WILLIAM PRESSON, A.B.  
*Associate Dewey Librarian*
- CLAIRE H. PULVER, A.B., M.S.  
*Assistant Humanities Librarian*
- JUDITH ELLEN RAY, B.A., M.L.S.  
*Assistant Dewey Librarian*
- KIRSTI ELIZABETH SCHNEIDER, B.A., M.L.S.  
*Circulation Librarian*
- PETER ROBERT SCOTT  
*Head, Microreproduction Laboratory*
- ASTRID HELEN STEELE, B.A., M.S.L.S.  
*Associate Science Librarian and Mathematics Librarian*
- FRANCES BURNET BARNES SUMNER, A.B., M.L.S.  
*Associate Humanities Librarian*
- CRAIG LEE THIERSCH, B.S.  
*Cataloger*
- SIBYL ELEANOR WARREN, S.B.  
*Cataloger*
- Engineering Library-Experimental Operations\***
- CARL F. J. OVERHAGE, PH.D.  
*Director*
- MARJORIE WALLACE CHRYSSOTOMIDIS, M.L.S.  
*Reference Librarian*
- BARBARA CLARK DARLING, A.B.  
*Aeronautics and Astronautics Librarian*
- JEFFREY JOHN GARDNER, A.B., M.S.  
*Circulation and Stack Control Librarian*
- JAMES MATTHEW KYED, M.L.S.  
*Associate Engineering Librarian*
- HELEN MAGEDSON, M.L.S.  
*Engineering Reference Librarian*
- SUSAN KEENE NUTTER, M.L.S.  
*Processing Librarian*
- MARY ELIZABETH PENNYL, M.L.S.  
*Librarian, Materials Center Reading Room*
- REBECCA LOUISE TAGGART, M.A.  
*Head, Engineering Libraries*
- DAVID CLARENCE VAN HOY, M.S.L.S.  
*Cataloger*
- LOWELL INSTITUTE SCHOOL**
- FRANKLIN LEROY FOSTER, SC.D.  
*Director*
- M.I.T. PRESS**
- CARROLL GAWAYNE BOWEN, B.A.  
*Director*
- CONSTANCE DORAINÉ BOYD, A.M.  
*Assistant to the Director*
- HAROLD FINE CHEVALIER, A.B.  
*Production Director*
- MICHAEL JOSEPH CONNOLLY, B.A.  
*Editor-in-Chief*
- MURIEL COOPER, B.S. IN ED., B.F.A.  
*Design Director*
- RUTH WELLS GILLIES, B.A.  
*Executive Editor*
- EDWARD HAAS, B.A., LL.B.  
*Financial Director*
- REBECCA M. MCGOVERN, B.S.  
*Sales and Promotion Manager*
- JOSEPH STEIN  
*Senior Manuscript Editor*

\* Project Intrex (Information Transfer Experiments)

ADMINISTRATION

OTHER ADMINISTRATION

LORETTA HELEN MANNIX, B.S., M.A.  
*Administrative Assistant*

ADMINISTRATIVE OFFICERS, EMERITI

GEORGE W. MORSE, M.D.  
*Professor, Emeritus; Medical Director, Emeritus*

ROBERT GRANVILLE CALDWELL, PH.D., D.LITT.  
*Dean of Humanities, Emeritus*

HORACE SAYFORD FORD, LL.D.  
*Treasurer, Emeritus*

JOSEPH CHRISMAN MACKINNON, S.B.  
*Registrar, Emeritus*

JOHN JAMES ROWLANDS  
*Director of the News Service, Emeritus*

HELEN ELIZABETH MACKINNON  
*Assistant to the Registrar, Emerita*

BRAINERD ALDEN THRESHER, S.B., A.M.  
*Professor, Emeritus; Director of Admissions, Emeritus*

ERNEST HAMLIN HUNTRESS, PH.D.  
*Professor, Emeritus;*

*Secretary of the Graduate School, Emeritus*

THOMAS PALM PITRÉ, B.A.  
*Director of Student Aid, Emeritus;*

*Associate Dean of Student Affairs, Emeritus*

JOHN ELY BURCHARD, L.H.D., D.ARCH.  
*Dean of the School of Humanities and Social Science, Emeritus*

GEORGE RUSSELL HARRISON, PH.D., D.SC., LL.D.,  
D.ENG.  
*Dean of the School of Science, Emeritus*

MARY CATHERINE HURLEY  
*Schedules Assistant, Emerita*

PIETRO BELLUSCHI, DOTT.ING., LL.D., SC.D., D.F.A.  
*Dean of the School of Architecture and Planning, Emeritus*

WOLCOTT ANDERS HOKANSON  
*Bursar, Emeritus*

PAUL MAYNARD CHALMERS, A.M.  
*Associate Director of Admissions, Emeritus*

CLAIRE PERHAM EDWARDSON  
*Administrative Assistant, Emerita, Office of the President*

HENRY BUGBEE KANE, S.B.  
*Director of the Alumni Fund, Emeritus*

JULIUS ADAMS STRATTON, SC.D., D.ENG., LL.D.,  
L.H.D.  
*President, Emeritus*

FREDERICK GARDINER FASSETT, JR., M.A.  
*Dean of Residence, Emeritus*

HAROLD LOCKE HAZEN, SC.D.  
*Dean of the Graduate School, Emeritus*

FRANKLIN LEROY FOSTER, SC.D.  
*Director of the Division of Sponsored Research, Emeritus*

**Libraries**

CECILE BARSKY, S.B. *Emerita*

MARGUERITE CHAMBERLAIN, A.B., S.B. *Emerita*

MARGARET MORRIS DE LEVIN, S.B., M.A. *Emerita*

RUTH MCGLASHAN LANE, B.A., S.B., ED.M. *Emerita*

GERTRUDE PERRY *Emerita*

MIRIAN SPRAGUE SMITH, S.B. *Emerita*

LOUISE TRAINOR *Emerita*

HILDEGARDE ZIEGLER, A.B., S.B. *Emerita*

## OFFICERS AND STANDING COMMITTEES OF THE FACULTY

HOWARD WESLEY JOHNSON, LL.D., D.H.L., SC.D.      EDWARD NEAL HARTLEY, A.M.  
*President*      *Secretary of the Faculty*  
WILLIAM TED MARTIN, PH.D.      PRESCOTT ARTHUR SMITH, S.B.  
*Chairman of the Faculty*      *Assistant Secretary of the Faculty*  
JEROME BERT WIESNER, PH.D.  
*Provost*

### UNDERGRADUATE PLANNING PROFESSOR

EDGAR H. SCHEIN

### MEMBERS OF THE FACULTY EX OFFICIO

(See page 379 for members of the Academic and Faculty Councils)

PETER P. GIL	<i>Associate Dean for Executive Programs, Alfred P. Sloan School of Management</i>	MYER M. KESSLER	<i>Associate Director of Libraries</i>
JACK H. FRAILEY	<i>Director of Student Aid</i>	NATALIE N. NICHOLSON	<i>Associate Director of Libraries</i>
WILLIAM SPEER	<i>Associate Dean for Student Counseling</i>	ROBERT H. COOK	<i>Associate Registrar</i>
ROBERT J. HOLDEN	<i>Associate Dean for Student Affairs</i>	LEONARD V. GALLAGHER	<i>Associate Director of Student Aid</i>
EUGENE R. CHAMBERLAIN	<i>Associate Director of Admissions</i>	J. SAMUEL JONES	<i>Associate Director of Student Aid</i>
M. BRYCE LEGGETT	<i>Associate Director of Admissions</i>	ROBERT K. WEATHERALL	<i>Assistant Dean of the Graduate School; Director of Placement</i>
PETER H. RICHARDSON	<i>Associate Director of Admissions</i>	JAY C. HAMMERNESS	<i>Assistant Dean for Student Affairs</i>
ROBERT A. SCHUITEMAN	<i>Associate Director of Admissions</i>	RICHARD A. SORENSON	<i>Assistant Dean for Student Affairs</i>
WILLIAM J. HECHT	<i>Associate Director of Admissions; Director of the Educational Council</i>	MICHAEL S. BARAM	<i>Executive Officer of the Graduate School</i>

### STANDING COMMITTEES OF THE FACULTY 1969-70<sup>1</sup>

#### Academic Performance

CAMPBELL L. SEARLE      1971  
*(Chairman)*  
DEAN FOR STUDENT AFFAIRS\*  
REGISTRAR\*  
MEDICAL DIRECTOR\*  
DIRECTOR OF STUDENT AID\*  
CHAIRMAN OF THE FRESHMAN  
ADVISORY COUNCIL\*  
MERTON C. FLEMINGS      1970  
D. QUINN MILLS      1970  
WILLIAM R. MOORE      1971  
ERNEST G. CRAVALHO      1972  
W. GILBERT STRANG      1972  
FREDERICK J. MC GARRY †  
PRESCOTT A. SMITH  
*(Executive Officer)*

#### Curricula

EDWARD B. ROBERTS      1971  
*(Chairman)*  
ASSOCIATE PROVOST\*  
REGISTRAR\*  
CHAIRMAN OF THE FRESHMAN  
ADVISORY COUNCIL\*  
UNDERGRADUATE PLANNING  
PROFESSOR\*  
THEODORE R. MADDEN      1970

HARVEY M. SAPOLSKY      1970  
LISA A. STEINER      1970  
RICHARD L. DE NEUFVILLE      1972  
PETER ELIAS      1972  
KENT F. HANSEN †

#### Discipline

ROY LAMSON *(Chairman)*      1971  
DEAN FOR STUDENT AFFAIRS\*  
LOUIS S. OSBORNE      1970  
DAVID J. SELLMYER      1970  
ABRAHAM J. SIEGEL      1970  
ELIAS P. GYFTOPOULOS      1972  
THOMAS B. SHERIDAN      1972  
ROY KAPLOW †

#### Educational Policy

WILLIAM T. MARTIN\*      (no term)  
*(Chairman)*  
PROVOST\*  
ASSOCIATE PROVOST\*  
UNDERGRADUATE PLANNING  
PROFESSOR\*  
RICHARD L. CARTWRIGHT      1970  
RICHARD M. HELD      1970  
VERNON M. INGRAM      1970  
ROY KAPLOW      1970  
FREDERICK J. MC GARRY      1970

FRANCO MODIGLIANI      1970  
FRANKLIN M. FISHER      1971  
FREDERICK W. FREY      1971  
ROBERT G. GALLAGHER      1971  
LEON B. GROISSER      1971  
KENT F. HANSEN      1971  
MARCUS KAREL      1971

#### Graduate School Policy

DEAN OF THE GRADUATE  
SCHOOL\*  
*(Chairman)*  
ASSOCIATE DEAN OF THE  
GRADUATE SCHOOL\*  
*(Secretary)*  
EXECUTIVE OFFICER OF THE  
GRADUATE SCHOOL\*  
DIRECTOR OF ADMISSIONS\*  
CHAIRMAN OF THE FACULTY\*  
JAMES M. AUSTIN  
JUDSON R. BARON  
GLENN A. BERCHTOLD  
RICHARD L. CARTWRIGHT  
PHILIP L. DE BRUYN  
PETER S. EAGLESON  
RICHARD S. ECKAUS  
J. HARVEY EVANS  
AARON FLEISCHER

<sup>1</sup> The dates to the right indicate the years in which the terms of appointment expire.

† Appointed from the Committee on Educational Policy

\* *Ex officio*

‡ Presidential appointment

COMMITTEES

KENNETH L. HALE  
 FRANCIS B. HILDEBRAND  
 GEORGE F. KOSTER  
 SALVADOR E. LURIA  
 PAUL W. MAC AVOY  
 THEODORE R. MADDEN  
 JOHN R. MYER  
 LUCIAN W. PYE  
 NORMAN C. RASMUSSEN  
 WHITMAN A. RICHARDS  
 WARREN M. ROHSENOW  
 CAMPBELL L. SEARLE  
 GLENN C. WILLIAMS  
 GERALD N. WOGAN

**Industrial Liaison**

EDWARD A. MASON  
 (Chairman) 1970  
 THEODORE H. PIAN 1970  
 DWIGHT M. B. BAUMANN 1971  
 HERBERT H. WOODSON 1971  
 DONALD C. CARROLL 1972  
 NICHOLAS P. NEGROPONTE 1972

**Libraries**

*Executive Board:*

CHARLES KINGSLEY, JR.  
 (Chairman) 1970  
 DIRECTOR OF LIBRARIES\*  
 ASSOCIATE DIRECTOR OF  
 LIBRARIES\*  
 GENE MONTE BROWN † 1971  
 MYRON WEINER 1971  
 BRUCE MAZLISH 1972  
 C. GARDNER SWAIN 1973

*Advisory Board:*

MICHAEL B. BEVER  
 WILLIAM F. BOTTIGLIA  
 HERBERT S. BRIDGE

FRANKLYN M. CLIKEMAN  
 ALBERT G. DIETZ  
 EVSEY D. DOMAR  
 LAWRENCE B. EVANS  
 ROBERT M. FOGELSON  
 EUGENE GOODHEART  
 RAYMOND H. GRENIER  
 SIGURDUR HELGASON  
 DANIEL M. HOLLAND  
 NORMAN JONES  
 ROBERT D. LOGCHER  
 HAROLD O. MC EACHERN  
 NORMAN A. PHILLIPS  
 WILLIAM H. PINSON, JR.  
 LELAND E. PRENTICE  
 RONALD F. PROBSTEN  
 HAROLD Y. WACHMAN  
 WAYNE A. WICKELGREN  
 GEORGE WOLF

**Nominations †**

HARTLEY ROGERS, JR.  
 (Chairman) 1970  
 JAY W. FORRESTER 1970  
 ARTHUR T. IPPEN 1970  
 EUGENE BELL 1971  
 CHARLES P. KINDLEBERGER 1971  
 ROBERT L. HALFMAN 1972

**Outside Professional Activities**

THOMAS M. HILL (Chairman) 1972  
 PETER T. DEMOS 1970  
 J. FRANCIS REINTJES 1971  
 WARREN M. ROHSENOW 1971  
 ROBLEY D. EVANS 1972

**Staff — Administration**

*Staff:*  
 JAMES A. FAY (Chairman) 1970  
 LAWRENCE J. CORWIN 1970

J. EDWARD VIVIAN 1970  
 DAVID N. NESS 1971  
 MICHAEL J. PIORE 1971  
 J. HARVEY EVANS 1972  
 ROBERT J. KOLENKOW 1972

*Administration: †*

ROBERT A. ALBERTY  
 RAYMOND L. BISPLINGHOFF  
 MALCOLM G. KISPERT  
 WILLIAM F. POUNDS  
 JACK P. RUINA  
 JOSEPH J. SNYDER

**Student Environment**

ROY E. FELDMAN (Chairman) 1971  
 DEAN FOR STUDENT AFFAIRS\*  
 ASSOCIATE DEAN FOR STUDENT  
 AFFAIRS\*  
 JOHN C. GRAVES 1970  
 ALAN M. HERSHDORFER 1970  
 ALVIN W. DRAKE 1971  
 MARTIN DEUTSCH 1972  
 SHEILA E. WIDNALL 1972  
 RICHARD M. HELD †

**Undergraduate Admissions and Student Aid**

ANTHONY P. FRENCH  
 (Chairman) 1970  
 DIRECTOR OF ADMISSIONS\*  
 DIRECTOR OF STUDENT AID\*  
 REGISTRAR\*  
 RICHARD B. ADLER 1970  
 ROBERT J. SILBEY 1971  
 GEORGE E. VALLEY, JR. 1971  
 ARTHUR D. KALIEDIN 1972  
 LEON TRILLING 1972  
 FREDERICK W. FREY †

## COUNCILS

## ACADEMIC COUNCIL

President (Chairman)  
 Provost (Vice Chairman)  
 Associate Provosts  
 Vice President and Treasurer  
 Vice President, Academic Administration  
 Vice President, Operations  
 Vice President and Secretary  
 Vice President for Special Laboratories  
 Vice President, Organization Systems  
 Vice President, Special Projects  
 Dean of the School of Architecture and Planning  
 Dean of the School of Engineering  
 Dean of the School of Humanities and Social Science  
 Dean of the Alfred P. Sloan School of Management  
 Dean of the School of Science  
 Dean of the Graduate School  
 Dean for Institute Relations  
 Dean for Student Affairs  
 Chairman of the Faculty  
 Director of Libraries  
 Comptroller  
 Assistant to the President (Secretary)

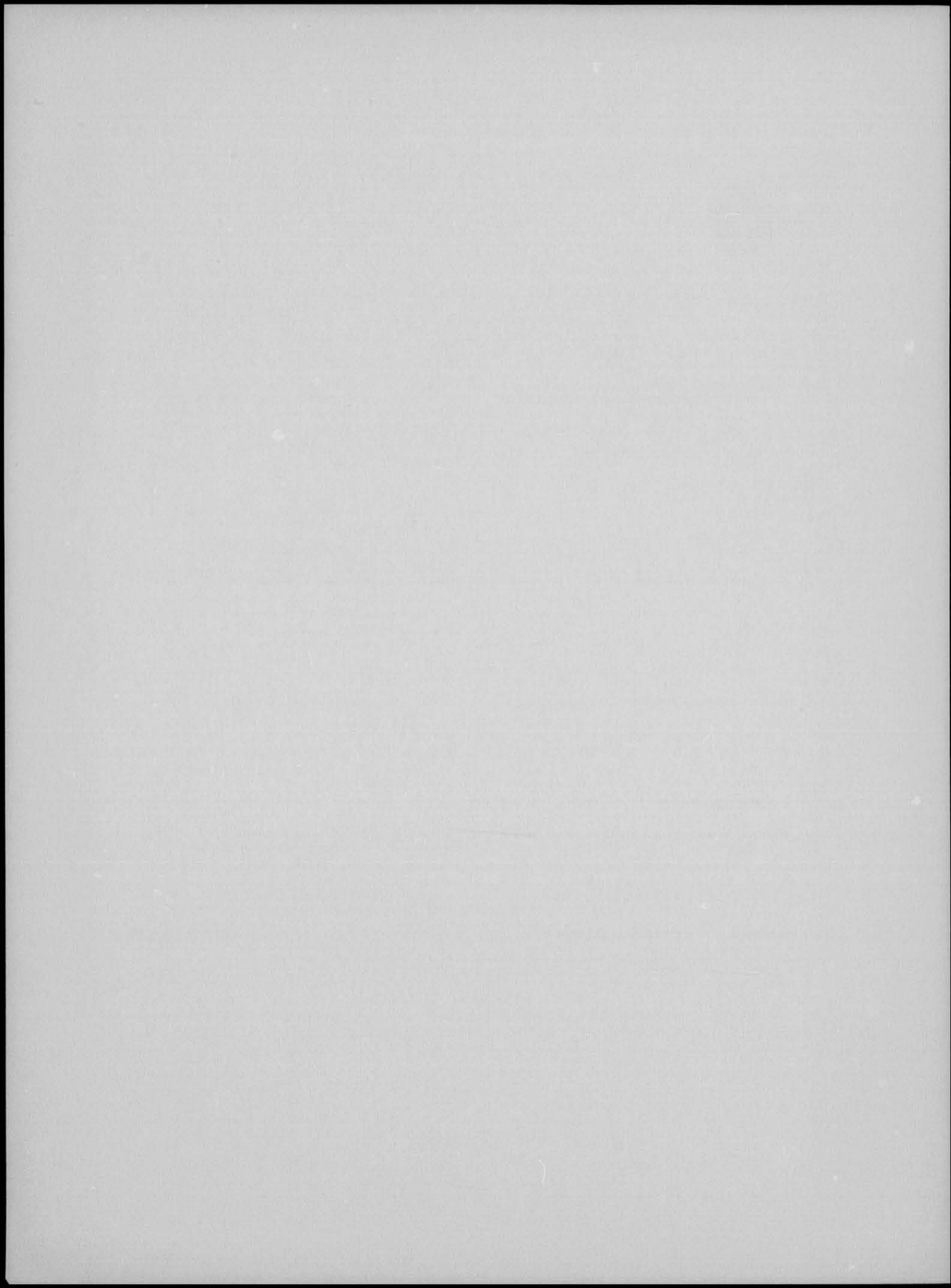
## FACULTY COUNCIL

President (Chairman)  
 Chairman of the Corporation  
 Members of the Academic Council  
 Heads of Departments and Professional Courses  
 Secretary of the Faculty  
 Undergraduate Planning Professor  
 Director of Admissions  
 Director of the Analytical Studies Group  
 Director of Athletics  
 Director of the Center for Advanced Engineering Study  
 Director of the Center for International Studies  
 Director of the Center for Materials Science and Engineering  
 Director of the Center for Space Research  
 Director of the Education Research Center  
 Director of Information Processing Services  
 Director of the Instrumentation Laboratory  
 Director of the Laboratory for Nuclear Science  
 Director of Lincoln Laboratory

Medical Director  
 Director of the M. I. T. Press  
 Director of the Office of Administrative Systems  
 Director of the Operations Research Center  
 Director of the Research Laboratory of Electronics  
 Director of the Spectroscopy Laboratory  
 Director of the Summer Session  
 Registrar  
 Associate Dean for Student Affairs  
 Associate Dean of the Graduate School  
 Associate Dean of the Alfred P. Sloan School of Management  
 Administrative Director of the Division of Sponsored Research  
 Assistant Dean of the School of Engineering  
 Assistant to the President (Secretary)

## ADMINISTRATIVE COUNCIL

President (Chairman)  
 Members of the Academic Council  
 Director of Admissions  
 Director of the Analytical Studies Group  
 Director of Athletics  
 Director of the Industrial Liaison Office  
 Director of Information Processing Services  
 Director of the Instrumentation Laboratory  
 Director of Lincoln Laboratory  
 Medical Director  
 Director of the Office of Administrative Systems  
 Director of the Office of Personnel Relations  
 Director of Placement  
 Director of Public Relations  
 Director of Student Aid  
 Director of the Summer Session  
 Registrar  
 Planning Officer  
 President of the Alumni Association  
 Executive Vice President of the Alumni Association  
 Editor of *Technology Review*  
 Associate Dean for Student Affairs  
 Administrative Director of the Division of Sponsored Research  
 Assistant Dean of the School of Engineering  
 Assistant to the President (Secretary)



## APPENDIX A: STUDENT FINANCIAL AID

*Scholarships for Undergraduates*

A wide range of scholarship assistance is available to undergraduates at M.I.T. All grants are based on an evaluation of financial need and are apportioned as equitably as possible among all eligible students. An application for financial aid is an application for assistance from whatever funds the Student Aid Committee may deem appropriate. While a limited number of full-need scholarship grants are made, the great majority of the financial aid awards include some combination of scholarship, loan, or employment.

These forms of financial aid are in addition to the Deferred Payment Plan and tuition payment arrangements, described in Section 1 of this Catalogue.

The following is an alphabetical list of some of the funds from which scholarship awards are made. The figures in parentheses are the dates of establishment.

**Frank W. and Carl S. Adams Memorial Fund (1955)**

Established by Mr. and Mrs. Charles E. Adams, with The First National Bank of Boston as Trustee, and named in memory of their two sons as the Frank W. and Carl S. Adams Memorial Fund, this fund is used to assist needy and deserving students at M.I.T. A limited amount may also be available to assist an impecunious student who is unable to participate in recognized functions incident to graduation.

**Alcoa Scholarships (1965 and 1968)**

Three annual awards of \$750, for needy and deserving undergraduate students in metallurgy and the information sciences.

**AMF Foundation Scholarship (1960)**

This two-year grant is awarded annually to a member of the junior class majoring in mechanical or electrical engineering. Recipients are chosen on the basis of academic achievement, demonstrated need, extracurricular activities, leadership, and citizenship. Preference is given to residents of New England, New Jersey, New York, and Pennsylvania.

**Anaconda Scholarships**

Two scholarships in the fields of Materials Science and Engineering and Earth Sciences have been made available by the Anaconda Company for children of company employees. First preference will be given to qualified applicants who meet this requirement. Awards will be made by the M.I.T. Committee on Student Financial Aid, employing its usual criteria in the selective process. Stipends will be set in amounts of demonstrated financial need. Awards to Anaconda Scholars are renewable each year subject to performance and in accordance with financial need.

**Nils Anderson Scholarship (1961)**

This scholarship, founded by a gift and added to by a bequest of Nils Anderson, Founder and Chairman of the Board of Debevoise-Anderson Company, Inc., is intended to assist promising students interested in entering the foundry industry.

**William P. Anderson, Jr. Fund (1965)**

The income only to be expended for such purposes as the Institute may, from time to time, deem most appropriate, preference to be given to student financial aid.

**Louie G. Applebee Fund (1942)**

This bequest is "to be expended in assisting deserving students."

**Army and Navy Scholarships (1930)**

Sons of regular Army, Navy, Air Force, Marine Corps, and Coast Guard officers who are admitted as undergraduate students to the Institute will be considered for grants toward their tuition based on their demonstrated need, with a maximum of one-half tuition, upon recommendation of the Student Aid Committee — the total number

not to exceed ten each year. Preference will be given to qualified applicants admitted to the first-year class. Applications should be accompanied by documentary evidence that the applicant's father is a regular commissioned officer, active, retired, or deceased.

These scholarships may be renewed upon annual reapplication.

**Association of Iron and Steel Engineers — Madsen Scholarship Fund (1966)**

The income of this fund, established by the Association of Iron and Steel Engineers as a memorial to Ingvald Elias Madsen '33, is used to support one or more undergraduate students with preference given to those enrolled in the School of Engineering.

**Athan Scholarship (1962)**

This annual scholarship was established by D. J. Athan '54, for upperclassmen in the Department of Architecture. Demonstrated need and professional competence are the basic criteria for the grant. Selection and recommendations are based in part on nominations made by the Department of Architecture.

**Elisha Atkins Fund (1894)**

This fund, established by Mrs. Mary E. Atkins of Boston with a gift of \$5,000, is used for undergraduate scholarships.

**Hattie G. Atkins Fund (1962)**

The income of this fund, established by the bequest of Mrs. Hattie G. Atkins in memory of her ancestor, Matthew Gannett, is used to provide not more than two annual grants "to worthy students."

**Julian M. Avery Fund (1957)**

Established by Julian M. Avery '18, this fund is designated for undergraduate scholarships in metallurgy.

**Jason S. Bailey Fund (1952)**

Established by the estate of Jason S. Bailey, this fund is used for undergraduate scholarships at the Institute.

**Thomas Wendell Bailey Fund (1914)**

The income from this bequest of Thomas Wendell Bailey is used to assist "needy students in the Department of Architecture."

**Charles Tidd Baker Fund (1922)**

One-half of the net income of this bequest from Charles Tidd Baker is "applied each year to the assistance of poor and worthy students."

**Constance and Arthur H. Ballard Memorial Scholarship Fund (1969)**

This fund, established by the bequest of Constance Ballard, is used for four-year undergraduate scholarships to students in electrical or mechanical engineering, physics, or chemistry. Recipients are selected on the basis of character, ability and demonstrated financial need.

**John Rice Bell Memorial Scholarship (1961)**

The income of this fund, established by Kenneth E. Bell '17, in memory of his brother, John Rice Bell '11, is used to assist undergraduate students, preferably in chemical engineering.

**Alf K. Berle Memorial Scholarship Fund (1960)**

Income of this fund, established by his wife in memory of Alf K. Berle '27, is used to assist worthy and needy young men at M.I.T.

**Billings Student Aid Fund (1900)**

A bequest of \$50,000 from Robert C. Billings founded the Billings Student Fund. "Any student receiving benefit from this fund is expected to abstain from the use of alcohol or tobacco in any of their varied forms."

**Ernst Henri Birnbaum Memorial Fund (1964)**

The income of this fund, established by bequest of Mr. David Bingham in memory of his son, is used for one or more scholarships for students in chemical engineering.

**Huse Templeton Blanchard Fund (1946)**

This bequest of Huse T. Blanchard '01 is for "the benefit of worthy boys of the State of New Hampshire."

**Levi Boles Fund (1915)**

The net income of this bequest from Frank W. Boles in memory of his father, Levi Boles, is "applied annually to the assistance of needy and deserving students."

**Jonathan Bourne Fund (1915)**

This bequest from Hannah B. Abbe constitutes a fund "known as the Jonathan Bourne Scholarship Fund, the income only to be used in aid of deserving students."

**Albert G. Boyden Fund (1931)**

This bequest from Elizabeth R. Stevens is a permanent fund, known as the Albert G. Boyden Fund, "income only to be awarded as scholarships to assist worthy and needy students, preference to be given to young men or women residents of the town of Swansea or the city of Fall River (Mass.)."

**Bertram Brewer Scholarships (1952)**

The income from this bequest under the will of Bertram Brewer is used "to provide annual scholarships for deserving undergraduates of good character and ability. . . ."

**Hubert D. Broderic (1965)**

The income of this fund, established by Stuart C. Broderic '47 and Mrs. Guyetta G. Custance in memory of Hubert D. Broderic, is used to provide scholarship assistance to worthy and needy students at M.I.T.; first preference is given to residents of Lexington, Massachusetts.

**Harriet L. Brown Fund (1932)**

This bequest of Harriet L. Brown is "to be held in trust as a scholarship . . . the income to be given to such needy and deserving young women desiring to become students at M.I.T., as would otherwise be unable to attend; and in case of two or more applicants of equal merit, preference shall be given to a native of either Massachusetts or New Hampshire."

**Walter Stanley Brown Scholarship Fund (1968)**

The income of this fund, established by the bequest of Maud M. Brown, is used for undergraduate scholarships, with preference for students from Vermont.

**Denison K. Bullens Scholarship Fund (1958)**

A gift of Denison K. Bullens '09, this fund is used to provide scholarships for needy and worthy undergraduates, with first preference to students in metallurgy.

**Cabot Corporation Scholarships (1955)**

The income of a fund established by the Cabot Foundation, Inc., provides scholarships for children (sons and daughters) of employees of the Cabot Corporation and its subsidiary and associated companies. Candidates are required to have certification of their eligibility for scholarship grants by first applying to the Personnel Office of the Cabot Corporation and are expected to comply with the usual policies governing the award of Institute scholarships. In any year when there are no applicants admitted to the Institute included as children of employees of the Corporation, the income may be used for scholarships for other qualified applicants for admission to the Institute.

**Godfrey L. Cabot Fund (1950)**

Scholarships made possible by this gift are awarded with preference to students of chemistry or chemical engineering.

**Thomas D. Cabot Scholarship Fund (1960)**

Two-thirds of the income of this fund, established by Mr. and Mrs. Thomas D. Cabot, is used to assist worthy students with financial aid, and one-third is used for salaries for teachers.

**Cambridge Scholarships (1916)**

A limited number of scholarships are granted to students entering the first-year class at the Institute who are graduates of schools in Cambridge and children of legal residents of that city. These Cambridge Scholarships, which carry a stipend of full tuition, are confined to students who make application furnishing evidence of need. An award may be continued in the second, third, and fourth years upon annual reapplication, providing the holder maintains a satisfactory scholastic record and continues to furnish evidence of need.

**Mabel Blake Case Fund (1920)**

This bequest from Caroline S. Freeman is "known as the Mabel Blake Case Fund, income to be used to aid deserving students (preferably women) who are in need of assistance."

**Nino Teshler Catlin Fund (1926)**

A gift from Maria T. Catlin established this fund in memory of her son, Nino T. Catlin '18, the income "to be awarded to needy and deserving students."

**Francis Ward Chandler Memorial Fund (1969)**

Established by H. Daland Chandler in memory of his father, this fund is used to provide scholarship assistance to graduate or undergraduate students, with first preference being given to students in architecture.

**Clapp and Poliak Scholarships (1966)**

This annual gift of \$20,000 from a fund established by Clapp and Poliak Inc. in honor of the Design Engineering Show Exhibitors, is for undergraduates in the field of design engineering, to provide awards up to full tuition and living expenses.

**Lucius Clapp Fund (1905)**

This gift from Lucius Clapp formed a fund "to aid worthy students who may not be able to complete their studies without help."

**Clark Foundation Scholarships (1953)**

This fund, established by the Edna McConnell Clark Foundation, provides scholarships for foreign students entering as freshmen, who would otherwise have insufficient means to allow them to matriculate.

**Thomas L. Clark Memorial Scholarship (1956)**

The income from this endowment, established in memory of Thomas Lynn Clark '59, by a number of his friends at M.I.T., is used to assist an entering freshman.

**A. V. Clarke Fund (1950)**

The proceeds of this gift by Mr. Clarke are "used for student aid at the discretion of the Student Financial Aid Committee."

**Class of 1887 Scholarship Fund (1967)**

This fund was established by members of the M.I.T. Class of 1887. Its income is used for undergraduate scholarships.

**Class of 1895 Scholarship Memorial Fund (1945)**

This fund was given by the Class of 1895 on its fiftieth anniversary, "the income annually to be used to provide scholarships for suitably qualified descendants of members of the Class of 1895. If in any year the total income is not required for this purpose, the balance shall be added to the Technology Loan Fund."

**Class of 1906 Scholarship Fund (1967)**

This fund was initiated by members of the M.I.T. Class of 1906. A portion of the interest is to be used for general purposes, with preference for scholarships.

**Class of 1909 Memorial Fund (1957)**

The income of this fund, initiated by gift from the widow of Carl W. Gram '09, and augmented by subsequent gifts in memory of Felix A. Burton, James H. Critchett, Benjamin W. Dow, Harold I. Eaton, Harry L. Havens, Reginald L. Jones, George A. Haynes, Helen Longworth Paul, William R. Reilly, and Clark S. Robinson, all members of this class, is used for scholarship aid, with first preference to descendants of members of the Class of 1909.

**Class of 1910 Scholarship Fund (1967)**

This fund was established by the members of the M.I.T. Class of 1910. The income is to be used for undergraduate scholarships.

**Class of 1931 Compton Memorial Freshman Scholarship Fund (1956)**

The income from this fund, established at the twenty-fifth reunion of the Class of 1931 as a memorial to Dr. Karl Taylor Compton, is used for freshman scholarships.

**Class of 1932 Fund (1951)**

The income from this fund, the twenty-five year gift of the Class, provides undergraduate scholarship grants.

**Class of 1933 Fund (1958)**

The income of this fund, a gift of the Class at its twenty-fifth reunion, is available for scholarship grants to undergraduates.

**Class of 1934 Fund (1959)**

The income of this fund, an endowment by the Class as its twenty-five-year gift, provides awards known as the Karl T. Compton Scholarships.

**Class of 1938 Scholarship Fund (1938)**

The income of gifts from the Class of 1938 is used for scholarships, preference being given those applicants "who have shown their desire for an education by earning part of their expenses; and/or to those applicants who are descendants of the Class of 1938."

**Fred L. and Florence L. Coburn Fund (1932)**

The income of this bequest from Fred L. Coburn "shall be expended by the Trustees in giving aid and assistance to students of M.I.T. . . . preference being given by said Trustees to students residing in Somerville, Massachusetts."

**Coffin Memorial Fund (1929)**

This gift from the executors of the estate of Charles A. Coffin — a bequest — carried out the wishes of Mr. Coffin. The fund is used for loans or other aid to students as determined by the Executive Committee of the Corporation.

**W. A. Conant Scholarship Fund (1943)**

This bequest was made "for the purpose of establishing a permanent fund to be known as the W. A. Conant Scholarship Fund, the income therefrom to be used for the education of native born American Protestant boys of New England of American Protestant parents, who are graduates of some high or preparatory school, public or private, in New England, preference to be given to the graduates of the public schools of Brookline, Massachusetts, but without limitation thereto, and whose parents are financially unable to send them to the Institute and whose own means are insufficient to allow them to attend the Institute."

**Albert Conro Scholarship Fund (1943)**

This bequest of Mary T. Conro, sister of Emma O. Conro '84, in memory of their uncle, is "for the purpose of establishing and maintaining a scholarship . . . to be known as the Albert Conro Scholarship." Awards are made to students in metallurgy.

**The George R. Cooke Fund (1939)**

Established by a gift in memory of George R. Cooke '08, the income of this fund is awarded preferably to a student in civil engineering or a related field. Consideration is given to those who have had experience through employment in a field before undertaking formal study; the recipient need not necessarily be a candidate for a degree. Grants will be based on character, achievement, need, and future promise.

**John G. Crane Scholarships (1951)**

This gift of J. G. Crane '90 is for undergraduate awards.

**Allen S. Crocker Memorial Fund (1961)**

The income of this fund, established as a memorial by the wife of Allen S. Crocker '97, is used to assist worthy and needy young men. Stipendiary awards will be according to demonstrated financial need up to a maximum of tuition in any one year. First preference in the selection is given to students domiciled in the Rochester, New York, area.

**Lucretia Crocker Fund (1916)**

By the will of Matilda H. Crocker, the Institute was made the residuary legatee of her estate "for the establishment of one or more scholarships for women in memory of my sister, Lucretia Crocker . . . the income to aid one or more young women in need of pecuniary assistance in obtaining instruction at said Institute."

**Eunice McLellan Cruft Fund (1949)**

This bequest of Eunice McLellan Cruft was made "to assist young men whose means are inadequate to pay their expenses at the Institute."

**Ralph E. Curtis Scholarship (1960)**

Income of this fund, established by gifts of the Curtis Universal Joint Company, Inc., is used to assist needy and worthy young men of Springfield, Massachusetts, to achieve their educational objectives at the Institute. Open to entering freshmen, initial preference is given to children and nephews and nieces of five-year employees of the Curtis Universal Joint Company, Inc. In the selection of awards for entering students, first preference is given to graduates of Springfield Technical High School; second preference to graduates of other Springfield high schools; and third preference to secondary school graduates resident in western Massachusetts.

**Isaac W. Danforth Fund (1903)**

This bequest from James H. Danforth for scholarship purposes was a memorial to his brother, Isaac Warren Danforth.

**Tenney L. Davis Scholarship Fund (1967)**

This fund, established in memory of Tenney L. Davis '13, is to be used in assisting students with need who show great ability in the study of chemistry.

**Robert Taylor Dawes Scholarship Fund (1969)**

The income of this fund, established by Mrs. Robert T. Dawes in memory of her husband, is used for scholarships for deserving and needy undergraduates.

**The Delafield Memorial Fund (1960)**

This fund was established by the parents of Benjamin T. Delafield '60 to be used to assist needy and deserving students at M.I.T. Preference is given to students from Pittsburgh or Sewickley, Pennsylvania.

**Orville B. Denison Memorial Fund (1960)**

The income of this fund, donated by the members of the Class of 1911 as a memorial to Orville B. Denison '11, is used to assist worthy and needy undergraduates at the Institute.

**Carl Pullen Dennett Memorial Scholarship Funds (1956 and 1959)**

Established by gifts in memory of Carl Pullen Dennett, these two funds provide awards for students in the School of Science, either graduate or undergraduate, who are deemed qualified by scholastic performance, intelligence, character, and promise. The annual selections are made by the Director of Student Aid and the Dean of Student Affairs.

**Marie G. Dennett Scholarship Fund (1963)**

Established by gift of the Marie G. Dennett Foundation, this fund provides an award for students in the School of Science, either graduate or undergraduate, who are deemed qualified by scholastic performance, intelligence, character and promise. The annual selections are made by the Director of Student Aid and the Dean of Student Affairs.

**Thomas C. Desmond Scholarship (1952)**

Established by the gift of Thomas C. Desmond '09, this scholarship is awarded to qualified students in civil engineering.

**Thomas C. Desmond Scholarship Fund (1960)**

The income of this gift of Thomas C. Desmond '09 is awarded to deserving undergraduates at the Institute in accordance with the general policies of the Institute.

**Development Fund Scholarships (1950)**

Scholarships provided by gifts to the M.I.T. Development Fund consist of grants to students who demonstrate need for financial assistance. They are open to all candidates from secondary schools.

**Ann White Dickinson Fund (1898)**

This bequest from Ann White Dickinson was made "to establish free scholarships in M.I.T. . . . such persons enjoying benefit . . . shall be worthy young men of American origin."

**Frederick N. Dillon, Jr. Scholarship Fund (1968)**

The net income of this fund, established by the will of Frederick N. Dillon, Jr. '22, is used for providing scholarships for undergraduate work to deserving students from Fitchburg, Massachusetts, and the immediate area.

**Fred C. Dobbs Fund (1960)**

The income of this fund, established in the name of Dr. F. C. Dobbs by his friends, is used to assist undergraduates to meet their expenses at the Institute. Selection is limited to citizens of the United States who have demonstrated a need for financial assistance and have given evidence of promise.

**Dormitory Fund (1903)**

This fund for scholarship purposes was raised by miscellaneous subscriptions; it was formerly known as Students' Aid Fund.

**Henry C. Dresser Fund (1965)**

Established from the bequest of Henry C. Dresser '92, the income is used for scholarships, preference being given to students residing in Southbridge, Massachusetts.

**Thomas Messinger Drown Scholarships (1928)**

A bequest from Mary Frances Drown was designated "to establish scholarships for deserving undergraduate students, to be known as the Thomas Messinger Drown Scholarships."

**Charles Dyer Scholarship Fund (1968)**

This fund was established by Ira Dyer '49, in memory of his father, Charles Dyer. The income is used for scholarships to undergraduates.

**Daniel W. Edgerly Fund (1964)**

The income of this fund, established by bequest of Daniel W. Edgerly '98, is used for the purpose of maintaining undergraduate scholarship aid for upperclassmen in the science departments, preferably in chemistry, physics, or biology.

**Edgerton, Germeshausen and Grier, Inc., Scholarships (1955)**

This gift provides scholarships, preferably for students in electrical engineering.

**Leola M. Farnham Scholarship Fund (1966)**

Bequest for the purpose of supporting part tuition or full tuition for undergraduate students in the field of science.

**Farnsworth Fund (1889)**

This fund was founded by Mrs. Mary E. Atkins of Boston, the income to be used for scholarship purposes.

**Alton J. Farrel, Jr. Scholarship Fund (1967)**

Income from this fund is used to provide scholarships to students with need who are residents of Ansonia, Connecticut, or its vicinity or to other residents of the state of Connecticut.

**Francis Edwin Faxon Scholarship Fund (1967)**

The income from this fund, established by the Charlotte F. Faxon Trust, is used to provide scholarship aid to male undergraduates.

**Charles Lewis Flint Fund (1889)**

This bequest from Charles L. Flint is for the "support of some worthy student, preference to be given to some graduate of the English High School, Boston."

**Sarah S. Forbes Fund (1913)**

Originally given in trust in 1868 by Sarah S. Forbes to William Barton Rogers and Henry S. Russell, trustees, this fund was transferred in 1913 to the Institute "for the maintenance and education of a scholar in M.I.T."

**Clara and F. Joseph Ford Scholarship (1951)**

The income of a fund established by Mr. and Mrs. Joseph F. Ford is awarded "to worthy and well-qualified students who have demonstrated a democratic and tolerant spirit and who are well disposed toward people of all creeds and races."

**Forging Industry Educational Research Foundation Scholarships (1967)**

This fund provides two undergraduate scholarships annually to students in the Department of Metallurgy and Materials Science, with preference given to students showing interest and promise in the field of hot working and hot behavior of materials. Stipends are determined on the basis of demonstrated financial need.

**Foundry Educational Foundation Scholarships (1947)**

Established by the Foundry Educational Foundation, which represents the American Foundrymen's Association, the Gray Iron Founders' Society and the Malleable Founders' Society, and the Foundry Equipment Manufacturers Association, these awards are open to third- and fourth-year students in management, mechanical engineering, and metallurgy.

**Arthur E. Fowle Fund (1956)**

The income of this fund established under the will of Arthur E. Fowle '93 is to be used for undergraduate scholarships.

**Evert W. Freeman Scholarship Fund (1956)**

The income of this fund, established by bequest of Evert W. Freeman '20, "shall be awarded annually to a student . . . who shows promise of substantial accomplishment but is in financial need."

**Philip Jacob Friedlander Fund (1945)**

This fund was the gift of Israel Friedlander "in appreciation of the opportunity my son, Philip Jacob Friedlander, had of spending a little more than a year at M.I.T. before enlisting in the United States Naval Reserve . . . the income to be used with the income from other such funds for the purpose of helping qualified students at M.I.T. regardless of race, creed, or color, or geographical origin, who may be in need of financial assistance . . ."

**Jurgis J. Geguzis Fund (1957)**

Established under the will of the late Jurgis J. Geguzis, this fund is to be used for tuition and expenses for a student of Lithuanian parentage. The recipient is selected by the Institute upon the condition that he shall repay the amount of his award "when and if able so that other students may be granted the same benefits and privileges in the future."

**General Motors Scholarships (1955)**

These four-year grants, established under the General Motors College Scholarship Plan, are open to citizens of the United States and are intended for individuals who give evidence of potential leadership. Three awards are made to entering first-year students. Stipends will be fixed on the basis of demonstrated need.

**Norman H. George Fund (1919)**

This bequest of Norman H. George is "to be used for the assistance of needy and worthy students in obtaining an education in M.I.T."

**Arthur B. Gilmore Fund (1941)**

This bequest from Arthur B. Gilmore is ". . . for the purpose of assisting needy students who shall be members of the Beta Theta Pi fraternity . . . said net income to be divided among not more than two students in any one year."

**James R. Glazebrook Fund (1959)**

The income of this fund is to be used to assist needy and worthy undergraduates at the Institute.

**Ethel A. Gleason Memorial Scholarship (1963)**

The income of this fund, established as a memorial to Ethel A. Gleason '01, by her nephew, Dr. Anthony H. Gleason, is used to assist worthy and needy undergraduates.

**Goodyear Scholarship (1957)**

A stipend of \$1,500 made available by the Goodyear Tire & Rubber Company Fund is granted to a male U.S. citizen majoring in chemical engineering in his junior or senior year. Awards will be made on the basis of academic standing, character and leadership qualities, and financial need.

**Barnett D. Gordon Fund (1942)**

The income from this fund, established by bequest of Barnett D. Gordon '16, is to be used "as scholarships for deserving students at M.I.T."

**John H. Gregory Fund (1963)**

The income of this fund, established by bequest of Sarah James Gregory in memory of her husband, John H. Gregory '95, is used to provide scholarships for juniors and seniors in civil engineering.

**John A. Grimmons Fund (1952)**

This fund was established by the estate of Katie M. A. Grimmons in memory of her son, John A. Grimmons '21. The income is to be used for scholarships for students . . . with preference to those in the Department of Electrical Engineering.

**Robert E. Gross — Lockheed Aircraft Corporation Scholarships (1963)**

The income of this fund, established by the Lockheed Aircraft Corporation to perpetuate the memory of Robert E. Gross, founder and principal officer of the Corporation for many years, is available to citizens of the United States who are studying in science, engineering, or other fields applicable to the aerospace, electronics, marine, manufacturing, and construction industries.

**Rita Welch Gruber Memorial Scholarship (1961)**

The income of this Memorial Fund, established by the gift of Rudolf E. Gruber '16, is used to assist undergraduate foreign students to pursue a course of study at the Institute. Grants are available to foreign students in all departments of the Institute, and there are no limitations

in fields of study. In its selection the Committee gives first preference to students who are nationals and residents of Germany, Italy, or France.

**Gulf and South America Steamship Company Fund (1953)**

Fund established by Gulf and South American Steamship Company from which scholarship grants may be made upon initiative of the Department of Naval Architecture and Marine Engineering. Preference is given to students in the course in Shipping and Shipbuilding Management (Course XIII-B).

**William T. Haebler Memorial Scholarship (1960)**

This fund was established by his daughter in memory of her father, William T. Haebler '22. The income is used to assist worthy and needy students who are undergraduates and are citizens of the United States.

**Humphrey M. Haley Scholarship Fund (1958)**

This bequest of Humphrey M. Haley '04 is held in trust and the income used as scholarship aid to one or more deserving students, with first preference to students residing in the St. James Parish in Salem, Massachusetts.

**Lucia G. Hall Scholarships (1945)**

The income from this bequest of Louise K. Gunn, to "be known as 'The Lucia G. Hall Scholarships' . . . is to be used for the aid of worthy students."

**Hall-Mercer Scholarship Fund (1940)**

The income from this bequest of Alexander G. Mercer is to be used "for the benefit of such poor students as have passed through some of the public schools with the best reputation for character and ability."

**Claire Morton Prince Hanks Fund (1966)**

This fund, established by bequest of Claire Morton Prince Hanks, is to be used for "such purpose connected with financial aid as the Executive Committee may deem appropriate." Awards from this fund are made to undergraduate students who are citizens of the U.S.

**Harrington Scholarship Fund (1961)**

The income of this fund, established by Joseph Harrington, Jr. '30, in commemoration of his father, Joseph Harrington '96, is used for student aid purposes.

**James H. Haste Fund (1930)**

This bequest of James H. Haste '96 is "for the aid of deserving students . . . of insufficient means."

**Charles Hayden Memorial Scholarships (1939)**

Established through a grant from the Charles Hayden Foundation, these scholarship awards are in memory of the late Charles Hayden, graduate of the English High School Class of 1886 and of the M.I.T. Class of 1890.

**Joseph Hewett '96 Fund (1965)**

Established from the bequest of Joseph Hewett '96, the income from this fund is used in maintaining scholarships at M.I.T.; preference is given to students from the public schools of Brockton, Massachusetts.

**Bancroft Hill Memorial Fund (1957)**

This fund was established by Frances G. Hill in memory of her husband, Bancroft Hill '11. The income is used for scholarship assistance to students in civil engineering who are in need of financial help.

**George Hollingsworth Scholarship (1916)**

A bequest from Rose Hollingsworth founded the George Hollingsworth Scholarship.

**Loren C. Holm Scholarship Fund (1950)**

Established by Marie Holm in memory of her father, this fund is designated for worthy and needy students.

**Theodore V. Houser Scholarship Fund (1956)**

The fund, established by gifts of Theodore V. Houser, is used for scholarship purposes.

**Elias Howe, Jr., Scholarships (1949)**

The income from a fund established under the will of Julia Howe Stockwell Smith "shall be available for aiding such students and in such amounts as shall be recommended by the Faculty."

**Dr. and Mrs. Chiao-Yue (nee Yueh-Gin Gung) Hu Scholarship (1970)**

Established by the gift of Dr. and Mrs. Chiao-Yue (nee Yueh-Gin Gung) Hu in honor of their beloved son, Robert Hsueh-Ko Hu '65, who graduated with high honors and was elected as an Associate Member of the Society of Sigma Xi at the time of his graduation. The stipend of this scholarship shall be awarded annually to needy undergraduate students of Chinese ancestry, restricted to students majoring in mathematics, physics, chemistry, or any branch of engineering in that order.

**Huguenot Society of America Scholarship (1962)**

This annual grant of \$1,000 for an M.I.T. undergraduate is provided by the Huguenot Society of America. Applicants must be certified by the Huguenot Society of America as descendants of a Huguenot who

came into the territory (now United States) prior to November 28, 1877. The Committee on Student Financial Aid will make a selection from certified and qualified applicants.

**Samuel P. Hunt Fund (1945)**

This gift of Samuel P. Hunt '95 was designated for scholarship purposes.

**T. Sterry Hunt Scholarship (1894)**

A bequest from T. Sterry Hunt, for seven years Professor of Geology at M.I.T., was designated to found a scholarship in his name. The award is restricted to students in chemistry, and preference is given to those in the higher years.

**William F. Huntington Fund (1892)**

From Susan E. Covell the Institute received a gift to constitute a fund in memory of William F. Huntington '75, the "income to apply to payments of tuition of needy and deserving students . . . preference to be given to students in civil engineering."

**Cuthbert Hurd Scholarship Fund (1968)**

The income of this fund, established by Cuthbert Hurd, is used for scholarships to students in the mathematical sciences.

**John Jay Ide Prize Scholarships (1962)**

These six prize scholarships were donated by Mrs. John Jay Ide to honor the memory of her husband, the late Captain John Jay Ide. They are prize awards for the freshman year carrying a fixed stipend of \$2,200 and are limited to students who are planning to study aeronautical engineering.

**Charles L. Iresson Scholarship Fund (1959)**

Income of this fund, established by the will of Jennie E. Iresson, is devoted to the education of worthy students who may require financial assistance.

**Jakobson Scholarship (1951)**

Established by Jakobson Shipyard, Inc., this annual freshman scholarship carries a grant of \$1,000. First preference is given to a son of an employee of Jakobson Shipyard, Inc.; second preference is to graduates of the following New York high schools: Glen Cove, Huntington, Manhasset, Oyster Bay, Port Washington, Roslyn, Sea Cliff; and third preference is to secondary school graduates who reside on Long Island, excepting the counties of Kings or Queens.

**David L. Jewell Fund (1928)**

The income from this bequest from Colonel David L. Jewell is "to be used to pay part of the tuition charges for five young men who may be selected by the President or Board of Trustees of the Institute as worthy of assistance, and who, were it not for such assistance, might be unable to pursue their studies at such Institute."

**Edward A. Jones Scholarship Fund (1947)**

A bequest from Edward A. Jones was designated to be used for the establishment and maintenance of one or more scholarships."

**Joy Scholarship (1886)**

Established by the gift of Nabby Joy, this scholarship was created pursuant to a decree of the Supreme Judicial Court of Massachusetts for the benefit of "one or more women studying Natural Science at M.I.T."

**Sarah Maude Kaemmerling Fund (1952)**

This fund was established by a gift in 1952 and subsequently added to by a testamentary bequest in 1959. The income is used for scholarships or some alternate form of student aid.

**William R. Kales Scholarship Fund (1953)**

This fund, endowed by a gift of the Whitehead and Kales Company for scholarship purposes, provides income to assist worthy and needy undergraduates.

**Henry Donald Kemp Fund (1964)**

The income of this fund is to be used to provide scholarship aid to students in the Department of Electrical Engineering.

**Bo Kwang Kim Scholarship Fund (1957)**

Established under the will of Bo Kwang Kim, this scholarship is for students of complete Korean ancestry. It is open to any deserving and needy Korean students. An award of \$500 is made only when the income of the Fund permits.

**Robert M. Kimball '33 Memorial Scholarship (1964)**

This fund has been established by the Class of 1933 as a memorial to Robert M. Kimball '33. Awards are made to students with established need, and preference, whenever possible, is given to descendants of the Class of 1933.

**Amelia S. Kniesner Scholarship Fund (1944)**

Gift of William T. Kniesner '16 and his sisters, the income is used "to provide scholarship aid to meritorious or needy students, either entering freshmen or undergraduate students of the Institute, preference to be given to graduates of the high school or high schools of Danbury, Connecticut."

**Kollsman Instrument Fund Scholarship (1961)**

Four annual awards, established by the Kollsman Instrument Corporation, are awarded to outstanding undergraduates in the Schools of Engineering and Science.

**Kurrelmeyer Fund (1947)**

This fund was raised by contributions by alumni "for an undergraduate scholarship award to a needy student."

**George J. Leness Scholarship Fund (1969)**

The income from this fund is used to aid needy and worthy undergraduate students of the Institute in good standing who take an active part in intercollegiate athletics.

**Y. T. Li Fund (1959)**

The income of this fund, established by Y. T. Li '38, is used to assist a worthy and needy student enrolled in the Department of Aeronautics and Astronautics; second preference is given to a student of Chinese origin.

**Jacob and Jennie Lichter Fund (1949)**

This scholarship fund is "for the aid of students who shall satisfy all entrance requirements of the Institute and be endorsed as to character and personality."

**Gustaf Robert Lindberg Fund (1957)**

This fund was established by Otto C. Lindberg, President of the General Drafting Company, to create the Gustaf Robert Lindberg Scholarships. The income is used for scholarships "that shall provide tuition, board and other necessary expenses preferably to one or more students who are citizens and residents of . . . Finland; second preference to citizens and residents of Sweden. If no worthy candidates from either Finland or Sweden, the scholarships may be awarded to the best qualified candidates who are citizens of the United States preferably of Finnish or Swedish extraction."

**Paul Weeks Litchfield Scholarship (1954)**

Established in honor of Paul W. Litchfield '96, this scholarship fund aids worthy and needy students at the Institute. Preference in selection is given to those students who have been members of the Boy Scouts of America.

**William Litchfield Scholarship (1910)**

A bequest from William Litchfield established "a single scholarship . . . known as William Litchfield Scholarship, income to be awarded and paid annually to such student in said Institute as may . . . be determined by the President of said Institute to be entitled thereto for excellence in scholarship and conduct."

**Littmann Foundation Scholarship (1960)**

This four-year grant, supplied by the Littmann Foundation, is available to a male student desiring to pursue a course of study either in engineering or management as related ultimately to manufacturing. First preference in the selection is given to a well-qualified secondary-school graduate, resident either in the general area of St. Louis, Missouri, or Charles City, Iowa. The amount of the award is based on demonstrated need up to the amount of tuition.

**Charles E. Locke Memorial Fund (1923)**

Preference in making awards from this fund, which was established by the Class of 1896, is given to descendants of members of the Class of 1896, including freshmen.

**Lockheed Leadership Fund Scholarships (1953)**

Established by the Lockheed Leadership Fund, these scholarships are for worthy young men and women who are citizens of the United States. Recipients must be secondary school graduates under twenty-five years of age who plan to major in a field of engineering applicable to the aircraft industry. In the selection for this award, the Student Financial Aid Committee will give recognition to factors other than scholastic achievement. Grants are for full tuition plus \$500 toward living expenses, renewable for three additional years — or the total undergraduate period.

**Richard W. Lodge Fund (1955)**

The income of this fund, established by the will of Mary L. Lodge in memory of Richard W. Lodge '79, is used for worthy and needy students.

**Sheridan A. Logan Fund (1964)**

A gift of Sheridan A. Logan, the income and principal used as required to provide scholarships to outstanding young men coming from the St. Joseph, Missouri, area.

**Elisha T. Loring Fund (1890)**

This bequest from Elisha Thacker Loring is for "the assistance of needy and deserving pupils."

**George J. Loveley Scholarship Fund (1960)**

The income of this fund is used to assist needy students, with first preference to sons of widows, whose fathers were native born citizens of Massachusetts, preferably of Boston and vicinity.

**Lowell Institute Fund (1923)**

Gifts from the alumni of the Lowell Institute School founded this fund, the income of which is annually awarded to assist some graduate of that School who desires to enter upon undergraduate studies at M.I.T.

**Percival Lowell Scholarships (1955)**

The income of this gift is used for scholarships awarded from time to time at the discretion of the President of the Massachusetts Institute of Technology to students in astronomy, physics, and mathematics.

**Loyal League Scholarships (1959)**

Three \$1,000 scholarships established by the Loyal League Philanthropies, Inc., are available to entering freshmen, graduates of public secondary schools in the Greater New York Metropolitan Area, who have demonstrated academic excellence and great financial need.

**Samuel E. Lunden Leadership Grant (1968)**

From a fund established at the Institute by Samuel E. Lunden '21, a grant is made annually to an entering freshman who evidences the potential of becoming a leader in the affairs of the nation. Recipients are selected primarily on the basis of high personal promise of leadership qualities; stipends are determined on the basis of need. First preference goes to applicants from the territory of the M.I.T. Club of California, second to applicants from the western region of the U.S. Recipients must be U.S. citizens.

**H. W. McCurdy Scholarship (1957)**

Established by the Puget Sound Foundation in honor of H. W. McCurdy '22, this gift provides one scholarship for an entering freshman who plans to follow a career in naval architecture or mechanical engineering. Preference will be given to a student from the Seattle area.

**Eugene and Margaret McDermott Scholarship Fund (1960)**

The income of this fund, established by Mr. and Mrs. McDermott, is used for four-year scholarship grants for superior students. First preference is given to students resident in Texas, Arizona, New Mexico, and Oklahoma, desiring to study in the earth sciences or related fields.

**Alice Maclaurin Scholarship (1951)**

Gifts created a scholarship in memory of Mrs. Richard C. Maclaurin.

**Georgia Lamar Malone Scholarship (1961)**

Income from this fund, established as a memorial to his mother by Charles B. Malone, Jr. '15, is used for scholarships for undergraduates, with first preference to students from Georgia or the Deep South.

**Theodore A. Mangelsdorf Fund (1961)**

The income of this fund, established by gift of the Brookdale Foundation, is used to provide undergraduate scholarships.

**Francisco Marcucella Fund (1953)**

This gift of Francisco Marcucella '27 was designated for undergraduate scholarship purposes.

**Rupert Anderson Marden Fund (1933)**

This fund was established by an anonymous gift "toward a memorial to be known as the Rupert Anderson Marden Scholarship Fund, income available annually to aid a worthy student at M.I.T. — Protestant and of American origin — preference to a student taking the Cooperative Course in Electrical Engineering."

**Martin-Marietta Foundation Scholarship Fund (1954)**

This fund of \$25,000 functions as an endowment to provide scholarships for students majoring in fields identified with the operations of the Aerospace Group of the Martin-Marietta Corporation. Students from the Baltimore, Maryland, Washington, D.C., Denver, Colorado, Orlando-Canaveral, Florida, and Vandenberg, California, areas are eligible.

**Waldo A. Martin Scholarship Fund (1950)**

This fund was established by Eleanor P. Martin in memory of her brother, Waldo A. Martin '90. Until 1975 first preference in awards is to be given to male friends or relatives of Waldo A. Martin and the donor, and second preference to graduates of Milton High School, Milton Academy, or a resident of Milton. Awards are for the freshman year only, on the basis of character, integrity, and ability.

**Margaret A. Matthews Fund (1947)**

The income of this bequest from Margaret A. Matthews is "for the benefit of such of the women students at M.I.T. who intend to become teachers."

**Thomas Mayor Fund (1963)**

The income from this fund is for scholarships to aid worthy and needy young men who are citizens of the United States, with preference given to those of the Protestant Christian faith and of English or Scottish descent.

**George J. Mead Prize Scholarships (1951)**

This bequest of George J. Mead '16 established prize scholarships in aircraft propulsion open to juniors, seniors, and graduate students in

this field. Consideration is also given to candidates from related engineering fields as applied to aircraft propulsion. Recommendation may be made by the Department of Aeronautics and Astronautics to the Student Financial Aid Committee.

**Charles E. Merrill Scholarship Fund (1955)**

The gift of Charles E. Merrill, this fund is for "students having financial need . . . who have demonstrated through personality traits, initiative, or by scholastic achievement that they will become substantial democratic citizens." One-half the income is used to meet the overhead expense of the Institute.

**Arthur Merkel Miller Fund (1960)**

Income of this fund, established by the will of Arthur Merkel Miller '17, is to provide scholarship assistance to worthy students.

**Robert W. Milne Fund (1943)**

This bequest was made as "an endowment fund under the title of 'The Robert W. Milne Fund,' the income thereof to be used and applied for the assistance of worthy and needy students in obtaining an education in said Institute."

**Milton High School Fund (1885)**

Founded by the Institute in recognition of contributions from residents of Milton, this scholarship is conferred upon such former pupils of the Milton High School in good standing at the Institute as the Master of that school and the School Committee of the town may select.

**Joseph R. Minevitch Memorial Scholarship Fund (1957)**

This bequest of Joseph R. Minevitch '16, in the name of his mother, Fannie Minevitch, and his brother, Borrah Minevitch, is to assist deserving young men or women with first preference to graduates of the Boston English High School, second preference to graduates of any Boston public high school, and third preference to graduates of any other public high school in the United States.

**Li Ming Scholarship Fund (1969)**

Income from this fund, established by bequest of Li Ming, is used for scholarships to undergraduates, preference being given to students of Chinese birth, descent, or nationality.

**James H. Mirrlees Fund (1886)**

This gift from James Buchanan Mirrlees of Glasgow, Scotland, constituted a scholarship in memory of his son, James Henry Mirrlees, who died in 1886 while attending the Institute. The income is awarded to the "student in the third or fourth year of the Mechanical Engineering Course most deserving pecuniary assistance."

**M.I.T. Alumni Fund National Scholarships (1957)**

These four-year scholarships were established by the M.I.T. Alumni Fund Board to give opportunity to well-qualified young people in the continental United States to come to the Institute. Grants are made to outstanding freshmen on the basis of demonstrated financial need, and continued awards depend upon achievement as well as need for assistance.

**M.I.T. Boston Stein Club—New England and National Scholarship Funds (1955)**

The income of these funds is granted to qualified applicants for the freshman year only. One or more awards are available to New England residents as well as to residents of other parts of the United States. There are no restrictions as to sex, religion, race, or color.

**M.I.T. Club of Chicago Scholarship Fund (1944)**

This fund was initiated by Harold B. Harvey '05 "to establish scholarships to be known as the Technology Club of Chicago Scholarship Fund," the awards to be made by a committee composed of the Honorary Secretaries of the Chicago area and the Director of Student Aid, and restricted to students who reside in the area of the club membership.

**M.I.T. Club of Rochester Scholarship Fund (1968)**

This fund was established by the M.I.T. Club of Rochester — income is used for scholarships to undergraduates, with preference given to students from Rochester, New York.

**Morningstar Scholarship (1953)**

This undergraduate scholarship gives first preference to students in the Department of Physics. Grants are equivalent to one term's tuition and are continued to a recipient for the entire undergraduate period.

**Fred W. Morrill Scholarship Fund (1941)**

The income from this bequest of Hattie B. Morrill is to be used "for the purpose of providing financial assistance to some student or students at the discretion of the Trustees of said Institute. . . ."

**Frederick Taft Moses Scholarship Fund (1959)**

This scholarship provides four-year awards ranging from \$200 to \$2,000 annually, and is offered to young people of superior talent and promise.

**Gertrude B. Newman Scholarship (1952)**

This bequest from the estate of Mrs. Gertrude B. Newman is to aid worthy and deserving students.

**Niarchos Scholarship (1956)**

Established by Stavros S. Niarchos as a memorial for merchant mariners who gave their lives during World War II, these grants provide opportunities for higher education to the sons of merchant seamen. The awards are based upon demonstrated need and achievement in secondary school experience. In the selection of candidates, first preference is given to sons of merchant seamen and ships' officers who lost their lives in the line of duty during wartime. In other cases, candidates' fathers must be regularly employed in a seagoing capacity or, if deceased, so last employed. These awards are not limited to courses in marine engineering and naval architecture, but consideration may be given to the desire of qualified candidates to pursue careers in these fields.

**Nichols Scholarship (1895)**

This bequest from Mrs. Betsy F. W. Nichols constitutes the Nichols Scholarship in memory of her son, William Ripley Nichols '69, for sixteen years Professor of General Chemistry at the Institute. Preference is given to students in the Course in Chemistry.

**Charles C. Nichols Scholarship (1904)**

This bequest from Charles C. Nichols constitutes a scholarship fund.

**Hart and Arthur Nichols Scholarship Fund (1966)**

This fund, in process of being established by gifts from W. Hart Nichols '27 and Arthur A. Nichols '28, is to be used for undergraduate scholarships.

**William E. Nickerson Scholarship Fund (1949)**

The income from this fund, established by the Nickerson Trust, is used for a scholarship for a worthy student.

**Howard A. Noble '97 Scholarships (1956)**

The income of a fund established under the will of Catherine B. Noble and enriched by the bequest of Howard A. Noble, is used to maintain scholarships in engineering.

**John Felt Osgood Scholarship (1909)**

This bequest was made by Elizabeth P. Osgood "to establish and maintain a scholarship in electricity in memory of my husband, John Felt Osgood."

**Louise Parks Knight and Charles F. Parks Memorial Fund (1952)**

Established as a memorial to Louise Parks Knight and her father, Charles F. Parks '75, this fund is "used for the aid of poor but worthy students who have already entered upon a course of study but are unable to finish owing to lack of funds."

**George L. Parmelee Fund (1921)**

This bequest from George L. Parmelee of "one third of my property and estate" specified that "interest thereof be used for tuition of worthy students, either special or regular, according to the direction of the Faculty."

**Frank E. and Seba B. Payne Foundation Scholarship Fund (1962)**

A gift of the Frank E. and Seba B. Payne Foundation is used for scholarships in the School of Engineering.

**Langdon Pearse Memorial Scholarship (1958)**

This fund was established by gift of Mrs. Langdon Pearse in memory of Langdon Pearse '01. Income from the fund is used toward the tuition of students in the field of sanitary engineering, with second preference to undergraduate students in the field of civil engineering.

**Frank Stetson Pecker Fund (1947)**

This fund was established by the wills of Frank Stetson Pecker and Annie J. Pecker for scholarships.

**Richard Perkins Fund (1887)**

The income from half of this bequest from Richard Perkins is available for the "support of free scholarships in said Institute."

**St. Elmo Tower Piza Memorial Fund (1962)**

The income of this fund, a bequest of Margaret Piza Crane established in memory of her brother, St. Elmo Tower Piza '15, provides for "tuition or expenses of a man or woman student in any of the five years of the Course in Architecture." The grants are awarded on the basis of scholarly achievement, demonstrated qualities of leadership, and financial need, but entirely without regard to race, color, or creed.

**Charles H. and Helen Bartlett Pray Fund (1950)**

Established under the wills of Charles H. and Helen Bartlett Pray, this fund provides "for scholarships for needy young men."

**Florence E. Prince Fund (1943)**

This bequest of Florence E. Prince is "for the aid of worthy students who may need assistance in the matter of maintenance and living expenses while pursuing their studies."

**Procter and Gamble Scholarship (1955)**

The Procter and Gamble Company awards a four-year scholarship to each entering freshman class. The stipend of the scholarship is distributed by the Student Aid Committee to one or more outstanding freshmen, on the basis of demonstrated need.

**George H. Rand Scholarship (1958)**

The income of this fund, established by a bequest of the estate of George H. Rand, provides scholarships for deserving undergraduate students.

**Thomas Adelbert Read Scholarship (1934)**

This bequest from Julia A. Read was designated "to establish the Thomas Adelbert Read Scholarship, in memory of my late brother of that name; the income of said fund to be awarded to some worthy and needy student of that institution, preferably to a resident of Fall River...."

**Willis Ward Reeves, Jr. Fund (1945)**

Established by Mr. and Mrs. Willis Ward Reeves of Hazard, Kentucky, "as a memorial to their son, Willis Ward Reeves, Jr. '46, late Lieutenant, U.S. Army Air Forces, killed in action over France during World War II... the income to be used for scholarship aid to deserving undergraduate students, with preference to those from Kentucky."

**Arthur Reid Memorial Scholarship (1966)**

This fund is available to qualified needy students from the Avon, Massachusetts, community and was established by the Institute as a Memorial to Arthur Reid, who passed away while employed at M.I.T.'s Laboratory for Nuclear Science, assisting with frontier developments in High Energy Physics.

**Charles A. Richards Fund (1939)**

This bequest is "known as the Charles A. Richards Fund... the income only for assistance of poor Protestant students in the Institute."

**Frederick L. Richards Memorial Fund (1960)**

The income of this fund, established as a memorial to Frederick L. Richards '95 by his sister, is used to provide scholarship assistance to undergraduate students in chemistry, chemical engineering, or other curricula based on chemistry.

**I. D. Richheimer Memorial Scholarship (1961)**

The income of this fund, bequeathed as a memorial by Rose N. Richheimer, is used for scholarships to worthy students.

**John Roach Scholarship Fund (1937)**

This bequest from Emeline Roach constitutes a fund "to be known as the John Roach Scholarship Fund, the income to be used to provide an annual scholarship to a needy and deserving student pursuing the Course in Naval Architecture and Marine Engineering."

**Karl Robbins Scholarship (1951)**

First preference for this scholarship, a gift of the Robbins Foundation, is for either a graduate or undergraduate in textile technology; second preference is to a student in mechanical engineering.

**Willard F. Rockwell Scholarship Fund (1961)**

The income of this fund, established in honor of Willard F. Rockwell '08, is used to assist needy and worthy undergraduates.

**William Barton Rogers Scholarships (1947)**

A limited number of four-year grants established in honor of William Barton Rogers, founder of the Institute, enable young men of superior ability and future promise but of limited financial means to pursue an education in engineering, science, or architecture. Stipends are awarded according to demonstrated need. These scholarships are open to all freshmen with no restrictions of geographical location.

**William P. Ryan Memorial Fund (1935)**

The income from this fund, established by friends of the late Professor William P. Ryan '18, is used for scholarship aid (graduate or undergraduate) in chemical engineering, the award to be made on recommendation of the Head of the Department of Chemical Engineering.

**John P. Schenkl Fund (1922)**

This bequest from Johanna Pauline Schenkl is "to be held in trust to establish one or more scholarships in the Department of Mechanical Engineering" in memory of her father, John P. Schenkl.

**George Scher Fund (1949)**

This gift of George Scher established a fund to be used for scholarship purposes.

**Science Scholarship (1956)**

Donated by friends of M.I.T., this scholarship is designated to assist a needy and promising student in the field of science after the completion of his freshman year. The award is made to citizens of the United States up to the amount of tuition.

**Science Teaching Scholarships (1955)**

Established by the Institute to encourage young people who wish to follow a career in science teaching in secondary schools, these scholarships are open to students who have completed two years at the Institute and plan to follow a curriculum in science and mathematics teaching. Grants are based on demonstrated need, with a maximum of full tuition.

**Paul D. Seghers, Jr. Scholarship (1948)**

This award was established by the estate of May Towles Kirk Seghers in memory of Second Lieutenant Paul Dotreng Seghers, Jr. '45, U.S. Army Corps of Engineers, who was killed in action in the Asiatic area on July 11, 1945, to aid worthy and needy Protestant students at the discretion of the Institute.

**Louis E. and Theresa Seley Student Aid Fund (1961)**

The income of this fund, the gift of Louis A. Seley, provides scholarships for undergraduate students who are needy and worthy.

**Irving Shakhov Scholarship (1954)**

The income from this fund, established as a memorial for Irving Shakhov '43, is available for an undergraduate scholarship for a student in the Department of Physics.

**Frederick J. Shepard, Jr. Fund (1959)**

Income from the gift of the Lewis-Shepard Fund in honor of Frederick J. Shepard, Jr. '12, is used to assist needy and worthy young men from New Hampshire with first preference to graduates of Pinkerton Academy in Derry Village.

**James and Donald H. Sheridan Scholarships Fund (1961)**

The income of this fund, established by the bequest of James Sheridan, is used to aid needy and worthy students.

**Frank Arnold Sherman Scholarship Fund (1947)**

The income from this bequest of Frank Arnold Sherman '03 is used "first and preferentially for a scholarship to some boy graduate of Westerly High School, Rhode Island, or if no suitable candidate, preferentially to a boy graduate of some other Rhode Island high school."

**Thomas Sherwin Scholarship (1871)**

Founded with a gift from the English High School Association in memory of Thomas Sherwin, this scholarship is limited to graduates of the English High School of Boston who are pursuing a regular course at the Institute.

**Sloan National Scholarships (1953)**

Established by the Alfred P. Sloan Foundation, Inc., these scholarships provide aid for students in science and engineering and are open to male students resident throughout the continental United States. Sloan National Scholars hold positions of academic honor at the Institute. Awards are made to men of high character, sound personality, leadership potential, and academic promise. Grants range from \$200 prize scholarships to \$2,500 per annum. Awards are renewable each year, subject to performance and in accordance with changing financial need.

**G. H. Miller Smith Fund (1945)**

Established by Mr. and Mrs. George Blackwell Smith of Lookout Mountain, Tennessee, "as a memorial to their son, G. H. Miller Smith '43, late Lieutenant, U.S. Army, killed in action in France during World War II . . . the income to be used for scholarship aid to deserving undergraduate students, with preference to those from Tennessee."

**H. Hilliard Smith Fund (1950)**

This bequest of Grace J. F. Smith in memory of her husband, H. Hilliard Smith '96, is for the purpose of assisting young men in architecture.

**Horace T. Smith Fund (1931)**

This bequest from Horace T. Smith '98 provides scholarships to worthy students, with preference given to graduates of the East Bridgewater (Massachusetts) and Bridgeport (Connecticut) High Schools.

**Society of Naval Architecture and Marine Engineering Scholarships (1957)**

These grants were established by the Society of Naval Architects and Marine Engineers. Four scholarships, each in the amount of \$1000, for students in, or planning to be in the Department of Naval Architecture and Marine Engineering. Preference will be given to secondary school graduates of outstanding promise. These awards may be renewed annually upon application.

**Sons and Daughters of New England Puritan Colony Scholarship (1931)**

Holder of this scholarship, made possible by a gift from the Sons and Daughters of New England Puritan Colony, must be of New England ancestry.

**Anna Spooner Fund (1939)**

The income from this bequest is used "in assisting meritorious students."

**Standard Oil Company of California Scholarships (1955)**

This annual grant, sponsored by the Standard Oil Company of California, is made to a senior in chemical engineering.

**Wentworth Stevens Fund (1957)**

One-half of the income from this fund, established by William Wentworth Stevens '98 in honor of his mother and father, is made available for scholarship aid.

**Philip Stockton Fund (1961)**

The income from this fund, given in memory of Philip Stockton by Mrs. Philip Stockton, is used for undergraduate scholarships.

**Albert F. Sulzer Scholarship (1955)**

Established under the will of Albert F. Sulzer, this fund is "to be used by the trustees of the Massachusetts Institute of Technology for the establishment and maintenance of scholarships for meritorious first-year students who are non-residents of the State of Massachusetts."

**Tau Beta Pi Memorial Scholarship Fund (1947)**

This gift from members of Tau Beta Pi, Massachusetts Beta Chapter, on their twenty-fifth anniversary, provides an annual award of \$500 for freshmen to be selected by the M.I.T. Student Financial Aid Committee. There is no restriction of geographical area, and candidates are selected on high scholastic standing, character, and future promise.

**Howard F. Taylor Memorial Scholarship Fund (1962)**

The income from this fund, donated by students, friends, and associates of Professor Taylor, is used for assistance to undergraduate and graduate students interested in foundry and allied fields.

**Lawrence E. Teich '40 Memorial Scholarship Fund (1966)**

This fund, established by the Curt Teich Foundation as a Memorial to Lawrence E. Teich, Class of 1940, who gave his life while on active duty during World War II, is used to support the undergraduate scholarship program.

**Texaco Scholarships (1959)**

This gift of the Texas Company is to assist worthy and needy students who have completed two years of college work and who have selected a curriculum which will prepare them for a career in the petroleum industry.

**Mary Thacher Scholarship (1956)**

This bequest established a scholarship fund, the income of which is applied against the tuition of needy students, with first preference to students from Yarmouth, Massachusetts; second to students from the Cape Cod region; and third to students from the Commonwealth of Massachusetts.

**Richard H. Tingey Memorial Fund (1962)**

This fund, a gift from the Herman W. Falk Foundation, was established in memory of Richard H. Tingey '27, a noted ship propulsion engineer. Its income provides scholarship grants to undergraduate students.

**Samuel E. Tinkham Fund (1924)**

Established by the Boston Society of Civil Engineers, this fund is to aid a worthy student in civil engineering.

**Arthur L. Townsend Fund (1960)**

Income of this fund, established by the bequest of Professor A. L. Townsend '13 of the Department of Mechanical Engineering and Director of Lowell Institute, is used exclusively for M.I.T. scholarships. Preference is given to worthy and well-qualified graduates of Lowell Institute who are in good standing and taking a regular full-time day program, preferably in mechanical or electrical engineering.

**Y. T. Tsai Memorial Scholarship (1955)**

This fund for worthy and needy students was established by gift.

**John L. Turner Fund (1960)**

Income of this fund, established by John L. Turner '31, is used to assist needy and worthy young men. First preference is given to students who are direct relatives of the donor or residents of the State of Mississippi; second preference to students domiciled in the Southeast.

**Uniroyal Foundation Scholarships (1957)**

These grants, established by a gift from the Uniroyal Foundation, are awarded to students in the junior or senior year who demonstrate need for financial assistance, who show capacity for higher education, and who are interested in a career in industry. The Foundation expects that beneficiaries will assume a moral obligation to repay a part of their grants after graduation and over a reasonable period of time; such repayments will be made to the Institute's scholarship fund and will then be used to help other needy students.

**Susan Upham Fund (1892)**

This gift from Susan Upham is "to assist students deserving financial aid."

**Samson R. Urbino Fund (1927)**

This bequest from Samson R. Urbino is "to be used to aid students who need assistance, Germans preferred."

**Vermont Scholarship (1924)**

This scholarship "in memory of Vermonters who, having received their education at the Institute, served as engineers in the Armies of the Allies in the World War" was founded by a gift from Redfield Proctor

'02. The income is awarded annually "to worthy students . . . preference to any *bona fide* residents of Vermont doing undergraduate work at the Institute, and also Vermont students doing graduate work, or students who are graduates of or transfer from Middlebury College or Norwich University . . . who shall meet regular scholastic and other requirements."

**F. P. von Olker Fund (1962)**

The income of this fund, established by the bequest of F. P. von Olker, is to be used "yearly in giving scholarships for the benefit of deserving students."

**Ann White Vose Fund (1896)**

This bequest from Ann White Vose was designated "to establish free scholarships in M.I.T. . . . such person enjoying benefit . . . shall be worthy young men of American origin."

**Arthur M. Waitt Fund (1925)**

This bequest from Arthur M. Waitt was designated for "assisting needy and deserving students in the second-, third-, and fourth-year classes of the Mechanical Engineering Course."

**Grant Walker Fund (1943)**

The income from this bequest is used "for scholarships for deserving students."

**Muriel Alvord Ward Fund (1960)**

The income of this fund, established by the gift of Mrs. Ferrari P. Ward, is used to assist needy and worthy undergraduates.

**Henry E. Warren Fund (1961)**

As a memorial to Henry E. Warren '94, the Trustees of the Warren Benevolent Fund, Inc., contribute to the support of a limited number of entering freshmen. Grants are made by the Committee on Student Financial Aid to students who demonstrate financial need. The Committee gives first preference to well-qualified students domiciled in New England and second preference to women students from any part of the United States or its possessions. It is hoped that beneficiaries of this fund will make contributions to the Warren Fund after graduating, so that other students may benefit from it.

**Henry Arthur Waterman Scholarship Fund (1969)**

The income of this fund, established by the will of Henry A. Waterman, is used for scholarships to benefit worthy and needy undergraduate students.

**John J. Watson Memorial Fund (1963)**

The income of this fund, given by the Watson Foundation as a memorial to John J. Watson, one of its founders, is for scholarships for needy and deserving undergraduates.

**James Watt Scholarship (1942)**

This bequest of Jennie A. Douglas established "a scholarship in mechanical engineering to be known as the James Watt Scholarship."

**Louis Weissbein Fund (1915)**

This bequest from Louis Weissbein was designated "to found a scholarship to be awarded each year to a promising student, preference to be given a Jewish boy in making the award."

**Western Electric Scholarships (1956)**

These two scholarships in engineering, established by the Western Electric Company, are awarded on the basis of need and ability, with a maximum grant of \$1,000.

**Frances Erving Weston Fund (1912)**

This bequest of Frances Erving Weston is "to aid a native-born American Protestant girl of Massachusetts."

**Samuel Martin Weston Fund (1912)**

This bequest of Frances Erving Weston was made to found a scholarship in memory of her husband, Samuel Martin Weston, "to aid a native-born American Protestant boy, preference to be given one from Roxbury."

**Archer E. Wheeler Scholarship Fund (1957)**

This fund is a bequest of Archer E. Wheeler '95; its income is used for scholarship towards fees for undergraduates at the Institute.

**Kay Hill White Memorial Fund (1956)**

Income from this fund, established by Frances French White in memory of Ray Hill White '05, is used for scholarship assistance for poor and needy students.

**Amasa J. Whiting Fund (1927)**

This bequest from Mary W. C. Whiting was designated "to constitute a fund to be known as Amasa J. Whiting Fund . . . the income . . . to pay or help to pay tuition of deserving students whose means are limited . . . Preference shall be given to students coming from the town of Hingham, Massachusetts."

**Granger Whitney Fund (1957)**

Income of this bequest, made by the will of Julia Whitney in the name of Granger Whitney '87, is used to assist worthy students of the Institute, with first preference being given to students residing in the area of the M.I.T. Club of Detroit.

**Harold O. Whitney Scholarship Fund (1968)**

This fund was established by members of the M.I.T. Class of 1916 in honor of Harold O. Whitney '16. The income of the fund is used for scholarships for male native-born citizens of the United States.

**Thomas H. Wiggin '95 Fund (1965)**

Established by the bequest of Thomas H. Wiggin '95, the income is used to provide scholarship assistance to needy and worthy students.

**Elizabeth Babcock Willmann Fund (1935)**

This bequest from Elizabeth Babcock Willmann is "to help in paying the tuition of girl students taking the Chemistry Course."

**Wilson Scholarship (1953)**

Gift of John J. Wilson '29 in memory of his parents, the income for scholarships to worthy undergraduates.

**Gilbert Williams Winslow Memorial Fund (1967)**

A gift from Mrs. Edward Williams Winslow established this fund in memory of her son, Gilbert Williams Winslow '37. The income of this fund is available to assist undergraduates, with a preference for students in Civil Engineering.

**Morrill Wyman Fund (1915)**

The income from this bequest of Morrill Wyman is "applied in aid of deserving and promising students, but without exclusion in regard to rank, upon the understanding that if later in life the person receiving aid shall find it possible, he shall reimburse the said fund for moneys so applied, but there shall be no legal obligation to make such reimbursement."

**Conrad Henry Young Scholarship Fund (1957)**

Established by the will of Abby W. Young in memory of Conrad Henry Young '96 the income of this fund is used for scholarships.

## Financial Aid for Graduate Students

Financial aid is available to graduate students from a variety of sources and in a variety of forms — fellowships, traineeships, scholarships, teaching and research assistantships, and loans. A general description of the various sources and forms of aid and of the relevant requirements and application procedures will be found in Section 3 of this Catalogue.

Listed here are fellowships and scholarships which have been generously given by individuals and corporations. About 250 awards are made from these funds each year. A student who files an Application for a Graduate Fellowship, Traineeship, or Scholarship, as explained in Section 3 of the Catalogue, is automatically considered for all of the awards for which he is eligible.

### VARIOUS FIELDS

#### Edward Austin

Bequest of \$360,000, the income for needy, meritorious students and teachers to assist them in paying academic expenses.

#### Joseph Warren Barker

Fellowship for a graduate student in engineering.

#### Boeing Company

Fellowship for a graduate student in an engineering discipline related to the aerospace industry, with preference given to a student in aeronautical or electrical engineering; tuition plus a stipend of \$2,100.

#### William Sumner Bolles

Bequest of \$25,000 by William P. Bolles in memory of his son, to support a fellowship, travelling scholarship, or resident scholarship, the recipient of which must have character, ability, or promise.

#### M.I.T. Canadian Trust Fund

A limited number of grants for graduate study leading to advanced degrees in any of the five academic schools for graduates of Canadian universities and colleges who are Canadian citizens. For consideration, an applicant should direct a request by letter to the Executive Officer, Graduate School, M.I.T., prior to February 15. Awards will be announced in late March or early April.

#### Helen Collamore

Bequest of \$10,000, the income for aid to women students in post-graduate courses.

#### Douglas Aircraft Company

For a highly recommended graduate student in aeronautics and astronautics, or electrical, or mechanical engineering; tuition plus not less than \$2,100.

#### Daniel W. Edgerly

Bequest of \$240,000 by Daniel W. Edgerly '98 the income for undergraduate scholarships for upperclassmen or for graduate scholarships and fellowships in the Science Departments, preferably in chemistry, physics, or biology.

#### Alfred Willard French

Founded in memory of Alfred Willard French '89 by the French Oil Mill Machinery Company, for a graduate student in engineering (preferably mechanical) or business administration, with preference to a student from within a 100-mile radius of Piqua, Ohio.

#### Frank M. Greenlaw

Bequest of \$74,000 by Frank M. Greenlaw '90 the income to establish a fellowship for research in physics or chemistry or related fields of learning.

#### International Business Machines Corporation

Three fellowships for doctoral candidates in the fields of physics, chemistry, mathematics, electrical engineering, computer science, or materials science. Stipend of \$3,000 plus dependency allowance; also tuition and department allowance.

#### Joint Center For Urban Studies

Doctoral fellowships to graduate students in any department of either Harvard or M.I.T. writing a doctoral dissertation on any aspect of urban life, in fields such as: government, science and engineering, social relations, design, economics, planning, history, law, or industrial management; award including stipend up to \$5,500.

#### John A. Lyons

Under the will of the late John A. Lyons, five or more fellowships will be available in 1967 and subsequent years for the support of graduates of Boston College, subject to the following provisions: the recipients must be of the Roman Catholic faith; they must have been born within a radius of 20 miles of the Massachusetts State House; preference will be given to applicants whose father and mother were of Irish descent; the fellowships are only for those who do not consume alcohol in any form; they must live at the Institute during the academic year. The fellowships will cover tuition and will provide a stipend to help meet living expenses. They will be renewable from year to year.

#### Henry Bromfield Rogers

Bequest of \$20,000 by Anna Perkins Rogers, the income for a fellowship or scholarship for women graduates of M.I.T. or other colleges whose graduate work is carried on at M.I.T.

#### Henry Saltonstall

Bequest of \$10,000, the income to aid one or more needy students.

#### James Savage

Bequest of \$10,000, the income for scholarships in the institution "where my son-in-law, William B. Rogers, is President."

#### Solar Energy

Four fellowships for graduate students, candidates for the doctorate in chemistry, physics, or engineering or candidates for the degree of Master in Architecture, for study and research which may lead to improved use of solar energy; tuition plus \$2,100, with dependency allowance for a married student; normally for two terms but renewable.

#### Susan H. Swett

Bequest of \$10,000, the income to support a graduate scholarship.

#### Gerard Swope

Gift of \$100,500 by Gerard Swope '95, the income to support fellowships for graduate students of exceptional ability and promise.

#### United States Steel Foundation

One fellowship for student who shows interest in graduate program relevant to a career in management based on a science or engineering background. Annual stipend of \$5,000 plus tuition.

#### Thomas Upham

Bequest of \$409,000 by Marcella B. Upham, the income for assisting poor and deserving students or graduates of the Institute.

#### Jonathan Whitney

Bequest of \$525,000 by Mrs. Francis B. Green, the income to assist poor and deserving young men and women in obtaining an education at M.I.T.

#### Hugh Hampton Young Memorial Fund

A fund in memory of Dr. Hugh Hampton Young to provide premium financial assistance to outstanding students with exceptional breadth of interests who show great promise of becoming capable and efficacious directors and co-ordinators of broad projects covering many disciplines and who are selected with great discrimination and with more consideration given to personal qualities and character than to scholastic record. Open to undergraduate, graduate and postdoctoral students.

### AERONAUTICS AND ASTRONAUTICS

#### AC Electronics Fellowship

For a graduate student in instrumentation; tuition plus \$2,100.

#### Aviation Week

For a male U.S. citizen enrolled for an advanced degree; tuition plus \$2,100.

#### Donald W. Douglas

Gift of \$73,725 in honor of Donald W. Douglas '14, Honorary Chairman of the Board of Directors of the McDonnell Douglas Corporation, the income to be used to support deserving graduate students in aerospace and related fields.

#### Richard C. du Pont

Memorial fellowship in aeronautics and astronautics, for a graduate student in any year of his work toward an advanced degree; tuition plus \$2,100.

#### Lester D. Gardner

Fellowship in memory of Lester D. Gardner '98; tuition plus \$2,100.

#### General Dynamics

For a graduate student in aeronautics and astronautics; tuition plus not less than \$2,100.

#### Lockheed Leadership Fund

For a graduate student in the field of aerodynamics; tuition plus not less than \$2,100.

## ARCHITECTURE AND PLANNING

**Avalon Foundation**

Gift of \$250,000, the income to support fellowships and scholarships for graduate students in the School of Architecture and Planning.

**Francis Ward Chandler Memorial Fund**

Bequest of \$100,000; net income to be used to provide scholarship assistance to graduate or undergraduate students with first preference being given to students in architecture.

**W. Danforth Compton Memorial**

Gift of \$90,000 in memory of W. Danforth Compton '47, the income to support fellowships in the Department of Architecture.

**William Emerson Fund**

The income of the bequest of \$29,000 of the late William Emerson, Dean of the School of Architecture, is used for fellowships in the Department of Architecture.

**William Emerson**

Gift of \$5,000 by Dean William Emerson, the income to support graduate students in City Planning.

**William and Frances Emerson**

Gift of \$100,000, the income to aid graduate and special students in the School of Architecture and Planning.

**Ernest A. Grunsfeld Fund**

To underwrite living expenses up to \$2,000 per year for a black student admitted to one of the graduate professional programs in architecture.

**William E. Hartmann Scholarships (1962)**

This fund was established to assist students in architecture who hold baccalaureate degrees from an institution not offering professional architectural studies. Awards may be made for the first year at the Institute.

**Samuel A. Marx**

Established by gifts of \$33,900 in memory of Samuel A. Marx '07, the income for an annual fellowship in the School of Architecture and Planning.

## CHEMICAL ENGINEERING

**American Cyanamid Company**

For graduate students attending the School of Chemical Engineering Practice. Award is adjusted to pay pro-rate tuition and expenses while at the Bound Brook Station.

**Eastman Kodak Company**

For a graduate student in chemical engineering; tuition plus \$1,075 per term.

**Esso Research and Engineering Company**

For a graduate student in chemical engineering; tuition plus \$1,075 per term.

**Arthur D. Little**

Fellowship in memory of Arthur D. Little '85, for a candidate for a doctorate; tuition plus \$1,075 per term.

**Procter and Gamble Company**

For a graduate student in chemical engineering; tuition plus \$1,075 per term.

**Scientific Design Company**

For a graduate student in chemical engineering; tuition plus \$1,075 per term.

**Union Carbide Chemicals Division**

For a graduate student in chemical engineering; tuition plus \$1,075 per term.

**Union Oil Company of California Foundation**

For graduate students attending the School of Chemical Engineering Practice. Award is adjusted to pay a portion of tuition and expenses.

## CHEMISTRY

**Lewis Paul Chapin**

Bequest of \$100,000 by Mrs. Mary Richardson Chapin in memory of her husband Lewis Paul Chapin, formerly Assistant in Inorganic Chemistry, the income to assist worthy postgraduate students in the Department of Chemistry.

**Goodyear Tire and Rubber Company**

Fellowship for a graduate student in chemistry; tuition plus \$2,250.

**Arthur D. Little**

Fellowship in memory of Arthur D. Little '85, for a candidate for a doctorate in chemistry; tuition plus \$2,800 for 12 months.

**Minnesota Mining and Manufacturing Company**

For a graduate student in chemistry; tuition plus \$2,100.

**Forris Jewett Moore Memorial**

Gift of \$24,000 by Mrs. Forris Jewett Moore in memory of her husband, formerly Professor of Organic Chemistry, the income to assist a graduate in his studies at M.I.T. or elsewhere with preference given to a student in organic chemistry; tuition plus \$2,100.

**James Flack Norris**

Bequest of \$65,000 by James Flack Norris, formerly Professor of Organic Chemistry, the income to support a graduate fellowship; tuition plus \$2,100.

**Procter and Gamble Company**

Tuition plus \$2,100 single; tuition plus \$2,500 married.

**Union Carbide Corporation**

For a graduate student in his final year of predoctoral study; tuition plus \$1,800 single, \$2,100 married.

## ECONOMICS

**Center for International Studies**

For graduate students interested in economic development and international economics; tuition plus \$2,000.

**Clarence J. Hicks Memorial**

For a graduate of not more than five years (exclusive of military service) since his baccalaureate from a college or university in the U.S. or Canada, who is a candidate for a doctorate at M.I.T. in the field of industrial relations; tuition plus stipend.

**Joseph N. Scanlon**

In memory of Joseph N. Scanlon, formerly a Lecturer at M.I.T. in industrial relations; tuition plus stipend.

## ELECTRICAL ENGINEERING

**Grass Instrument Company**

An endowment established by the Company and Dr. Albert M. Grass '34, the income for fellowships in electrical engineering, preferably for foreign students. Awards are made as often as sufficient income has accumulated to provide an appropriate grant to a student.

**Schlumberger Foundation**

For a graduate student in electrical engineering; tuition plus a stipend of not less than \$2,500.

## MANAGEMENT

**Dresser Industries, Inc.**

Graduate fellowships for U. S. black and disadvantaged students in management.

**Sloan School of Management**

For college graduates seeking the Master's or doctor's degree who have demonstrated substantial academic competence and leadership promise. A number of fellowships and scholarships.

**MECHANICAL ENGINEERING**

**Cummins Engine Foundation**

For a U.S. citizen and full-time student preferably working toward a doctorate; tuition for 12 months plus \$2,800 single or married with no children, \$3,200 married with children. Stipend prorated for 9 months.

**The Camille and Henry Dreyfus Foundation, Inc.**

For a candidate for the M.S. or the doctorate in Mechanical Engineering with research interest in fibrous materials. Tuition plus \$2,000 single, for 9 months.

**Wilfred Lewis**

Gift of \$5,000 by Mrs. Emily Sargent Lewis in memory of Wilfred Lewis '75, the income to be applied for the support of a graduate student in Mechanical Engineering.

**METALLURGY AND MATERIALS SCIENCE**

**Allegheny-Ludlum Steel Corporation**

For a graduate student whose thesis research is on a topic of interest to the alloy steel industry; tuition plus stipend.

**American Metal Climax Foundation**

For a graduate student whose research is in the general area of non-ferrous extractive metallurgy; tuition plus stipend.

**American Optical Corporation**

For a graduate student whose research is in the general area of glass science and technology; tuition plus stipend.

**Climax Molybdenum Company**

For a graduate student in physical metallurgy; tuition plus stipend.

**Fairchild Camera and Instrument Corporation**

For a graduate student whose research is in glassy materials or semiconductor ceramics; tuition plus stipend.

**General Telephone and Electronics Laboratories, Inc.**

For a graduate student in the field of electronic materials; tuition plus stipend.

**International Nickel Company**

For a graduate student in the field of materials science and engineering; tuition plus \$2,250.

**Kennecott Copper Corporation**

For a graduate student in metallurgy and materials science; tuition plus \$2,250.

**National Steel Corporation**

For a graduate student in metallurgy and materials science whose research is in the general field of the plastic behavior of steel; tuition plus \$2,250.

**National Steel Corporation**

For a graduate student whose research is in the general area of metallic corrosion; tuition plus stipend.

**Owens-Illinois Incorporated**

For a graduate student whose research is in the field of glass science; tuition plus stipend.

**Titanium Metals Corporation of America**

For a graduate student working in the field of deformation processing; tuition plus \$2,250.

**NAVAL ARCHITECTURE AND MARINE ENGINEERING**

**General Dynamics Corporation**

A fellowship for graduate study in Naval Architecture and Marine Engineering; tuition plus \$2,100 for two terms, and an allowance for thesis expense.

**Gulf and South American Steamship Company**

Fund established by Gulf and South American Steamship Company from which scholarship grants may be made upon initiative of the Department of Naval Architecture and Marine Engineering. Preference is given to students in the fifth year in Shipping and Shipbuilding Management (Course XIII-B).

**NUCLEAR ENGINEERING**

**General Electric Foundation**

For a graduate student in nuclear engineering; tuition plus \$2,025 single, \$2,500 married.

**NUTRITION AND FOOD SCIENCE**

**Bernard E. Proctor Memorial**

Scholarship in memory of Professor Bernard E. Proctor '23, formerly head of the Department; tuition.

**PHYSICS**

**Karl Taylor Compton Fellowships in Physics**

For a graduate student in physics; tuition plus stipend of \$3,000 for the academic year and \$1,000 for summer study.

**Fairchild Foundation Fellowship in Applied Physics**

For a U.S. citizen or permanent resident in the field of applied physics; tuition plus \$2,400 for nine months, and allowances.

**Kennecott Copper Corporation**

For a graduate student in physics; tuition plus not less than \$1,800 single or married without children, \$2,000 married with one or more children.

**RESEARCH LABORATORY OF ELECTRONICS**

**Hughes Aircraft Company**

For graduate work in electronics; tuition plus \$2,100 single, \$2,700 married.

**Radio Corporation of America**

For graduate work in electronics; tuition plus \$2,100 single, \$2,700 married.

**Sperry Rand Corporation**

For graduate work in electronics; tuition plus \$2,100 single, \$2,700 married.

**Xerox Corporation**

For graduate work in information science; tuition plus \$2,100 single, \$2,700 married.

## Student Educational Loan Funds

Loans are available to both graduate and undergraduate students at M.I.T. The amount of any loan granted by the Student Aid Committee is based on financial need. Information about how financial need is determined and the procedure for application will be found in this Catalogue: Section 2 for undergraduates and Section 3 for graduates.

### GOVERNMENT INSURED LOAN PROGRAM (GILP)

The Federal government's Guaranteed Loan Program is designed to aid students in meeting the expenses of their education. M.I.T. expects each applicant for aid to pursue the possibility of loan assistance under the Program, which is administered by the several states. The loans are obtained through local banks and other lending agencies under certain conditions, and prospective students would be well advised to inquire at the earliest possible date about their eligibility for such assistance. The interest rates and repayment provisions are fixed by Federal and State legislation, but are by design more favorable than standard commercial terms.

### TECHNOLOGY LOAN FUND (TLF)

M.I.T.'s Technology Loan Fund, established in 1931, was the first major loan fund established by a college; today it is the nation's largest. Since its founding, M.I.T. students have benefited from more than \$10,000,000 in loans from this fund. Awards are made on the basis of financial need; and in the interest of its students, M.I.T. sets reasonable limits on the annual amounts borrowed from this fund, and on the total indebtedness accumulated by each borrower.

### NATIONAL DEFENSE STUDENT LOAN (NDSL) FUND

M.I.T. also administers loan awards under the National Defense Student Loan Program, using need criteria established by the Student Aid Committee, and eligibility criteria established by the U.S. Department of Health, Education and Welfare. The maximum loan available to an undergraduate from this program for any one academic year is \$1,000; no undergraduate may borrow more than a total of \$5,000.

### REPAYMENT TERMS FOR M.I.T. AND NDS LOANS

Repayment rates for loans acquired directly through the Institute will be established in each case by M.I.T. on graduation or termination of enrollment. (NDSL regulations established by the Federal government state a maximum repayment period of ten years on NDSL notes. The regulations further outline a minimum annual repayment of \$180 on these notes.)

Repayment commences six months after graduation. A student may apply for deferment of repayment if he enters a graduate school, military service, or the Peace Corps. (A maximum of three years' deferment is allowed in the latter two cases.)

## OTHER LOAN FUNDS

The following funds have been established for special purposes at the Institute. Except where stated, these loans funds are administered under terms similar to those governing the Technology Loan Fund, and no separate application need be made.

### *Boston Stein Club Freshman Loan Fund (1953)*

Established by the M.I.T. Boston Stein Club, this fund is designed to assist needy students resident in the Greater Boston area. It is open only to first-year students who show good promise, and, in general, grants are for less than full tuition. Recipients are required to sign notes to repay amounts granted, without interest, after graduation.

### *Anna J. and Francesco Casaretto Loan Fund (1966)*

Established in memory of Anna J. and Francesco Casaretto, to be operated as a loan fund for the benefit of needy and worthy students, regardless of race, creed or color.

### *Francis W. Chandler Loan Fund (1927)*

This fund was established as a loan fund to assist worthy and needy students in the Department of Architecture.

### *Ruth Hornblower Churchill Memorial Loan Fund (1958)*

Established by a gift in the name of Ruth Hornblower Churchill, this loan fund is used to help needy students at M.I.T.

### *Class of 1917 Loan Fund (1937)*

The income and principal of this fund is used to assist deserving students, preference given to direct descendants of members of the Class of 1917. Beneficiaries are expected to issue notes agreeing to repay the face value, without interest, of amounts received.

### *Class of 1963 Loan Fund (1963)*

This fund, established by the members of the M.I.T. Class of 1963, is used as a source of short-term emergency and special-use funds, without some of the restrictions associated with the Institute's educational loan funds. Repayment is expected before graduation in most cases; where appropriate the repayment period may be extended to one year beyond graduation. Preference is given to undergraduates.

### *Thomas F. and Lida Niles Connors Loan Fund (1962)*

Established by the bequest of Lida Niles Connors, the principal and income of this fund is available to "qualified and deserving students who are undergraduates in Civil Engineering." Procedures of the Technology Loan Fund are followed in granting loans.

### *Ethel I. Fryer Scholarship Loan Fund (1951)*

This fund was a gift of Herbert Fryer '11 to establish a loan fund for deserving students from the states of Washington, Oregon, and California. Grants are limited to \$600 per student and are repayable within five years of graduation.

### *Nathan R. George Loan Fund (1943)*

This bequest from Professor Nathan R. George of the Department of Mathematics is "to be loaned to undergraduates of M.I.T. who are either citizens or who intend to become citizens" and who are members of the third- or fourth-year classes.

### *Gerald L. Hartstein Memorial Loan Fund (1963)*

The principal and income of this memorial fund, established at the request of Mr. Hartstein's mother, are available for loans to undergraduates.

### *John A. Herlihy Loan Fund (1962)*

This commemorative fund was established by gift of the United Air Lines Foundation in honor of John A. Herlihy '27, Senior Vice President of United Air Lines. Grants from this fund, limited to undergraduates in the field of aeronautics and astronautics, are administered in the same manner as those from the Technology Loan Fund.

### *Rebecca R. Joslin Loan Fund (1924-36)*

This fund is open to undergraduate and graduate students in chemical engineering and is restricted to students who are residents of Massachusetts and who abstain from using tobacco in any form.

### *Klock-Overton-Mills-Roberts-Longyear Loan Fund (1961)*

This loan fund, established by Felix S. Klock '36, on the 25th anniversary of his graduation from M.I.T. in recognition of the people who significantly influenced and guided him in his education, functions on the same basis as the Technology Loan Fund. In granting awards, the Committee gives preference to needy and worthy students who are children of the employees of the Klock Corporation.

**Lamson-Virgin Loan Fund (1946)**

This bequest from Elizabeth H. Lamson is used in aiding a worthy student of excellent character who "must have shown not only respect for his parents but also proper consideration for the rights of others." Students thus aided shall repay if and when they find themselves able to do so.

**Harry J. and Iolia R. Lohbiller Loan Fund (1962)**

This fund was established by trusts created by Harry J. '01 and Iolia R. Lohbiller. Loans are restricted to juniors and seniors and in certain instances to sophomores.

**George H. May Loan Fund (1914)**

A gift from George H. May '92 provides a fund "to assist graduates of the Newton High Schools who are students at M.I.T. and who have been recommended as eligible by the Superintendent and Headmaster of the Newton High Schools." Beneficiaries under this fund are expected to issue notes agreeing to repay, without interest, the amounts received.

**Helen and Leo Mayer Loan Fund (1967)**

Established by a gift of the Helen and Leo Mayer Charitable Trust, the principal and interest of this fund are administered in the same manner as those from the Technology Loan Fund.

**George J. Mead Loan Fund (1951)**

This bequest of George J. Mead '16 is for loans to upperclassmen in aeronautics and astronautics and mechanical engineering.

**Arthur T. Nelson, Jr. Memorial Loan Fund (1962)**

Established by a gift of Mrs. Arthur T. Nelson and the Trustees of Arthur T. Nelson, Jr., this fund is used for loans administered under the regular procedures adopted by the Institute to students residing in certain states.

**Michael Joseph Pollock Loan Fund (1962)**

The income of this memorial fund, established by the parents, relatives, and friends of Michael Joseph Pollock '59, is available for loans to deserving students.

**Ellen H. Richards Loan Fund (1964)**

This fund, established by a gift from the Eastern Massachusetts Home Economics Association as a memorial to Ellen H. Richards, is used to provide loans, preference being given to women students in chemistry relating to food processing and food technology.

**M. H. Rogers Loan Fund (1945)**

This bequest of Minnie Hempel Rogers '90 is for loans to worthy students.

**Lillie C. Smith Fund (1965)**

Income from this fund in memorial of an early alumna is administered by the Association of M.I.T. Alumnae for aid to women students.

**Technology Matrons Loan Fund (1960)**

This gift of the Technology Matrons is used to assist needy and worthy students with loans.

**Robert Kelley Thulman Loan Fund (1963)**

The gift of the wife of Robert Kelley Thulman '22, this fund is designated for loans to students.

**Timbie Memorial Fund (1954)**

This fund was established by graduates of the Cooperative Course in Electrical Engineering (VI-A) in the name of William H. Timbie. It is used to provide loans for students in the Cooperative Course.

**F. B. Tough Fund (1924)**

Established by a gift of Mr. F. B. Tough, this fund is used to provide loans "for the purpose of extending financial assistance to worthy students while pursuing their courses."

**Frank P. Wakefield Loan Fund (1955)**

One-fourth of the income of this fund is available for loans to needy and worthy students majoring in chemistry, chemical engineering, and biology.

## APPENDIX B: PRIZES AND AWARDS

To encourage and recognize high achievement by students at M.I.T., a number of prizes have been established by individuals and organizations. In general, these awards are made each year by the office of the Dean of Student Affairs or by the departments or organizations concerned.

**Alpha Chi Sigma Prizes (1965)**

Two prizes of \$250 each are awarded annually to seniors in recognition of distinguished scholastic achievement, originality, and breadth of interest in chemistry and closely related fields.

**American Institute of Chemists Award (1957)**

The American Institute of Chemists offers annually two medals, one to a student in chemistry and one to a student in chemical engineering. The medals are given to students who show outstanding professional promise.

**Association of M.I.T. Alumnae Award (1958)**

This cash award is given to one or more outstanding women students in the junior class.

**Avery Allen Ashdown Award**

Awarded to a resident of the Ashdown House who carries on the tradition and spirit of service through participation in the affairs of the House.

**Baton Society Awards (1960)**

These awards are given to seniors for outstanding contributions to music at M.I.T.

**Robert A. Boit Prizes (1921)**

These annual prizes are made "to stimulate the interest in the best use of the English language." They are awarded to undergraduates on the basis of essays and imaginative works submitted by them. The prizes are made possible by a bequest of \$5,000 from Robert A. Boit.

**Borden Freshman Prize (1956)**

This \$200 prize established by the Borden Company Foundation is awarded to the student who has achieved the best academic record among all the members of his class for all college work during the freshman year.

**Karl Taylor Compton Prizes (1951)**

These prizes are awarded in recognition and encouragement of outstanding contributions in promoting high standards of performance and good citizenship within the Institute community. They are awarded from the income of a fund composed of gifts by members and friends of the Boston Stein Club.

**The Frederick Gardner Fassett, Jr. Award**

Awarded to a member of the Interfraternity Conference, for qualities of spirit, dedication, and service in furthering the ideals of the M.I.T. fraternity brotherhood.

**The Goodwin Medal**

The Goodwin Medal together with a cash prize may be awarded in any year (but not necessarily in every year) to a graduate student who is also a member of the academic staff of the Massachusetts Institute of Technology, in recognition of conspicuously effective teaching. Candidates for this award are nominated through departmental channels or by the Student-Faculty Committee to the Dean of the Graduate School. The award is in memory of Dr. Harry Manley Goodwin, the first Dean of the Graduate School, through a fund given by Mary B. and Richard H. Goodwin.

**Ellen King Prize (1950)**

This prize is a collection of books valued at approximately \$50, awarded for the best essay written by a freshman upon any topic suitable for treatment in literary form. Papers submitted in a regular subject, as well as extracurricular compositions, will be eligible for the prize. Specific topics must be registered and approved at the Headquarters of the Department of Humanities.

**Military Prizes**

A number of individual prizes are awarded to selected outstanding cadets in the Departments of Air, Military, and Naval Science on the basis of technical and professional proficiency.

**Outstanding Freshman Award**

This award is made to recognize distinguished scholarship, integrity, breadth of interests, adaptability, and high degree of unselfish activity toward the community at large. It is presented by the M.I.T. chapter of the Tau Beta Pi association, National Engineering honorary.

**Phi Lambda Upsilon Award in Freshman Chemistry**

This award is given yearly to the outstanding student in freshman chemistry. Taken into consideration are academic achievement for the two terms of freshman chemistry, over-all ability, interest, and promise.

**Phi Lambda Upsilon Sophomore Award**

This award is given annually to an outstanding sophomore who has demonstrated academic achievement and professional promise in pure and applied chemistry.

**Scott Paper Foundation Leadership Award**

This award of \$1,500 is made annually to a student in the spring of his junior year for senior and first-year graduate study. It is presented in recognition of demonstrated high character, actions on behalf of the welfare of colleagues, and potential for making outstanding contributions to the professional aspects of engineering in business or industry.

**William L. Stewart, Jr. Awards (1964)**

These awards are given to individual students and student groups for outstanding contributions to extracurricular life. They are made from an annual gift by the W. L. Stewart, Jr. Foundation in memory of Mr. Stewart, member of the Class of 1923, member of the M.I.T. Corporation from 1952 to 1963, and long-time friend and benefactor of the Institute.

**Stratton Prizes (1930)**

Awards presented yearly for outstanding skill in organized debating. They are made possible by the income of a fund established by the late President Samuel W. Stratton.

**AERONAUTICS AND ASTRONAUTICS****Luis de Florez Awards (1960)**

The late Admiral Luis de Florez, distinguished engineer and alumnus of the Department of Mechanical Engineering, Class of 1911, endowed awards totaling \$1,000 or more to recognize "original thinking or ingenuity" demonstrated by students in Aeronautics and Astronautics.

**James Means Memorial Prize (1925)**

A medal and monetary prize of \$100 or more is offered annually to a senior for excellence in systems engineering.

**Henry Webb Salisbury Memorial Award (1941)**

Established by the family and friends of Henry Webb Salisbury '33, this award, consisting of books chosen by the recipient, is given for outstanding work in the Department of Aeronautics and Astronautics.

**ARCHITECTURE AND PLANNING****Alpha Rho Chi Medal (1932)**

This medal is given each year to a graduating senior in the Department of Architecture who has shown an ability for leadership, performed willing service for his School and Department, and given promise of real professional merit through his attitude and personality.

**Architecture Travel Fellowship (1960)**

This award of \$1,500, made by an anonymous donor, is given to a graduating student in architecture for travel in Europe.

**Blumcraft of Pittsburgh Award (1962)**

An award of \$250 is made annually to a student in the Department of Architecture selected by the Committee on the recommendation of the Department.

**Ernest A. Grunsfeld, Jr. Traveling Fellowship (1952)**

This award of \$1,200 is given to a candidate for the Bachelor of Architecture for travel in Europe during the summer preceding his final year of study for that degree.

**Student Medal of the American Institute of Architects (1914)**

This medal is awarded on the recommendation of the Department to the member of the graduating Bachelor of Architecture class with the best record for the Course.

**ATHLETICS****Athletic Awards**

In addition to varsity letters and freshman numerals in 20 intercollegiate sports, a number of awards are given to undergraduates by student organizations for outstanding contributions to intramural and intercollegiate athletic activities.

**Class of 1948 Award**

Established by the Class of 1948, this award is given annually to the member of the graduating class who has best combined the traits of leadership and character with excellence in athletic performance.

**Admiral Edward L. Cochrane Award**

This award, made possible by Mrs. Cochrane in memory of her husband, is given to a member of the graduating class, participant in the intercollegiate athletic program, who has shown qualities of humility, leadership, and scholarship.

**Eastern College Athletic Conference Merit Medal**

This medal, established by the Conference to be awarded by its member institutions, gives recognition to an athlete for scholarship and athletic achievement.

**CHEMICAL ENGINEERING****Robert T. Haslam Cup (1959)**

Established by Mr. and Mrs. Louis E. Seley in honor of Robert T. Haslam '11, this cup is awarded annually by the Department of Chemical Engineering to a senior who shows outstanding professional promise in chemical engineering.

**Hunneman Prize (1927)**

Established by William Cooper Hunneman in memory of his son Roger DeFriez Hunneman '23, this award of \$100 is made to the most meritorious senior who has shown outstanding originality in his work in the regular Course in Chemical Engineering.

**CHEMISTRY****Uniroyal Foundation**

For the support of graduate training in research; \$3,400.

**CIVIL ENGINEERING****A.S.C.E. Student Chapter Scholarship**

Funds under this award are provided through the gift of Samuel Tapman as a scholarship given annually to an outstanding undergraduate who is a member of a Student Chapter of the American Society of Civil Engineers in A.S.C.E. Zone 1.

**Tucker-Voss Award (1953)**

Gift of the alumni and friends of the late Professors Ross F. Tucker and Walter C. Voss, former heads of the Course in Building Engineering and Construction, this prize is awarded annually to an undergraduate or a graduate student with high scholastic standing, leadership, and professional promise in the building field.

**Richard Lee Russel Prize (1967)**

This scholarship award of \$500 for graduate study in civil engineering at M.I.T. is for an outstanding senior selected by the faculty of the Department. The award is supported by the Richard Lee Russel '89 Fund established in 1904 by Mr. Theodore E. Russel.

**ELECTRICAL ENGINEERING****Morris J. Levin Award**

Award to juniors in electrical engineering who have demonstrated excellent performance through independent work in an undergraduate laboratory project.

**Supervised Investors' Services, Inc., Awards (1957)**

Four prizes of \$500 each are awarded to graduate students who are members of the teaching staff of the Department of Electrical Engineering. They are given to honor those who have demonstrated an interest and proficiency in the field of teaching and to help defray the expenses of graduate study for advanced degrees.

**Carlton E. Tucker Awards for Excellence in Teaching (1962)**

Two prizes of \$500 each, awarded to graduate students who are members of the teaching staff of the Department of Electrical Engineering, are given to honor those who have demonstrated an interest and proficiency in the field of teaching and to help defray the expenses of graduate study for advanced degrees. The Awards honor Professor Carlton E. Tucker, the Department's Executive Officer for 24 years, for his dedication to and interest in high teaching standards; they are supported in part from funds given in memory of Professor Tucker and Professor William H. Radford.

## APPENDIX B

### MANAGEMENT

#### **The Brooks Prize in Management**

The E. P. Brooks Master's Thesis Prize of \$100 is awarded each year for the thesis judged to be the best submitted for the Master of Science in Management. Nominations may be made by the chairman of any Master's Thesis Committee to the Sloan School of Management's Prize Committee.

#### **Editorship of the Industrial Management Review**

The editorship of the journal of the Sloan School of Management is awarded annually to selected graduate students in management who have achieved distinguished records of scholarship and leadership in the School.

#### **Sloan School of Management Senior Prize**

This annual award of \$100, established through the generosity of Samuel Berke, '15, is made to an outstanding senior student in the field of management with high scholastic standing, leadership, and professional promise.

### MECHANICAL ENGINEERING

#### **American Society of Mechanical Engineers Student Paper Awards**

This contest for outstanding professional papers by student members of A.S.M.E. is sponsored by the local chapter. Prizes totaling about \$60 are awarded, and local winners are eligible for regional and national contests.

#### **Luis de Florez Awards (1957)**

The late Admiral Luis de Florez, distinguished engineer and alumnus of the Department of Mechanical Engineering, Class of 1911, endowed these awards to recognize "outstanding ingenuity" demonstrated by students in mechanical engineering. Prizes totaling \$1,000 or more are awarded each year.

#### **Silent Hoist and Crane Company Materials Handling Award (1950)**

These annual prizes, totaling more than \$500, are awarded for the best papers or theses submitted on subjects in the field of production, materials handling, or machine design related to materials handling equipment, on the basis of a competition held each year. The award is a gift of the Wunsch Foundation, Inc.

#### **Ed Wellech—Corning Glass Works Award**

This award is to be given to students in the Mechanical Engineering sophomore subject Engineering Design and Manufacturing, 2.861. An aggregate of \$250 is awarded for the best design project (or projects) and an equal aggregate for the best manufacturing project report (or reports) submitted during each year.

### METEOROLOGY

#### **The Carl-Gustav Rossby Award in Meteorology**

This award was established, in part, by the gift of Julius Honig '53 in memory of Professor Carl G. Rossby who established the course in meteorology at M.I.T. The award of \$100 is made in any year for the most outstanding graduate thesis submitted to the Department of Meteorology.

### METALLURGY AND MATERIALS SCIENCE

#### **Dow Chemical Company Prize (1962)**

Prizes are awarded, from a \$500 gift by the Dow Chemical Company, for the best theses submitted for the degree of Bachelor of Science in Metallurgy and Materials Science.

#### **Metallurgy and Materials Prize (1963)**

The sum of \$150 is awarded to an outstanding junior in the Department. The award was established by graduate students and associates of Professor Morris Cohen in recognition of his significant contributions to undergraduate education in materials. It is presently supported by the Boston Section, A.I.M.E.

#### **American Metal Climax Foundation Prize (1969)**

The sum of \$300 is awarded to a student who performs an outstanding sophomore laboratory project.

### NAVAL ARCHITECTURE AND MARINE ENGINEERING

#### **American Bureau of Shipping Prize (1924)**

This award of \$100 is provided by the Bureau to the American citizen who attains the highest average in scholarship for the third and fourth years in either the Course in Naval Architecture and Marine Engineering or the Course in Shipping and Shipbuilding Management.

#### **Brand Award (1957)**

This award, in memory of Rear Admiral Charles L. Brand, U.S. Navy Class of 1915, is made annually by the American Society of Naval Engineers to the student officer in the graduating class who attains the highest scholastic average in the Course in Naval Construction and Engineering (XIII-A).

### NUCLEAR ENGINEERING

#### **General Electric Awards in Nuclear Engineering**

A cash award, in amount between \$150 and \$500, is made each year to one or more graduate student assistants in recognition of outstanding contributions to the teaching or research activities of the Department of Nuclear Engineering.

## ALPHABETICAL INDEX

- A**cademic Administration and Personnel 368-370  
 Academic Council 379  
 Academic officers x-xi  
 Academic preparation 65-66  
 Academic program 5  
 Academic standards, graduate 79  
 Academic year 34  
 Administration 367-376  
 Administrative Council 379  
 Admission 65-69  
   Advanced placement 67  
   Advanced credit (transfer) 69  
   First-year 65-68  
   Foreign students 68, 79  
   Graduate 77-79  
   Notification 67  
   Special Students 69  
   Transfers 68-69  
 Admissions Office 363  
 Advanced credit 69  
 Advanced Engineering Study, Center for 151-152  
   Advanced placement 67-68  
   Advanced standing examinations 35  
   Advanced Study, Program of 83  
 Aeronautics and Astronautics 104-108  
   Cooperative course 107  
   Descriptions of subjects 308-315  
   Graduate study 107-108  
   Staff xiv-xv  
   Undergraduate study 105-107  
 Aeroelastic and Structures Research Laboratory 105  
 Aerospace Research Division 105  
 Aerospace Studies, Department of xliii  
 Aerophysics Research Laboratory 105  
 Aerospace Studies 59-60  
   Descriptions of subjects 361  
   Staff xliii  
   Undergraduate program 59-60  
 Aid, financial 38, 64-65, 84-87  
   First year 38, 64-65  
   Graduate 82-87, 390-392  
   Undergraduate 38, 64-65, 381-389  
 Air Force R.O.T.C. program 59-60  
 Alpha Phi Omega 31  
 Alumnae, Association of 32-33  
 Alumni Association 32, 374  
 Alumni Placement Office 34  
 Applications  
   Advanced standing admission 67-68  
   Early decision on 67  
   Fees 37, 66  
   Foreign students 68  
   Graduate admission 77-79  
   Graduate fellowships and scholarships 84-87, 390-392  
   Procedure for undergraduates 66  
   Transfer 68-69  
 Applied Earth Sciences 118  
 Architecture 91-94  
   Descriptions of subjects 239-244  
   Graduate study 94  
   Staff xii  
   Undergraduate study 91-94  
 Army R.O.T.C. Program 58-59  
 Art Collection 31  
 Ashdown House 24  
 Associates Office, M.I.T. 17  
 Association of M.I.T. Alumnae 32-33  
 Athletic Department 367-368  
 Athletics 28-29  
 Attendance 34  
 Auditorium and Chapel 20  
 Auditorium, Kresge 20  
 Automobile regulations 36  
 Awards, Prizes and 394-396  
**B**achelor's and Master's degrees, simultaneous award of 46, 82  
 Bachelor's degrees in two courses 46  
 Baker House 22  
 Behavioral Science in Management 175  
 Bexley Hall 22  
 Biology 186-188  
   Description of subjects 263-265  
   Graduate study 187-188  
   Staff xxxiii  
   Undergraduate study 186-187  
 Bitter National Magnet Laboratory xlii, 9-10  
 Boathouse 29  
 Boston University 80  
 Briggs Field House 29  
 Brookhaven National Laboratory 16  
 Burton House 22  
**C**alendar, academic 34  
 Cambridge Electron Accelerator xlii, 10  
 Campus 18-20  
 Campus Activities 26-32  
 Careers in teaching 46, 165  
 Center for Advanced Engineering Study 151-152  
   Practicing Engineer Program 151  
   Staff xxv  
 Center for Advanced Visual Studies 10  
 Center for International Studies xliii, 10  
 Center for Materials Science and Engineering 10, 129  
 Center for Space Research 10-11  
 Center for Urban Studies, Joint xlii, 12  
 Ceramics 138-141  
 Chapel and Auditorium 20  
 Chemical Engineering 109-113  
   Chemical Engineering Practice 113  
   Description of subjects 275-279  
   Graduate study 111-113  
   Staff xv-xvi  
   Undergraduate study 109-111  
 Chemical Engineering Practice, School of 16, 37, 113  
 Chemistry 189-191  
   Description of subjects 244-247  
   Graduate study 189-191  
   Staff xxxiv  
   Undergraduate study 189  
 Choral Society 29  
 Civil Engineering 114-120  
   Description of subjects 214-223  
   Graduate study 117-120  
   Staff xvi-xvii  
   Undergraduate study 116-117  
 Civil Engineering Systems Laboratory 115, 120  
 Civil Rights Committee 31  
 College Entrance Examination Board 67  
 College Scholarship Service 65  
 College Transfers 68-69  
 Committee on Visual Arts 30-31  
 Committees on Joint Research Areas 16  
 Community Housing Service 25  
 Community Players 29  
 Concert Band 29-30  
 Conduct of students 35-36  
 Conferences (interviews) for admission 66, 68  
 Continuum Electromechanics Group 128-129  
 Cooperative arrangement with Boston University 80  
 Cooperative arrangement with Harvard University 64, 79-80  
 Cooperative arrangement with Tufts University 80  
 Cooperative Courses 36-37  
 Cooperative living 23  
 Corporation viii-ix, 17, 364-366  
   Auditing Committee 364  
   Standing Committees 364  
   Visiting Committees 365-366  
 Costs 36-37, 64 (see also Fees)  
 Councils 379  
 Courses of study 6-7, 41-43  
 Credits, system of 46-47  
**D**ames 32  
 Debating Society 31  
 Degree requirements  
   Graduate 81-84  
   Undergraduate 47  
 Degrees 6-7, 74, 82-84  
 Degrees with and without specification 82  
 Deferred Payment Plan 37-38  
 Departmental Programs 41, 42  
 Departments 6-7  
 Deposits 37  
 Descriptions of subjects 214-363  
 Discipline 35-36  
 Division of Sponsored Research 87, 371  
 Doctoral programs, interdepartmental 77  
 Doctor's degrees 83-84  
 Drama xlii, 29  
 Dramashop 29  
 David Flett du Pont Athletic Center 29  
 Dynamics of Management Systems 176  
**E**arly decision on applications 67  
 Earth and Planetary Sciences  
   Description of subjects 283-287  
   Graduate study 194-195  
   Oceanography 194  
   Staff xxxv  
   Undergraduate study 192-194  
 East Campus Houses 23  
 Eastgate 25  
 Economics 158-160  
   Description of subjects 292-297  
   Graduate study 159-160  
   Staff xxvi  
   Undergraduate study 158  
 Elective subjects, first-year 50  
 Electrical Engineering 121-130  
   Descriptions of subjects 247-263  
   Financial aid for graduate students 129  
   Graduate study 127-130  
   Staff xviii-xx  
   Undergraduate study 121-127  
 Electron Accelerator, Cambridge 10  
 Electronic Systems Laboratory 128  
 Electronics, Research Laboratory of 15, 128  
 Employment, student 38  
 Endicott House 20  
 Engineer degree 82-83  
 Engineering  
   Aeronautical (see Aeronautics and Astronautics)  
   Biochemical 204  
   Chemical 109-113  
   Civil 114-120  
   Electrical 121-130  
   Fuel 112-113  
   Marine 142-146

ALPHABETICAL INDEX

Materials 112, 119, 135  
 Mechanical 131-135  
 Metallurgy and Materials Science 136-141  
 Mineral 138-140  
 Nuclear 147-150  
 Process 111-112  
 Soil 118  
 Structural 119  
 Transportation 119-120  
 Urban Systems 120  
 Engineering and Living Systems  
   Graduate study 11  
   Undergraduate study 46  
 Engineering Council 103  
 Engineering, School of 101-152  
   Staff xiii  
 Entrance examinations 67, 68  
 Evening school (see Lowell Institute School)  
 Examinations  
   Advanced standing 35  
   Entrance 67, 68  
   Final 35  
   General 83  
   Graduate Record 79  
   Graduate study in business 79  
   Physical 52  
 Executive Development Programs in  
   Management 180  
 Expenses (see Fees)  
 Expenses, student's estimated 64  
 Experimental Plasma Facilities 148

**F**aculty  
   Committees 377-378  
   Councils 379  
   Officers x-xi, 377  
 Faculty Club 33  
 Faculty Council 379  
 Faculty Counselors 34  
 Fees 36-37, 64  
   Application 37  
   Deposits 37  
   House rentals and meals 23, 37, 64  
   Language examination 37  
   Late registration payment 37  
   Payment plans 37-38  
   Student Health Program 32, 37, 64  
   Thesis 36  
   Tuition 36-37, 64  
 Fellows  
   Graduate 84-86  
 Fellowships 84-86  
 Fields of study  
   Graduate 75-76  
   Humanities 53-57  
 Final examinations 35  
 Financial aid 38, 64-65, 84-87, 381-394  
 Financial and Business Administration 370-372  
 First-year program 47-50  
 Flight Transportation Laboratory 105  
 Fluid Dynamics Research Laboratory 105  
 Food Science (see Nutrition and Food Science)  
 Foreign Literatures and Linguistics  
   Description of subjects 354-360  
   Graduate study 161-162  
   Staff xxvii  
   Undergraduate study 161  
 Foreign students 68  
   Undergraduate admission 68  
   Graduate admission 79  
 Foreign study 63  
 Francis Russell Hart Nautical Museum 30  
 Fraternities 23  
 Freshman electives 50  
 Freshman grading 34

**G**as Turbine Laboratory 105  
 General Institute Requirements 41, 47  
 General Regulations 34-36  
 Geology and Geophysics (see Earth and Planetary Sciences)  
 Glee Club 29  
 Government, Student 26-28  
 Grade reports 34-35  
 Graduate assistantships 87  
 Graduate Record Examinations 79  
 Graduate School  
   Admission 77-79  
   Manual 74, 77  
   Organization 74-77  
   Undergraduate preparation for 77-78  
 Graduate Student Organization 74  
 Graduate Student Residence 24  
 Graduate students  
   Provisional 78  
   Regular 77  
   Special 78-79  
 Graduate study 71-87  
*Guide to Graduate Life, A* 31

**H**arvard University, Cooperative program with 79-80  
 High Voltage Research Laboratory 129  
 Hobby Shop 31  
 Homberg Memorial Infirmary 32  
 Housing, student 20-25  
 Humanities 52-57, 163-165  
   Descriptions of subjects 336-351  
   Graduate study 165  
   Staff xxvii-xxviii  
   Undergraduate requirements 52-57  
   Undergraduate study 163-165  
 Humanities and Engineering 163  
 Humanities and Science 163-164  
 Hydrodynamics and Water Resources 118  
 Hydrodynamics Laboratory 114

**I**ndustrial Liaison Office 17, 374  
 Infirmary, Homberg Memorial 32  
 Information Office 33  
 Information Processing Services 11-12  
*Innisfree* 31  
 Installment credit plan 38  
 Institute Relations 367-368  
 Instrumentation Division (Aeronautics and Astronautics) 105, 108  
 Inter-American Program in Civil Engineering 115-116  
 Interdepartmental doctoral programs 77  
 International Studies, Center for xlii, 10  
 Interviews for admission 66, 68

**J**azz Band 29, 30  
 John Rockwell Athletic Cage 29  
 Joint Center for Urban Studies xlii, 12  
 Joint Research Areas, Committees on 16  
 Julius Adams Stratton Building 18

**K**resge Auditorium 20

**L**aboratory for Nuclear Science xlii, 12-13  
 Laboratory Requirement 51  
 Laboratories, Special 373  
 Language requirement 83-84  
 Lecture Series Committee 29  
 Lectures 29  
 Libraries 13-14, 73, 374-375  
 Lincoln Laboratory 14  
 Linguistics (see Foreign Literatures and Linguistics)

Living Systems and Engineering  
   Graduate study 11  
   Undergraduate study 46  
 Loan funds 65, 87, 393-394  
 Logarithms 29  
 Lowell Institute Cooperative Broadcasting Council 33  
 Lowell Institute School 33, 375

**M**AC Project 14-15, 128  
 Man-Vehicle Control Laboratory 105  
 Management, Alfred P. Sloan School of 173-180  
   Descriptions of subjects 297-308  
   Executive Development Programs 180  
   Graduate study 178-180  
   Staff xxx-xxxii  
   Undergraduate study 174-178  
 Marine engineering (see Naval Architecture and Marine Engineering)  
 Married student housing 24-25  
 Master's Degrees 82  
 Materials 119  
 Materials engineering 108, 137  
 Materials Research Laboratory 115  
 Materials Science and Engineering, Center for 10, 129  
 Mathematics 196-199  
   Descriptions of subjects 323-331  
   Graduate study 197-199  
   Staff xxxvi-xxxvii  
   Undergraduate study 196-197  
 Matrons, Technology 33  
 McCormick Hall 23  
 Measurements Systems Laboratory 105  
 Mechanical Engineering 131-135  
   Advanced undergraduate program 134  
   Cooperative course 133-134  
   Descriptions of subjects 223-234  
   Graduate study 134-135  
   Honors course 134  
   Staff xxi-xxii  
   Undergraduate study 131-134  
 Medical Department 368-370  
 Medical Services and requirements 32, 80  
 Metabolism, Nutritional Biochemistry and 203-204  
 Metallurgy and Materials Science 136-141  
   Descriptions of subjects 234-239  
   Graduate study 138-141  
   Staff xxiii  
   Undergraduate study 136-138  
 Meteorology 200-201  
   Descriptions of subjects 331-333  
   Graduate study 200-201  
   Staff xxxvii  
   Undergraduate study 200  
 Military Science  
   Descriptions of subjects 361-362  
   Staff xliiii  
   Undergraduate program 58-59  
 Military Service  
   Graduate students 80-81  
   Undergraduate students 63  
 Mineral engineering 138-141  
 Minor requirement 83  
 M.I.T. Associates Office 17, 374  
 M.I.T. Press 33, 375  
 M.I.T. Research Reactor 148  
 M.I.T. Student House 23  
 Motor vehicles 36  
 Music xlii, 29-30

**N**ational Defense Student Loan Fund 393  
 National Magnet Laboratory, Bitter xlii, 9-10  
 Nautical Museum, Francis Russell Hart 30

- Naval Architecture and Marine  
 Engineering 142-146  
 Descriptions of subjects 287-292  
 Graduate study 144-146  
 Staff xxiv  
 Undergraduate study 142-144
- Naval Construction and Engineering 145-146
- Naval R.O.T.C. Program 60-63
- Naval Science  
 Descriptions of subjects 362  
 Staff xliii  
 Undergraduate program 60-63
- Non-Resident Student Association 23, 28
- Notification of admission 67
- Nuclear Engineering 147-150  
 Descriptions of subjects 351-354  
 Graduate study 149-150  
 Staff xxv  
 Undergraduate preparation 148-149
- Nuclear Science, Laboratory for xlii, 12
- Nutrition and Food Science 202-206  
 Cooperative Program 205  
 Descriptions of subjects 333-336  
 Graduate study 203-206  
 Staff xxxviii  
 Undergraduate study 202-203
- Nutritional Biochemistry and Metabolism 203-204
- O**ceanography 194, 201, 210
- Official notices 36
- Office of Student Employment 34, 38
- Operations 372
- Operations Research Center 15, 230
- Opportunity Development Office 370
- Organization of the Graduate School 74
- Organization of the Institute 17
- Organization Systems 373-374
- Outing Club 31
- Overseas study 63
- P**arking facilities 33-34
- Payments 37-38
- Personal Deposits Office 33
- Personnel 370
- Placement Office 368
- Physical Education Requirement 51-52
- Physics 207-209  
 Descriptions of subjects 265-272  
 Graduate study 209  
 Staff xxxix-xli  
 Undergraduate study 208-209
- Pierce Boathouse 29
- Placement Bureau 34
- Placement Office, Alumni 34
- Plasma facilities, experimental 148
- Political clubs, student 31
- Political Science 166-168  
 Descriptions of subjects 315-323  
 Graduate study 67-168  
 Staff xxix  
 Undergraduate study 166-167
- Practicing Engineer Advanced Study Program 151
- Prelaw education 46
- Premedical education 43-46
- Preparation  
 Graduate 77-78  
 Undergraduate 65
- President's Office 367
- Prizes and Awards 394-396
- Program of Advanced Study 83
- Project MAC 14-15, 128
- Provost's Office 367
- Psychology 169-170  
 Descriptions of subjects 272-275  
 Graduate study 169-170  
 Staff xxx  
 Undergraduate study 169
- R**andom Hall 22
- Registrar's Office 368
- Registration 34, 79
- Registration Officers 34
- Religious organizations 31
- Requirements, graduate  
 Degrees 81-84  
 Language 83-84  
 Major 82  
 Medical 80  
 Minor 83  
 Residence 84  
 Thesis 83
- Requirements, undergraduate  
 General Institute 41, 47  
 Degree 47  
 Science Distribution 50-51  
 Physical Education 51-52  
 Laboratory 51  
 Humanities 52-57
- Research assistantships 86
- Research Laboratory of Electronics 15, 128
- Research Resources 9
- Residence requirements, graduate 84
- Rockwell Athletic Cage 29
- R.O.T.C. 57-63
- S**ailing Pavilion 29
- Scholarships 64  
 Freshman 64  
 Graduate 84-86, 390-392  
 Undergraduate 64, 381-389
- School of Architecture and Planning 89-98
- School of Chemical Engineering Practice 16, 37, 113
- School of Engineering 101-152
- School of Humanities and Social Sciences 156-170
- School of Management, Sloan 173-180
- School of Science 183-210  
 Staff xxxii
- Schools 6-7
- Science Council 185
- Science Distribution Requirement 50-51
- Secretary 374
- Selective Service Office 63
- Seminars 29
- Senior Executives, Program for 180
- Senior House 23
- Shipping and Shipbuilding Management 143-146
- Soil Research Laboratory 114-115
- Soils 118
- Space Propulsion Laboratory 105
- Space Research, Center for 10-11
- Special Laboratories 373
- Special Projects 373
- Special Students 69
- Special Students' fees 36
- Spectroscopy Laboratory xlii, 16
- Sponsored Research, Division of 87
- SPURS Program 97-98
- Stratton Student Center 18
- Structures 119
- Structures Research Laboratory 115
- Student Affairs Office 367
- Student Aid Office 368
- Student Center 18
- Student employment 38
- Student Employment Office 34, 38
- Student Government 26-28
- Student Health Program 32
- Student housing 20-25
- Student Loan Funds 393-394
- Student publications 31
- Summer Session xliii, 34
- Symphony Orchestra, M.I.T. 29, 30
- System of credits 46
- T**albot House 20
- Tangent* 31
- Teaching assistantships 86
- Teaching resources 9-16
- Tech Engineering News* 31
- Technology Community Association 31
- Technology Dames 32
- Technology Loan Fund 393
- Technology Matrons 33
- Technology Student Enterprises 31
- Test of English as a Foreign Language 68, 79
- The M.I.T. Press 33
- The Social Beaver* 31
- The Tech* 31
- Theater 29
- Thesis  
 Doctoral 83  
 Engineer's 83  
 Master's 83  
 Thesis fees 36  
 Traineeships 84-86  
 Transcripts 35  
 Transportation Systems 119-120  
 Tufts University 80  
 Tuition 36-37, 64  
 Two-Degree Plan 69
- U**ndergraduate Association 26
- Undergraduate curricula  
 School of Architecture 91  
 School of Engineering 103  
 School of Humanities and Social Science 157  
 School of Management 176-178  
 School of Science 185
- Undergraduate education 41ff
- Undergraduate programs 42-47, 52-57
- Undergraduate residence 20-24
- Urban Action 31
- Urban Studies and Planning  
 Description of subjects 279-283  
 Graduate study 97-98  
 Staff xiii  
 Undergraduate study 96-97
- Urban Studies, Joint Center for xlii, 12
- Urban Systems Laboratory 16
- V**isual Arts xliii, 30-31
- Voo Doo* 31
- W**1MX 31
- WTBS 31
- Wellesley exchange subjects 43
- Westgate 25
- White Water Club 31
- Withdrawal 35
- Woods Hole Oceanographic Institution 194, 201, 210
- Woodwind and Brass Ensembles 29
- Wright Brothers Wind Tunnel Facility 105
- Y**ear, academic 34

## INDEX TO SUBJECTS OF INSTRUCTION

Abstract Analysis	326	American Electric Power Service Corporation, Industrial Project at the	262	Applied Mathematics, Methods of	328
Accounting, Managerial	303	American Federal System	316	Applied Mathematics, Principles of	324
Accounting Measurement Theory and Problems	304	American Folklore	340	Applied Mathematics, Seminar in	298
Acoustics	251	American Foreign Policy, Principles and Problems of	320	Applied Mathematics, Topics in	328
Acoustics and Shock Response of Marine Structures	291	American Foreign Policy, Science and	319	Applied Mechanics, Seminar in	225
Acoustics and Structural Vibrations	291	American History, The Businessman in	342	Applied Optimal Control	312
Acoustics, Architectural, Special Problems in	242	American History, Urban, Seminar on	282	Applied Thermodynamics	230
Acoustics, Environmental Control	242	American Ideas and Institutions	344	Approximation Methods, Theory of	327
Acoustics, Marine	287	American Intellectual History	344	Arabic, Structure of	358
Adhesives, Physics and Engineering Use of	228	American Law, Structure of	299	Archaeology, Near Eastern: The Foundations of Civilization	342
Administration, Metropolitan Planning	282	American Legal System	306	Architectural Acoustics, Special Problems in	242
Administration, Seminar in	308	American Metropolis, The	343	Architectural Communication	244
Administrative Theory and Practice	301, 302	American Political Process, The	316	Architectural Design	241
Aerodynamic Heating	309	American Politics, Graduate Seminar in	316	Architectural Design, Special Problems	241
Aerodynamics	309	American Revolution, The	344	Architectural Design, Special Problems in	242
Aerodynamics, Applied	310	American Science and Its Development: Current Issues and Problems	320	Architecture 1400-1750	243
Aerodynamics, Experimental Techniques in	314	American-Soviet Diplomacy	345	Architecture, Criticism of	243
Aerodynamics of Flight Vehicles	310	American University, Seminar on the	350	Architecture from 1750 to the Present	243
Aerodynamics of Wings and Bodies	310	American Values of the 1920's	351	Architecture in the Ancient World	243
Aerodynamics — Viscous Fluids	309	American World Power, Literature in the Emergence of	339	Architecture in the Eighteenth Century, Origins of Contemporary	243
Aeroelasticity, Advanced	315	Amplifiers, Transistor Multistage	251	Architecture in the Middle Ages	243
Aerospace Engineering	315	Analog/Digital Computation for Instrumentation and Control	226	Architecture, Modern, in Germany from 1895 to the Bauhaus	243
Aerospace Power, Seminar in Growth and Development of	361	Analysis	325	Architecture, Selected Topics in the History of Art and	244
Aesthetics	345	Analysis, Abstract	326	Architecture, Studies Toward a Theory of	243
Africa, Modern, The Emergence of	342	Analysis and Control, Simulation Methods for Analysis and Design of Shell Structures	221	Architecture, Theory and Method in the History of Art and	244
Africa, Nationalism in	321, 344	Analysis and Simulation of Chemical Processing Systems	276	Arms Control, Disarmament, and Foreign Policy	320
Africa, Nationalism in	321, 344	Analysis, Functional	327	Art and Architecture, Selected Topics in the History of	244
African Politics, Comparative	317	Analysis of Dynamical Systems	255	Art and Architecture, Theory and Method in the History of	244
Africa, Sub-Sahara, Politics and Government of, Seminar	317	Analysis of Geological Materials	284	Art, Modern, from Post-Impressionism to Cubism	242
Africa, Tropical, Political and Economic Development of	321	Analysis of Power, The	316	Art, Modern, Introduction to	242
Air and Sea Instruments	331	Analysis of Techniques for Fabricating Structures	289	Art, Modern, Symbolism in	243
Air Conditioning	231	Analysis of Uncertainty	214	Art Theories, Twentieth-Century	243
Air Conditioning, Advanced	231	Analytic Methods in Applied Geophysics	286	Art, Topical Studies in the History and Theory of	242
Air Conditioning, Environmental Control	231	Analytic Philosophy	347	Artificial Intelligence, Heuristic Programming and	253, 325
Aircraft and Spacecraft Design	314	Analytical Chemistry, Seminar in	247	Arts, Philosophy of the	347
Aircraft Engines	313	Analytical Mechanics	268	Asia, Philosophies and Religions of	347
Aircraft, Vertical Take-Off	313	Analytical Models for Human Processing of Sensory Inputs	255	Asian Politics, Comparative	316
Aircraft, Vertical Take-Off, Advanced	313	Analytical Treatment of Chemical Engineering Processes	276	Astronautical Guidance	312, 313
Air Force Cambridge Research Laboratories, Industrial Project at the	263	Anarchism	343	Astronomy	284
Air Force Cambridge Research Laboratories, Research and Development at the	262	Ancient World, Architecture in the	243	Astronomy and Astrophysics, Dynamical Problems of	328
Air Force Environment	361	Anelastic Deformation, Solid Mechanics — Plasticity and	225	Astronomy, Dynamical	272, 286, 312
Air Pollution Control, Seminar in	278	Antennas	257	Astronomy, Planetary, Methods of	286
Airpower and the World Military Systems	361	Anthropology, Economic	342	Astronomy, Radio, Fundamentals of	257, 272
Algebra	329	Anthropology, Philosophical	347	Astronomy, Workshop in	284
Algebra, Homological	329	Anthropology, Social, Introduction to	342	Astrophysics, Selected Topics in	272
Algebra, Linear	325	Application of Material Interface Phenomena	233	Astrophysics, Special Problems in	272
Algebra, Modern	326	Application of Operational Methods	290	Astrophysics, Special Problems in	272
Algebra, Topics in	329	Applications of Combinatorial Mathematics	250	Atmosphere, Elementary Physics of the	332
Algebraic Foundations for Computer Science	250	Applications of Digital Computers	239	Atmosphere, Upper, Physics of the	332
Algebraic Geometry	329	Applications of Multivariate Statistical Analysis	215	Atmospheres, Planetary	245, 286
Algebraic Number Theory	329	Applications of Probability and Random Variables	324	Atmospheric Precipitation Processes	332
Algebras, Lie, Lie Groups and	330	Applied Aerodynamics	310	Atomic Physics, Advanced	269
Algebras, Nonassociative	329	Applied Chemical Kinetics	278	Atomic Physics, Experimental	266
America, Conflict and Community in	337	Applied Econometrics	294	Atoms and Molecules, Physics of	266
America, Religion and Society in	350	Applied Elasticity	225	Atoms and Radiation, Selected Topics in Physics of	269
America, Social Criticism in, From Tocqueville to Riesman	343	Applied Hydrostatics	287	Atoms Toward Living Systems, From	258
America, Twentieth-Century, Dissent and Reform in	343	Applied Mathematics for Engineers, Methods of	325	Audio Frequency Communications Project Laboratory	260
American Constitutional History	344	Applied Mathematics, Introduction to	328	Auditory System, Signal Transmission and Coding in the	255
American Economic History	296				
American Economic Institutions, Development of	342				
American Electric Power Service Corporation, Industrial Practice at the	262				

Automata Theory, Switching and Finite..... 250  
 Automatic Computation, Introduction to..... 322  
 Automatic Control of Flight Vehicle..... 311  
 Automatic Control, Statistical Problems in..... 312  
 Automatic Control System Laboratory..... 311  
 Automotive Vehicles..... 230  
 AVCO Corporation, Industrial Practice at..... 261  
 AVCO Corporation, Industrial Project at..... 261

**B**  
 Background of Contemporary Philosophy..... 347  
 Bacteriology, Topics in..... 264  
 Banking Policy, Monetary and..... 294  
 Baroque Era, Western Music in the..... 349  
 Basic Electronic Instrumentation Laboratory..... 353  
 Bayesian Analysis Studies..... 306  
 Behavior, Brain and..... 273  
 Behavior in Groups..... 274  
 Behavior, Managerial, Seminar in..... 302  
 Behavior of Concrete Structures..... 220  
 Behavior of Metal Structures..... 220  
 Behavior of Metals at Elevated Temperatures..... 237  
 Behavior, Origins of, Seminar in the..... 274  
 Behavior Science Research Practicum..... 301  
 Behavioral Science, Mathematical..... 301  
 Behavioral Science Research Methods..... 301  
 Behavioral Science, Statistics for..... 300  
 Behavioral Sciences, Seminar in..... 300  
 Behavioral Theories of the Firm..... 301  
 Bell Telephone Laboratories, Inc., Industrial Practice at the..... 262  
 Bell Telephone Laboratories, Inc., Industrial Project at the..... 262  
 Biochemical Engineering..... 334  
 Biochemistry, Advanced..... 264  
 Biochemistry, Experimental..... 263  
 Biochemistry, General..... 263  
 Biochemistry Laboratory, Advanced..... 264  
 Biochemistry, Nutritional, and Metabolism..... 333  
 Biochemistry, Nutritional, and Metabolism, Advanced..... 333  
 Biochemistry, Seminar in..... 247, 265  
 Bioelectric Signals..... 255  
 Bioelectronics Project Laboratory..... 259  
 Biological and Cultural Determinants of Food Use..... 335  
 Biological Bases of Perception and Knowledge..... 351  
 Biological Effects of Nuclear Radiation..... 354  
 Biological Sciences, Experimental Statistics for the..... 336  
 Biological Systems Seminar, Molecular Configuration in..... 265  
 Biology, Experimental, Introduction to..... 263  
 Biology, Experiments in..... 263  
 Biology, General..... 263  
 Biology, Oral, Laboratory, Research Approaches to..... 336  
 Biology, Oral, Research Approaches to..... 336  
 Biology, Selected Topics in..... 265  
 Biology Seminar..... 264  
 Biomedical Engineering, Topics in..... 233  
 Biomedical Fluid Mechanics..... 228  
 Biophysical Chemistry..... 264  
 Biophysics, Chemical, Advanced Topics in..... 246  
 Biophysics, Introduction to..... 264  
 Biophysics of Neuroelectric Potentials..... 252  
 Biophysics, Optical Methods in..... 265  
 Black Ghetto, The..... 343  
 Bonding, Structure and Mechanism, Introduction to..... 245  
 Boston, Seminar on..... 350  
 Bound Brook Station, School of Chemical Engineering Practice —..... 279  
 Brain and Behavior..... 273  
 British Empiricists, The..... 346  
 Building Design Systems..... 217

Building Process..... 242  
 Bureaucracy..... 318  
 Business Forecasting..... 303  
 Business Game..... 307  
 Business Management, International..... 299  
 Business Practice and Policy Determination..... 308  
 Businessman in American History, The..... 342

**C**  
 Calculus..... 323, 324  
 Calculus, Advanced..... 324  
 Calculus for Engineers, Advanced..... 324  
 Calculus, Tensor..... 329  
 Cambridge, The Governance of..... 318  
 Capital Markets and Financial Institutions..... 302  
 Capitalism, Socialism and Growth..... 297  
 Career Development and Adult Socialization, Doctoral Seminar on..... 302  
 Cascades, Staged, in Chemical Processing..... 275  
 Case Histories in Engineering Science..... 236  
 Case Studies in Quantitative Analysis..... 306  
 Case Studies in Transportation Engineering..... 218  
 Catalysis..... 277  
 Cell Biology, Experimental..... 263  
 Cell Physiology, General and..... 263  
 Cementitious Materials..... 219  
 Ceramic Processes..... 238  
 Ceramics..... 235  
 Ceramics, Electrical and Optical Properties of..... 238  
 Ceramics, Physical..... 235, 238  
 Ceramics Seminar..... 238  
 Ceramics, Special Problems in..... 238  
 Changing Outlooks and Identities in World Affairs..... 316  
 Charged Particles in Space..... 271  
 Chaucer..... 339  
 Chemical Applications of Group Theory..... 244  
 Chemical Biophysics, Advanced Topics in..... 246  
 Chemical Engineering Design..... 277  
 Chemical Engineering in Medicine..... 277  
 Chemical Engineering Instrumentation Laboratory..... 275  
 Chemical Engineering Laboratory..... 275  
 Chemical Engineering, Nuclear..... 352  
 Chemical Engineering, Numerical Solution of Problems in..... 276  
 Chemical Engineering Processes, Analytical Treatment of..... 276  
 Chemical Engineering Processes, Dynamics and Control of..... 276  
 Chemical Engineering, Seminar in..... 279  
 Chemical Engineering Thermodynamics..... 275, 276  
 Chemical Equilibrium..... 246  
 Chemical Experimentation, Advanced..... 245  
 Chemical Experimentation, Intermediate..... 245  
 Chemical Experimentation, Introduction to..... 245  
 Chemical Kinetics and Reactor Design..... 276  
 Chemical Kinetics, Applied..... 278  
 Chemical Metallurgy..... 234  
 Chemical Processing, Staged Cascades in..... 275  
 Chemical Processing Systems, Analysis and Simulation of..... 276  
 Chemical Oceanography, Research in..... 287  
 Chemical Physics, Special Topics in..... 246  
 Chemical Reactions, Kinetics of..... 246  
 Chemical Research, Introduction to..... 245  
 Chemical Synthesis, Industrial..... 276  
 Chemical Thermodynamics..... 246  
 Chemistry..... 244  
 Chemistry, Analytical, Seminar in..... 247  
 Chemistry, Biophysical..... 264  
 Chemistry, Flavor, and Flavor Methodology..... 333  
 Chemistry for Undergraduates, Special Problems in..... 247  
 Chemistry, Industrial..... 275  
 Chemistry, Inorganic, Advanced..... 244

Chemistry, Inorganic, Principles of..... 244  
 Chemistry, Inorganic, Seminar in..... 247  
 Chemistry, Laboratory Problems in..... 245  
 Chemistry of Macromolecules, Physical..... 264  
 Chemistry of Materials..... 234  
 Chemistry of Polymers, Physical..... 278  
 Chemistry of Surfaces, Physics and..... 277  
 Chemistry of the Earth..... 285  
 Chemistry, Organic..... 245, 246  
 Chemistry, Organic, Seminar in..... 247  
 Chemistry, Organic, Special Topics in..... 246  
 Chemistry, Physical..... 246  
 Chemistry, Physical, Seminar in..... 247  
 Chemistry, Physiological, Advanced Nutrition and..... 334  
 Chemistry, Planetary, and Physics..... 284  
 Chemistry, Planetary Physics and..... 244, 267  
 Chemistry, Solid State, Advanced Topics in..... 247  
 Chemistry, Solid-State, Introduction to..... 235  
 Chemistry, Special Problems in..... 247  
 Chemistry, Surface and Colloid..... 277  
 Children, Seminar in Social Development of..... 274  
 China, Japan, and the West..... 344  
 Chinese Literature..... 340  
 Chinese Politics..... 317  
 Chinese Tradition, Science and Natural Philosophy in..... 343  
 Circuit Design, Computer-Aided..... 251  
 Circuits and Signals Laboratory, Electronic..... 259  
 Circuits, Electronic..... 253  
 Circuits, Electronic Devices and..... 248  
 Circuits, Microwave..... 257  
 Circuits, Signals, and Systems..... 248  
 Circulations, Oceanic..... 332  
 Cities, Deliberate Social Change in the..... 281  
 City and Regional Planning..... 279  
 City and Regional Planning, Introduction to..... 280  
 City Design..... 280  
 City Design, Advanced..... 280  
 City Form, Theory of..... 282  
 City Planning, Methods of Research in..... 282  
 City Planning, Problems in..... 279  
 City Planning Research..... 283  
 City Planning Techniques..... 280  
 City Structure and Economic Development..... 281  
 Civil Engineering..... 215  
 Civil Engineering, Advanced..... 223  
 Civil Engineering Laboratory..... 215  
 Civil Engineering, Research in..... 223  
 Civil Engineering, Special Studies in..... 223  
 Classic Era, Western Music in the..... 349  
 Classical French Drama..... 357  
 Classical Heritage, The, The Western Tradition:..... 336  
 Classical Philosophy..... 345  
 Clinical and Public Health Nutrition..... 336  
 Coastal Processes, Waves and..... 222  
 Coding in the Auditory System, Signal Transmission and..... 255  
 Cognitive Processes..... 274  
 Collaborative Design..... 280  
 Colloid Chemistry, Surface and..... 277  
 Colonialism, Research Seminar in Imperialism and..... 320  
 Color, Form and..... 240  
 Color, Light and..... 240  
 Color Science and Color Vision..... 274  
 Combinatorial Mathematics, Applications of..... 250  
 Combinatorial Theory..... 325  
 Combustion..... 228  
 Combustion Engine Laboratory, Internal..... 230  
 Combustion Engines, Internal..... 230  
 Combustion Engines, Internal, Advanced..... 230  
 Combustion Engines, Internal, Elementary..... 230

SUBJECTS INDEX

Combustion Engines, Internal, Special Problems in.....	230	Computation, Special Problems in.....	260	Control, Simulation Methods for Analysis and Control, Special Problems in.....	256
Combustion, Principles of.....	278	Computation Structures.....	249	Control, System Dynamics and, Advanced.....	226
Combustion, Research in.....	228	Computation, Theoretical Models for.....	250	Control System Principles.....	225
Comedy.....	340	Computational Models.....	252, 253	Control System Theory.....	256
Communication, Architectural.....	244	Computer-Aided Circuit Design.....	251	Control Systems, Operations Planning and.....	307
Communication, Literature and.....	351	Computer-Aided Design.....	232	Control Systems, Physical Components of.....	312
Communication, Managerial.....	302	Computer-Aided Urban Design.....	244	Control Systems, Principles of.....	352
Communication, Principles of.....	253	Computer Applications to Marine Problems.....	290	Control Systems, Seminar in Information and.....	304
Communication Problems in Science and Technology, Seminar on.....	302	Computer Approaches to Engineering Problems.....	216	Control Theory and Applications, Modern.....	226
Communication, Psychology of Language and.....	274	Computer Models of Physical and Engineering Systems.....	225	Controls and Fluidics, Fluid Power.....	226
Communication Sciences, Mathematical Backgrounds for.....	359	Computer Programming Systems, Digital.....	250	Controls, Management Information and.....	298
Communication Sciences Seminar.....	255	Computer Science, Algebraic Foundations for.....	250	Controls, Managerial Information and.....	303
Communication, Sensory.....	252	Computer Sciences, Special Topics in the.....	253	Conversational French.....	357
Communication, Speech.....	259, 359	Computer System Management and Use, Engineering.....	216	Conversion, Electrical Energy, Laboratory, Advanced.....	260
Communication, Statistical Theory of.....	254	Computer Systems.....	216	Conversion Systems and Components, Energy.....	289
Communication Systems and Optical Channels.....	254	Computer Systems, Advanced.....	304	Corps Training.....	361
Communication Systems, Mass Media and.....	315	Computer Systems Design, Engineering.....	216	Corrosion.....	238
Communications, International, Research Seminar in.....	316	Computer Systems for Naval Architecture and Marine Engineering.....	290	Cosmology.....	272
Communications, Mass, Influence Processes and.....	308	Computer Systems Seminar.....	283	Creative Photography.....	240
Communications Project Laboratory, Audio Frequency.....	260	Computers and Logic.....	325	Creep, Plasticity, Viscoelasticity and.....	310
Communications, Space.....	254, 312	Computers, Digital, Applications of.....	239	Criticism and Culture.....	339
Communism and Revolution.....	317	Computers, Digital Guidance, Elements of.....	313	Criticism of Architecture.....	243
Communism, International, Research Seminar on Sino-Soviet Relations and.....	318	Computers, Theory of.....	325	Crucial Problems in Linguistics.....	357
Communist Propaganda.....	318	Computing Systems, Structure of.....	252	Crystal Physics, X-rays and.....	269
Communist World, Soviet Foreign Policy and the.....	318	Concept Formation and Research Technique in the Social Sciences.....	321	Crystalline Material, Mechanical Behavior of.....	285
Community Action, Theory and Practice of.....	323	Concept of Freedom in Modern Literature, The.....	351	Crystalline Solids, Radiation Damage in.....	239, 354
Community Planning Design.....	279	Concepts of General and Limited War Systems.....	362	Crystallography.....	283
Comparative African Politics.....	317	Conceptual Design of Naval Ships.....	290	Crystallography and X-ray Diffraction, Principles of.....	235
Comparative Analysis of Organizations.....	301	Concrete, Portland Cement.....	220	Cultural Determinants of Food Use, Biological and.....	335
Comparative Asian Politics.....	316	Concrete Structures, Behavior of.....	220	Culture and Society in Medieval Europe.....	342
Comparative Asian Politics: Political Development in India.....	317	Conduction Processes in Solids.....	258	Culture, Criticism and.....	339
Comparative Economic Systems.....	295	Confession in Literature, The.....	340	Cultures, Préliterate.....	338
Comparative Histology.....	335	Conflict and Community in America.....	337	Cultures and Societies of Mexico.....	342
Comparative Instrumentation.....	311	Consciousness in Industrial Society, The Twentieth Century.....	338	Current Research in Meteoritics.....	245, 287
Comparative Instrumentation Laboratory.....	311	Contemporary French Drama.....	357	<b>Dante</b> .....	359
Comparative Pathology, Seminar in.....	335	Contemporary Moral Issues.....	337	Darwin, Marx, and Freud.....	343
Comparative Political Systems.....	317	Contemporary Philosophy and Theology.....	350	Data Analysis, Interactive.....	322
Comparative Politics of Latin America.....	318	Contemporary Soviet Literature.....	360	Data Structure for Symbol Manipulation.....	322
Comparative Politics, Research Seminar in: Western Europe.....	317	Continental Rationalists, The.....	347	Decision Processes in Ship Operation and Construction.....	290
Comparative Psychology.....	273	Continuous Media, Fields in.....	310	Decision Systems, Information and.....	303, 307
Comparative Psychology, Seminar in.....	273	Continuous Media, Solid Mechanics — Introduction to Mechanics of.....	225	Decision Theories in Engineering and Planning.....	216
Comparative Systems of Industrial Relations and Human Resource Development.....	296, 306	Continuum Electrodynamics, Advanced Topics in.....	255	Decision Theory: Statistical.....	298
Complex Organizations.....	300	Continuum Electromechanics.....	252	Decisions, Manufacturing, Seminar.....	307
Complex Variable, Introduction to Functions of a.....	326	Continuum Mechanics.....	276	Defects in Solids.....	236
Complex Variables, Functions of.....	326	Continuum Vibrations.....	315	Defense, Research Problems in.....	319
Components and Measurements, Electronic.....	259	Control and Optimization, Dynamic Systems, Control.....	249	Deformation Processing.....	237
Components of the Urban Environment.....	280	Control, Automatic, Principles of.....	311	Deliberate Social Change in the Cities.....	281
Composite Materials.....	220	Control, Automatic, Statistical Problems in.....	312	Descriptive Meteorology.....	331
Composition, Graphic.....	239	Control, Automatic, System Laboratory.....	311	Design, Advanced Projects in Systems and.....	232
Composition, Plastic.....	241	Control, Electronic Instrumentation and.....	257	Design and Analysis of Experiments.....	245
Compressible Fluid Mechanics.....	227	Control, Flight Vehicle, Advanced Stability and.....	310	Design and Analysis of Scientific Experiments.....	294
Computability, Formal Systems, and Logic.....	250	Control, Instrumentation, and Guidance, Special Problems in.....	311	Design and Experiment.....	231
Computation, Analog/Digital, for Instrumentation and Control.....	226	Control, Instruments for Measurement and.....	226	Design, Architectural.....	241
Computation and Symbol Manipulation, Mathematical Theory of.....	253	Control Laboratory, Feedback.....	249	Design, Architectural, Special Problems.....	241
Computation, Automatic, Introduction to.....	322	Control Mechanisms, Neuroendocrine.....	335	Design, Architectural, Special Problems in.....	242
Computation, Elements, Systems and.....	247, 248	Control of Chemical Engineering Processes, Dynamics and.....	276	Design, Chemical Engineering.....	277
Computation, Introduction to.....	247	Control of Rotating Machine Systems.....	226	Design, City.....	280
Computation, Machine, Elementary Programming and.....	225	Control, Optimal, Applied.....	312	Design, City, Advanced.....	280
Computation, Mathematical Theory of, Introduction to.....	325	Control, Optimal, Theory of.....	256	Design, Collaborative.....	280
		Control, Principles of Instrumentation and.....	311	Design, Computer-Aided.....	232
		Control, Process.....	256	Design, Computer-Aided Urban.....	244
		Control Processes and Systems.....	304	Design Concepts.....	232
		Control, Propulsion System Reliability and.....	289	Design, Engineering.....	232
		Control Research, Seminar in.....	256	Design, Form and.....	240
				Design of a Waterborne Vehicle.....	290
				Design, Process.....	276
				Design, Special Problems in Systems and.....	232
				Design Systems, Building.....	217
				Design, Urban.....	241

Design, Urban, Problems in.....	280	Dynamic Oceanography.....	332	Economics, Managerial.....	298
Design, Visual, Advanced.....	240	Dynamic Systems.....	224	Economics, Mathematical Approach to.....	293
Design, Visual, Problems.....	239	Dynamic Systems, Control and Optimization	249	Economics, Monetary.....	295
Design, Visual, Projects.....	239	Dynamic Systems, Modeling and Simulation of	226	Economics of Eastern Hemisphere Petroleum,	
Detection and Measurement of Radio		Dynamic Systems, Stochastic.....	256	Seminar in the.....	293
Astronomical Signals.....	257	Dynamical Astronomy.....	272, 286, 312	Economics of Fuel and Power.....	293
Detection, Estimation, and Modulation Theory	254	Dynamical Meteorology, Introduction to.....	331	Economics of Nuclear Power.....	352
Developing Areas, Social Organization and		Dynamical Problems of Astronomy		Economics of Particular Industries.....	293
Political Change in.....	321	and Astrophysics.....	328	Economics of Technology and Innovation.....	293
Developing Countries, Metropolitan and		Dynamical Problems of the Solar		Economics of the Soviet Union.....	295
Regional Planning in.....	281	System.....	272, 286, 312	Economics, Reading Seminar in.....	293
Development, Economic, City Structure and	281	Dynamical Systems, Analysis of.....	255	Economics, Real Estate.....	282
Development, Economic Growth and.....	297	Dynamical Systems, Non-Linear.....	256	Economics Seminar.....	293
Development Finance.....	299	Dynamics.....	224, 309	Economics, Shipping.....	290
Development of American Economic		Dynamics and Control of Chemical		Economics, Topics in, Seminar.....	293
Institutions.....	342	Engineering Processes.....	276	Economics, Urban.....	295
Development of General War Systems		Dynamics, Industrial.....	305	Economics, Urban: Positive Analysis.....	282, 295
and Strategies.....	319	Dynamics of Electric Machines.....	253	Economics, Urban: Positive and Normative	
Development of Inventions and Creative Ideas	252	Dynamics of Management Systems, Research		Analysis.....	282, 295
Development of Limited War Systems		Seminar in.....	305	Economists, Mathematics for.....	292
and Strategies.....	319	Dynamics of Structures.....	315	Education and Society.....	350
Development of Political Organizations, The	321	<b>E</b> arth and the Planets, The.....	283	Education, Urban, Politics of.....	323
Development, Organization, Practicum in.....	300	Earth, Chemistry of the.....	285	Education, Urban, Seminar in.....	351
Development Patterns, Urban, and Economic		Earth, Physics of the.....	286	Eighteenth Century, Origins of Contemporary	
Growth.....	282	Earth Structures.....	219	Architecture in the.....	243
Development, Social Aspects of.....	281	East, Far, Introduction to the.....	350	Elasticity, Applied.....	225
Development, Urban, Policy, Seminar on.....	281	East, Middle, Transitional, Politics in the.....	317	Elasticity, Introduction to.....	329
Developmental Biology.....	263	Eastern Hemisphere Petroleum, Seminar in the		Elasticity, Solid Mechanics —.....	225
Developmental Psychology.....	275	Economics of.....	293	Elasticity, Theoretical and Applied.....	329
Developmental Psychology, Seminar in.....	275	Eastern, Near, Archaeology: The Foundations		Electric and Magnetic Properties of Solids.....	249
Devices and Circuits, Electronic.....	248	of Civilization.....	342	Electric Machines, Dynamics of.....	253
Difference Equations, Partial.....	327	Econometric Theory.....	294	Electric Propulsion.....	313
Differential Equations.....	327	Econometrics.....	294	Electrical and Optical Properties of Ceramics	238
Differential Equations, Ordinary.....	324	Econometrics, Advanced Topics in.....	294	Electrical Discharges in Gases.....	267
Differential Equations, Partial.....	327	Econometrics, Applied.....	294	Electrical Energy Conversion Laboratory,	
Differential Geometry, Elementary.....	326	Economic Analysis.....	293	Advanced.....	260
Differential Topology.....	330	Economic Anthropology.....	342	Electrical Engineering Laboratory.....	260
Diffraction, Neutron.....	269	Economic Control, National, The Politics of	317	Electrical Engineering, Research in.....	261
Diffraction, X-ray.....	269	Economic Development, City Structure and.....	281	Electrical Engineering Research,	
Digital Computer Programming Systems.....	250	Economic Development of Tropical Africa,		Introduction to.....	259
Digital Processing of Signals.....	257	Political and.....	321	Electrical Engineering Seminar.....	252
Digital Systems, Introduction to.....	250, 251	Economic Development, Problems of.....	297	Electrical Engineering, Special Studies in.....	259, 260
Digital Systems Project Laboratory.....	251, 259	Economic Development, Seminar in.....	297	Electrical Engineering, Special Subjects in.....	259, 260
Digital Systems Project Laboratory, Advanced	251	Economic Development, Theory of.....	297	Electrical Engineering, Teaching.....	261
Diplomacy, Soviet-American.....	345	Economic Fluctuations and Growth.....	292	Electrochemistry.....	238, 277
Disarmament and Foreign Policy, Arms		Economic Growth and Development.....	297	Electrodynamics.....	248
Control.....	320	Economic Growth and Fluctuations.....	294	Electrodynamics, Continuum, Advanced	
Disease, Inherited, Metabolic Aspects in.....	336	Economic Growth and Fluctuations.....	297	Topics in.....	255
Diseases, Food-Borne, Epidemiology of		Economic Growth, Elements of.....	297	Electrodynamics of Waves, Media, and	
Nutritional and.....	334	Economic Growth, Technology and.....	341	Interactions.....	255
Dislocation Theory.....	228	Economic Growth, Urban Development		Electromagnetic Fields and Energy.....	248
Dissent and Reform in Twentieth-Century		Patterns and.....	282	Electromagnetic Theory.....	255, 268
America.....	343	Economic History.....	296	Electromagnetic Waves, Interactions of	
Distillation.....	277	Economic History, American.....	296	Plasmas with.....	270
Distributed Systems.....	226	Economic History, European.....	297	Electromechanical Fields and Systems.....	225
Distribution of Income and Employment		Economic History, Problems in.....	297	Electromechanics, Continuum.....	252
Opportunity.....	294	Economic Institutions, American,		Electron Microscope Techniques in	
Doctoral Dissertation Seminar.....	294	Development of.....	342	Neurobiology, Light and.....	273
Doctoral Seminar in Organization Studies.....	302	Economic Principles.....	292	Electron Microscopy.....	265
Doctoral Seminar on Career Development and		Economic Research Seminar.....	294	Electron Microscopy, Introduction to.....	219
Adult Socialization.....	302	Economic Systems, Comparative.....	295	Electron Microscopy Laboratory.....	265
Domestic and Foreign Politics of East Europe	318	Economic Theory, Advanced.....	293	Electron Optics and Electron Microscopy,	
Domestic Politics of Western Europe.....	317	Economic Theory, International, Seminar in	296	Introduction to.....	237
Dostoevsky, Tolstoi, Chekhov: Russia and the		Economic Thought, Schools of.....	293	Electron Physics.....	267
Modern Age.....	340	Economics and Finance: Principles and		Electronic Circuits.....	253
Drama and Community.....	340	Policies.....	292, 293	Electronic Circuits and Signals Laboratory.....	259
Drama, Classical French.....	357	Economics, Fiscal.....	295	Electronic Components and Measurements.....	259
Drama, French, Contemporary.....	357	Economics for Management.....	297	Electronic Devices and Circuits.....	248
Drama, Modern.....	340	Economics for Management, Seminar in.....	297	Electronic Instrumentation and Control.....	257
Drama, Modern German.....	356	Economics, Industrial, Problems in.....	293	Electronic Instrumentation Laboratory, Basic	353
Drama, Spanish.....	356	Economics, Industrial, Seminar.....	294	Electronic Light Measurements.....	249
Dynamic Behavior of Metallurgical Systems	238	Economics, International.....	295	Electronic Light Measurements Project	
Dynamic Fluid Machines.....	228	Economics, Interregional.....	296	Laboratory.....	260
Dynamic Hydrology.....	222	Economics, Labor.....	296, 306	Electronic Materials.....	239, 258
Dynamic Meteorology.....	331, 332	Economics, Labor, and Public Policy.....	296	Electronic Properties of Solids.....	258

SUBJECTS INDEX

Electronics in Instrumentation.....	249	Environmental Form, Psychological Functions of.....	280	Fast Power Reactors.....	352
Electronics, Introduction to.....	249	Epic, The.....	339	Fast Reactor Physics.....	353
Electronics, Quantum.....	258, 267	Epidemiology of Nutritional and Food-Borne Diseases.....	334	"Faust," Goethe's.....	356
Electronics, Quantum, Physics of.....	269	Equations, Differential.....	327	Federal System, American.....	316
Electronics, Semiconductor.....	257	Equations, Integral.....	328	Feedback Control Laboratory.....	249
Electrons and Atoms in Solids.....	235	Equations, Partial Difference.....	327	Feedback Dynamics Laboratory.....	304
Electrophysiology of the Visual System.....	273	Equations, Partial Differential.....	327	Fiber Processing Dynamics.....	233
Elementary Differential Geometry.....	326	Equilibrium, Chemical.....	246	Fiber Research Laboratory.....	234
Elementary French.....	356, 357	Estimation and Control of Stochastic Processes.....	312	Fibers and Polymers Seminar.....	234
Elementary German.....	355	Estimation, and Modulation Theory, Detection.....	254	Fiction, French Prose.....	357
Elementary Internal Combustion Engines.....	230	Ethics.....	346	Fiction, Introduction to the Writing of.....	338
Elementary Nuclear Physics.....	351	Ethics, Problems in.....	346	Fiction, Modern German.....	356
Elementary Number Theory.....	323	Europe, Central, from the French Revolution to the Third Reich, Nationalism and Politics in.....	344	Fiction, Narrative.....	339
Elementary Physics of the Atmosphere.....	332	Europe, East, Domestic and Foreign Politics of.....	318	Fiction, The Writing of.....	338
Elementary Russian.....	359	Europe, Industrial Structure of.....	299	Field Methods.....	358
Elementary Programming and Machine Computation.....	225	Europe, Medieval, Culture and Society in.....	342	Field Research in Political Development.....	321
Elements of Classical and Statistical Thermodynamics.....	229	Europe, Modern, Intellectual History of.....	343	Field Study, Management Science.....	304
Elements of Digital Guidance Computers.....	313	Europe, Reconstruction of, 1945-65.....	345	Fields and Energy, Electromagnetic.....	248
Elements of Economic Growth.....	297	Europe, Western, Domestic Politics of.....	367	Fields and Systems, Electromechanical.....	225
Elements of Seismology.....	286	Europe, Western: Research Seminar in Comparative Politics.....	317	Fields, Forces, and Motion.....	248
Elements of Systems Analysis.....	215	European Economic History.....	297	Fields in Continuous Media.....	310
Elements of Textile Materials and Processes.....	233	European Heritage, The, The Western Tradition.....	336	Film Making, Introduction to.....	241, 351
Elements of Urban Evolution.....	243, 350	European Liberalism, Nineteenth Century: Its Decline and Transformation.....	345	Finance, Development.....	299
Elements, Systems and Computation.....	247, 248	European States, West, The International Politics of the.....	317	Finance, Economics and: Principles and Policies.....	292, 293
Eliot, T. S.: Major Authors.....	340	European Tradition, The: Goethe Era.....	355	Finance, Public.....	294
Elliptic Operators.....	330	Evaluating Photography.....	240	Financial Administration of Industry.....	303
Emergence of Modern Africa, The.....	342	Evolution of Forces for Limited War.....	319	Financial Institutions, Capital Markets and.....	302
Empiricists, The British.....	346	Evolution of Strategic Nuclear Systems.....	318	Financial Intermediaries, The Management of.....	302
Employment Opportunity, Distribution of Income and.....	294	Evolution, Stellar.....	271	Financial Management.....	302
Employment, Theory of Income and.....	294	Exchange, Ion.....	277	Finite Automata Theory, Switching and.....	250
Endocrinology.....	334	Existentialism.....	346	Fiscal and Monetary Policy, Seminar in.....	295
Energy Conversion Systems and Components.....	289	Experiment, Design and.....	231	Fiscal Economics.....	295
Energy, Electromagnetic Fields and.....	248	Experimental Atomic Physics.....	266	Flavor Chemistry and Flavor Methodology.....	333
Energy Transmission and Radiation.....	248	Experimental Biochemistry.....	263	Flight Guidance, Principles of.....	312
Engineering Analysis.....	214	Experimental Biology, Introduction to.....	263	Flight, Interplanetary, Special Problems in.....	310
Engineering Analysis, Linear Methods of.....	215	Experimental Cell Biology.....	263	Flight Transportation.....	217, 303, 314
Engineering Analysis, Methods of.....	225	Experimental Engineering.....	232	Flight Transportation Facilities.....	217
Engineering Analysis, Numerical Methods of.....	215	Experimental Genetics and Microbiology.....	263	Flight Transportation Operations Analysis.....	314
Engineering and Planning, Decision Theories in.....	216	Experimental Hydromechanics.....	222	Flight Transportation Seminar.....	217, 303, 314
Engineering Computer System Management and Use.....	216	Experimental Nutrition.....	333	Flight Vehicle Engineering.....	314
Engineering Computer Systems Design.....	216	Experimental Petrology.....	285	Flight Vehicle Stability and Control, Advanced.....	310
Engineering Design.....	232	Experimental Physiology.....	264	Flight Vehicles.....	315
Engineering Design and Manufacture.....	233	Experimental Projects.....	314	Flight Vehicles, Aerodynamics of.....	310
Engineering Geology.....	219	Experimental Research Problem.....	279	Flow and Boiling Heat Transfer, Two-Phase.....	230
Engineering, History of.....	341	Experimental Soil Mechanics.....	219	Flow Free Surface.....	222
Engineering Materials.....	214	Experimental Statistics for the Biological Sciences.....	336	Flow in Porous Media.....	222
Engineering Mechanics.....	214	Experimental Stress Analysis.....	231	Flow Noise.....	224, 292
Engineering Science, Case Histories in.....	236	Experimental Stress Analysis, Research in.....	231	Flows, Viscous and Turbulent.....	227
Engineering Systems Analysis.....	216	Experimental Techniques in Aerodynamics.....	314	Fluctuations and Growth, Economic.....	292
Engineering Systems, Computer Models of Physical and.....	225	Experimentation, Chemical, Advanced.....	245	Fluctuations, Physics of Noise and.....	267
Engineering Systems, Introduction to.....	223	Experimentation, Chemical, Introduction to.....	245	Fluid and Plasma Physics, Selected Topics in.....	270
Engineering Physics of Plasma and Particle Devices.....	353	Experiments, Design and Analysis of.....	245	Fluid and Plasma Physics, Special Problems in.....	270
Engineering Problems.....	250	Experiments in Biology.....	263	Fluids and Plasmas, Introduction to Physics of.....	270
Engineering Problems, Computer Approaches to.....	216	Experiments, Scientific, Design and Analysis of.....	294	Fluid Dynamics.....	214
Engines, Aircraft.....	313	Explanation and Theory Formation, Problems of.....	346	Fluid Dynamics Laboratory.....	331
English Language, History of the.....	340, 358	Factors Determining Food Value.....	334	Fluid Dynamics, Planetary.....	332
English Renaissance, Literature of the.....	339	Far East, Introduction to the.....	350	Fluid Dynamics, Seminar in.....	328
English, Structure of.....	358	Fascism, Varieties of: Origins and Comparative Development in Germany and France, 1900-1945.....	345	Fluid Machines, Dynamic.....	228
English, Structure of: Advanced Syntax.....	358			Fluid Mechanics.....	222, 227
English Syntax, Seminar on.....	358			Fluid Mechanics, Advanced.....	227, 228
Enlightenment, The French.....	355			Fluid Mechanics and Transport Processes.....	276
Enterprises, New.....	308			Fluid Mechanics, Biomedical.....	228
Environment, Managerial.....	298			Fluid Mechanics, Compressible.....	227
Environment, Psychology of the.....	280			Fluid Mechanics, Introduction to.....	327
Environmental Control — Acoustics.....	242			Fluid Mechanics, Molecular.....	227
Environmental Control — Air Conditioning.....	231			Fluid Mechanics of Pollution.....	228
Environmental Control, Vehicle.....	231			Fluid Mechanics, Topics in.....	309

Food and Drug Industries, Research Management in the.....	336	Gas Dynamics, Advanced.....	309	Graduate Seminar.....	348
Food and Nutrition Research, Techniques in.....	334	Gas Dynamics, Reacting.....	228	Graduate Seminar in American Politics.....	316
Food Applications of Ionizing Radiations.....	335	Gas Dynamics, Real.....	309	Graduate Seminar in Political Psychology.....	316
Food Engineering.....	231, 333	Gas Flows, High Speed, Physics of.....	309	Graduate Topology Seminar.....	330
Food Engineering, Advanced.....	333	Gas-Surface Interactions.....	309	Grammar of Non-Indo-European Languages, Topics in the.....	359
Food Microbiology.....	334	Gas Turbines.....	230	Grammar, Theory of, Introduction to Linguistics.....	358
Food Science, Advanced.....	334, 335	Gasdynamics.....	309	Grammar, Universal, Seminar on.....	359
Food Science and Technology.....	333	Gases and Liquids, Properties of.....	277	Graphic Composition.....	239
Food Science Projects Laboratory, Nutrition and.....	333	Gases and Plasmas, Kinetic Theory of.....	227	Graphics Laboratory.....	239
Food Science, Selected Topics in Nutrition and.....	334	Gases and Plasmas, Reaction Kinetics of.....	227	Great Cities: Paris.....	243, 350
Food Science, Seminar in Nutrition and.....	335	Gases, Electrical Discharges in.....	267	Greek Tradition, The.....	354
Food Technology, Advanced.....	335	Gases, Ionized.....	313	Group Theoretical Methods in Physics.....	267
Food Technology Laboratory.....	333	General and Cell Physiology.....	263	Group Theory, Chemical Applications of.....	244
Food Toxicology.....	335	General Biochemistry.....	263	Group Theory, Physical Applications of.....	268
Food Toxicology Laboratory.....	335	General Biology.....	263	Groups, Behavior in.....	274
Food Value, Factors Determining.....	334	General Electric Company, Industrial Practice at the.....	261	Groups, Lie, and Lie Algebras.....	330
Force in International Relations, Negotiation and.....	319	General Electric Company, Industrial Project at the.....	261	Groups, Lie, Representations of.....	330
Forces and Motion, Fields.....	248	General Microbiology.....	264	Groups, Locally Compact.....	330
Forecasting, Long-Range.....	336	General Radio Company, Industrial Practice at the.....	262	Growth, Economic Fluctuations and.....	292
Foreign Policy, American, Principles and Problems of.....	320	General Radio Company, Industrial Project at the.....	262	Guidance, Astronautical.....	312, 313
Foreign Policy, American, Science and.....	319	Genetics.....	263	Guidance, Inertial.....	312
Foreign Policy, Arms Control, Disarmament, and.....	320	Genetics and Microbiology, Experimental.....	263	Guidance, Special Problems in Instrumentation Control and.....	311
Foreign Policy for Executives.....	308	Genetics, Molecular.....	265	Gyroscopic Instruments, Space Dynamics and.....	312
Foreign Policy, International Relations, and Research.....	320	Geochemical Research.....	285	<b>H</b> armonic Analysis and Potential Theory.....	327
Foreign Policy, Soviet, and the Communist World.....	318	Geochemistry.....	285	Harmonic and Statistical Analysis, Methods of.....	291
Foreign Policy, U.S. — Plans and Strategies.....	320	Geochemistry, Marine.....	285	Health, Public, Clinical and, Nutrition.....	336
Foreign Policy, U.S. — Process and Problems.....	320	Geochemistry, Research in Meteoritics and.....	285	Hearing, Sound, Speech and.....	251
Form and Color.....	240	Geochemistry, Seminar in Geology and.....	284	Heat and Mass Transfer.....	229, 277
Form and Design.....	240	Geodesy, Marine.....	287	Heat and Mass Transfer, Modes of.....	276
Foundations.....	219	Geoelectricity and Geomagnetism.....	286	Heat and Thermodynamics, Advanced Projects in.....	229
Fracture Mechanisms in Metal.....	237	Geological Materials, Analysis of.....	284	Heat Engineering.....	229
France: The Modernization of a Developed Society.....	344	Geology.....	283	Heat, Problems in.....	229
Free Surface Flow.....	222	Geology and Geochemistry, Seminar in.....	284	Heat Transfer.....	229
Free Surface Hydrodynamics.....	288	Geology, Engineering.....	219	Heat Transfer, Advanced.....	230
Free Will and Moral Responsibility.....	346	Geology, Isotope.....	285	Heat Transfer, Advanced Topics in.....	277
Freedom in Modern Literature, The Concept of.....	351	Geology, Isotope, Research in.....	285	Heat Transfer, Radiation.....	230
French, Conversational.....	357	Geology, Structural, Seminar in.....	285	Heat Transfer, Two-Phase Flow and Boiling.....	230
French Drama, Classical.....	357	Geomagnetism, Geoelectricity and.....	286	Heating, Aerodynamic.....	309
French Drama, Contemporary.....	357	Geometric Design.....	232	Heuristic Programming and Artificial Intelligence.....	253, 325
French, Elementary.....	357	Geometry, Algebraic.....	329	Higher Recursion Theory.....	330
French Enlightenment, The.....	355	Geometry, Elementary Differential.....	326	High Speed Gas Flows, Physics of.....	309
French, Intermediate.....	357	Geometry of Manifolds.....	330	Hilbert Space.....	326
French Literature, Seminar in.....	357	Geometry, Riemannian.....	326	Histology, Comparative.....	335
French Poetry, Modern.....	357	Geophysics, Applied, Analytic Methods in.....	286	Historical Studies, Advanced.....	298
French Prose Fiction.....	357	Geophysics, Regional, Interpretation Methods in.....	286	History, American Constitutional.....	344
French Reading.....	357	Geophysics, Special Problems in.....	286	History, American Economic.....	296
French Romanticism.....	357	Geotechnology.....	215	History, American Intellectual.....	344
French, Spoken.....	357	German, Advanced.....	355	History, American, The Businessman in.....	342
Freud, Marx, Darwin and.....	343	German Drama, Modern.....	356	History and Psychoanalysis.....	344
From Atoms Toward Living Systems.....	258	German, Elementary.....	355	History and Theory of Art, Topical Studies in the.....	242
Fuel and Power, Economics of.....	293	German Fiction, Modern.....	356	History, Economic.....	296
Fuels, Nuclear.....	238, 354	German, Intermediate.....	355	History, Economic, Problems in.....	297
Function of Law in the World Community.....	320	German Novel, The Modern.....	356	History, European Economic.....	297
Functional Analysis.....	327	German Poetry, Seminar in.....	356	History, Intellectual, of Modern Europe.....	343
Functions of a Complex Variable, Introduction to.....	326	German Reading.....	355, 356	History of Engineering.....	341
Functions of Complex Variables.....	326	German Romanticism.....	355	History of Materials.....	341
Functions of Real Variables.....	326	German, Spoken.....	355	History of Philosophy.....	345
Functions, Theory of.....	326	German, Structure of.....	358	History of Technology in the United States.....	342
Fundamentals of Radio Astronomy.....	257, 272	Germany from 1895 to the Bauhaus, Modern Architecture in.....	243	History of the English Language.....	340, 358
Fusion, Controlled, Plasmas and.....	353	Goethe Era, The European Tradition.....	355	History of Transportation in the United States.....	342
<b>G</b> alactic Structure, Stellar Dynamics and.....	328	Goethe's "Faust".....	356	History of Urban Form.....	243
Galaxy, Physics of the.....	271	Goethe's Poetry.....	355	History, Philosophy of.....	345
Game, Business.....	307	Gogol and Literary Methodology in Russia.....	360	History Seminar.....	338
Gas Dynamics.....	227	Governance of Cambridge, The.....	318	History, Special Topics in.....	345
		Government Policy, Scientific Development and.....	319	History, Urban American, Seminar on.....	282
		Government, Politics and Technology.....	319	History, World Military.....	361
		Government Regulation of Industry.....	293	Homological Algebra.....	329

SUBJECTS INDEX

Honeywell Incorporated, Industrial Practice at	261	Industrial Project at Radio Corporation		Intermediate Chemical Experimentation	245
Honeywell, Incorporated, Industrial Project at	262	of America	261	Intermediate French	357
Housing Problems	280	Industrial Project at the Air Force Cambridge		Intermediate German	355
Human Factors in Management	300	Research Laboratories	263	Intermediate Macroeconomic Theory	292
Human Nutrition	334	Industrial Project at the American Electric		Intermediate Microeconomic Theory	292
Human Processing of Sensory Inputs,		Power Service Corporation	262	Intermediate Russian	359
Analytical Models for	255	Industrial Project at the Bell Telephone		Internal Combustion Engine Laboratory	230
Humanities Seminar	338	Laboratories, Inc.	262	Internal Combustion Engines	230
Hydroacoustics	291	Industrial Project at the General Electric		Internal Combustion Engines, Advanced	230
Hydrodynamic Stability and Turbulence	328	Company	261	Internal Combustion Engines, Elementary	230
Hydrodynamics, Free Surface	288	Industrial Project at the General Radio		Internal Combustion Engines, Special	
Hydrodynamics, Marine	288	Company	262	Problems in	230
Hydrodynamics, Marine, Introduction to	287	Industrial Project at the International Business		International Affairs, Ocean Engineering and	292
Hydrodynamics, Propulsion	289	Machines Corporation	261	International Business Machines Corporation,	
Hydrodynamics, Theoretical	327	Industrial Project at the Naval Ordnance		Industrial Practice at the	261
Hydrofoil, Three-Dimensional, Theory	288	Laboratory	262	International Business Machines Corporation,	
Hydrofoil, Two-Dimensional, Theory	288	Industrial Project at the Raytheon Company	262	Industrial Project at the	261
Hydrologic Analysis and Synthesis	222	Industrial Relations and Human Resource		International Business Management	299
Hydrology, Dynamic	222	Development, Comparative Systems of	296, 306	International Communications, Research	
Hydromechanics, Advanced	222	Industrial Relations, Research Seminar in	296, 307	Seminar in	316
Hydromechanics, Experimental	222	Industrial Society, Political Ideas and	321	International Economics	295
Hydromechanics of Ship Design, Advanced	288	Industrial Sociology	301	International Economic Theory, Seminar in	296
Hydromechanics, Special Problems in	222	Industrial Statistics	297	International Politics of the West European	
Hydrospace Vehicles	291	Industrial Structure of Europe	299	States, The	317
Hydrostatics, Applied	287	Industries, Particular, Economics of	293	International Politics, Seminar in	320
		Industry, Financial Administration of	303	International Relations	320
<b>I</b> dentify and Autobiography: The Nineteenth		Industry, Government Regulation of	293	International Relations and Foreign Policy,	
Century	336	Inertial Guidance	312	Research	320
Identify and Autobiography: The Twentieth		Influence and Policy Decisions, Power	316	International Relations, Negotiation and	
Century	337	Influence, Attitude Change and Adult		Force in	319
Identity and Ideology	316	Socialization, Seminar on	300	International Relations, Research Seminar in	320
Ideology, Identity and	316	Influence Processes and Mass Communications	308	International Relations, Theories of	320
Image Transmission Systems	252	Information and Controls, Management	298	International Trade	295
Image Transmission Systems Project		Information and Control Systems, Seminar in	304	Interpersonal Dynamics Laboratory	300
Laboratory	260	Information and Decision Systems	303, 307	Interplanetary Flight, Special Problems in	310
Immunology, Seminar in	265	Information, Management Measurement and	308	Interpretation Methods in Regional	
Imperialism and Colonialism, Research		Information, Managerial, Advanced Concepts		Geophysics	286
Seminar in	320	in for Planning and Control	303	Interpretive Spectroscopy	245
Improvement of Engineering Properties of Soils	219	Information, Managerial, and Controls	303	Interregional Economics	296
Income and Employment Opportunity,		Information Processing, Introduction to	282	Introductory Network Theory	248
Distribution of	294	Information Systems	214, 249	Introductory Psychology	272
Income and Employment, Theory of	294	Information Systems, Management	304	Introductory Quantum Mechanics	246
Independent Study	341	Information Systems, Structural	221	Introductory Ship Design	290
India, Political Development in: Comparative		Information Technology, Management	304	Inventions and Creative Ideas,	
Asian Politics	317	Information Theory, Advanced Topics in	254	Development of	252
Indo-European	358	Information, Transmission of	254	Inventions and Patents	250
Industrial Change, Management of	302	Inherited Disease, Metabolic Aspects in	336	Investments	302
Industrial Chemical Synthesis	276	Innovation, Economics of Technology and	293	Ion Exchange	277
Industrial Chemistry	275	Inorganic Chemistry, Advanced	244	Ionized Gases	313
Industrial Dynamics	305	Inorganic Chemistry, Principles of	244	Ionizing Radiations, Food Applications of	335
Industrial Economics, Problems in	293	Inorganic Chemistry, Seminar in	247	Isotope Geology	285
Industrial Economics Seminar	294	Instrumentation and Control, Electronic	257	Isotope Geology, Research in	285
Industrial Management, Introduction to	298	Instrumentation and Control, Principles of	311	Italian Renaissance, The	343
Industrial Microbiology	334	Instrumentation, Chemical Engineering,			
Industrial Organization and Public Policy	293	Laboratory	275	<b>J</b> apan, China, and the West	344
Industrial Practice	315	Instrumentation, Comparative	311	Judeo-Christian Tradition, The	354, 355
Industrial Practice at AVCO Corporation	261	Instrumentation, Comparative, Laboratory	311		
Industrial Practice at Honeywell, Incorporated	261	Instrumentation Control and Guidance,		<b>K</b> ant	346
Industrial Practice at Radio Corporation		Special Problems in	311	Kinematics, Modern, Theory of	232
of America	261	Instrumentation, Electronics in	249	Kinetic Theory, Advanced Topics in	
Industrial Practice at the American Electric		Instrumentation Laboratory, Basic Electronic	353	Statistical Mechanics and	247
Power Service Corporation	262	Instruments for Measurement and Control	226	Kinetic Theory of Gases and Plasmas	227
Industrial Practice at the Bell Telephone		Integral Equations	328	Kinetic Theory, Plasma	270, 354
Laboratories, Inc.	262	Integrals, Singular	327	Kinetic Theory, Plasma, Advanced	
Industrial Practice at the General Electric		Intellectual History, American	344	Topics in	313, 354
Company	261	Intellectual History of Modern Europe	343	Kinetic Theory, Plasma, Introduction to	314
Industrial Practice at the General Radio		Intellectuals and Social Change	351	Kinetics, Applied Chemical	278
Company	262	Intelligence, Artificial, Heuristic		Kinetics, Chemical, and Reactor Design	276
Industrial Practice at the International		Programming and	253	Kinetics in Metallurgy and Materials Science	236
Business Machines Corporation	261	Interactions of Plasmas with Electromagnetic		Kinetics of Chemical Reactions	246
Industrial Practice at the Raytheon Company	262	Waves	270	Kinetics of Gases and Plasmas, Reaction	227
Industrial Practice, Special	262	Interactive Data Analysis	322	Kinetics, Space-Time Reactor	352
Industrial Project at AVCO Corporation	261	Interdisciplinary Studies, Special		Knowledge, Biological Bases of Perception and	351
Industrial Project at Honeywell, Incorporated	262	Topics in	349, 350	Knowledge, Problems of	346
		Interfaces, Structure and Properties of	239	Knowledge, Theory of	346

Labor Economics	296, 306	Literary Art, Social Vision in: Shaw, Lawrence, Faulkner	340	Management Laboratory	307
Labor Economics and Public Policy	296	Literary Methodology in Russia, Gogol and	360	Management Laboratory, Advanced	307
Labor Law	306	Literary Study, Linguistics and	341	Management-Labor Relations and Public Policy	306
Labor-Management Relations and Public Policy	306	Literature and Communication	351	Management, Mathematics for	298
Labor Problems Seminar	296	Literature and Interpersonal Relationships	341	Management Measurement and Information	308
Labor Relations	296	Literature and Language, Special Problems in	358	Management of Financial Intermediaries, The	302
Labor Relations, Public Policy on	296, 306	Literature and National Values, Studies in	340	Management of Human Resources	300
Laboratory Measurement and Control	239	Literature, Chinese	340	Management of Industrial Change	302
Laboratory Problems in Chemistry	245	Literature, Classical, Poetic and Scientific Discourse in	350	Management, Operations	307
Land Use, Law of	282	Literature, Contemporary Soviet	360	Management Problems in Science and Technology, Seminar on	302
Landscape, Urban	280	Literature, Forms of a Major Theme	337	Management, Public, of Science	319
Language Acquisition, Seminar in	357	Literature, French, Seminar in	357	Management, Quantitative Methods in	298
Language and Communication, Psychology of	274	Literature of the English Renaissance	339	Management, Research	302
Language and Communication, Seminar in Psychology of	274	Literature in the Emergence of American World Power	339	Management, Research, in the Food and Drug Industries	336
Language and Literature, Special Problems in	358	Literature, Modern, The Concept of Freedom in	351	Management Science Field Study	304
Language, English, History of the	340, 358	Literature, Non-Western	340	Management, Special Studies in	308
Language, Philosophy of	348	Literature, Philosopher in	347	Management System Dynamics, Study and Research in	308
Language, Problems in the Philosophy of, Seminar:	348	Literature, Russian, Introduction to	360	Management Systems, Research Seminar in Dynamics of	305
Languages, Non-Indo-European, Topics in the Grammar of	359	Literature: Self, Nature and Society	337	Managerial Accounting	303
Latin America, Comparative Politics of	318	Literature, Spanish, Masterpieces of	356	Managerial Behavior, Seminar in	302
Law, American, Structure of	299	Literature, Soviet Russian	360	Managerial Communication	302
Law and Morality, Responsibility in	346	Literature, Soviet, Selected Problems in	360	Managerial Economics	298
Law in the World Community, Function of	320	Literature, Spanish, Introduction to	356	Managerial Environment	298
Law, Labor	306	Literature, Spanish, Twentieth-Century	356	Managerial Information and Controls	303
Law, Morality and the	350	Literature, Special Topics in	341	Managerial Information for Planning and Control, Advanced Concepts in	303
Law of Land Use	282	Literature, The Confession in	340	Managerial Psychology	298
Leadership Development	362	Literature, The Nature of	355	Manifolds, Geometry of	330
Leadership Practice	361	Literature Today	341	Manned Systems, Life Support and Physiological Modeling in	227, 312
Learning	274	Literature, Utopian	339	Manufacturing Analysis, Studies in	307
Learning and Motivation, Neural Mechanisms of	273	Living Systems, From Atoms Toward	258	Manufacturing Decisions Seminar	307
Learning, Seminar in	274	Local Politics, State and	317	Manufacturing Project Laboratory	233
Learning Theory, Mathematical	328	Locally Compact Groups	330	Marine Acoustics	287
Legal Aspects of New Technology	234, 306, 315	Logic, Computability, Formal Systems and	250	Marine Engineering, Computer Systems for Naval Architecture and	290
Legal System, American	306	Logic, Computers and	325	Marine Engineering, Special Problems in Naval Architecture and	291
Liberalism, Nineteenth Century European: Its Decline and Transformation	345	Logic, Mathematical	330	Marine Geochemistry	285
Liberty, Nature and Justification of	346	Logic, Mathematical, Introduction to	330	Marine Geodesy	287
Lie Groups and Lie Algebras	330	Logic of Questions, The	346	Marine Hydrodynamics	288
Lie Groups, Representations of	330	Logic of Social Research	322	Marine Hydrodynamics, Introduction to	287
Life Science, Perspectives in	263	Logic, Philosophy of	346	Marine Problems, Computer Applications to Marine Structures	290
Life Sciences, Philosophy and the	347	Logic, Symbolic	346	Marine Structures, Acoustics and Shock Response of	291
Life Support and Physiological Modeling in Manned Systems	227, 312	Long-Range Forecasting	331	Marketing	299, 307
Light and Color	240	Low Temperature Refrigeration	231	Marketing Models	308
Light and Electron Microscope Techniques in Neurobiology	273	Lubrication, Research in	231	Marketing, Research Seminar in	308
Light Measurements, Electronic	249	Lyric and Discourse	341	Markets, Capital, and Financial Institutions	302
Light Measurements Electronic, Project Laboratory	260	<b>M</b> achine Systems, Rotating, Control of	226	Marx, Darwin, and Freud	343
Linear Algebra	325	Machine Tool Fundamentals	233	Mass Media and Communication Systems	315
Linear Mathematical Systems	324	Macroeconomic Theory, Intermediate	292	Mass Transfer, Advanced Topics in	277
Linear Methods of Engineering Analysis	215	Macromolecular Physics, Principles of	233	Mass Transfer, Heat and	229, 277
Linear Systems, Probability Theory and	254	Macromolecules, Physical Chemistry of	264	Masterpieces of Spanish Literature	356
Linguist in Society, Seminar on the	359	Magnetic Properties of Solids, Electric and	249	Material, Crystalline, Mechanical Behavior of	285
Linguistic Change	359	Magnetics, Microwave	258	Material Interface Phenomena, Application of	233
Linguistic Change, Seminar on	359	Magnetism, Quantum Theory of	259	Material Interface Phenomena, Theory of	233
Linguistic Structure	358	Major Authors: Friedrich Nietzsche	340	Materials	242
Linguistics and Literary Study	341	Major Authors: T. S. Eliot	340	Materials, Cementitious	219
Linguistics and Poetics	357	Mammalian Neuroanatomy, Outline of	272	Materials, Chemistry of	234
Linguistics, Crucial Problems in	357	Man-Machine Systems	226	Materials, Composite	220
Linguistics, General, Survey of	359	Man, Society and	315	Materials, Electronic	239, 258
Linguistics, Introduction to: Phonology	358	Management and Leadership, Naval Industrial	362	Materials, History of	341
Linguistics, Introduction to: Syntax	358	Management, Business, Taxation and	303	Materials, Mechanical Behavior of	228
Linguistics, Introduction to: Theory of Grammar	358	Management, Economics for	297	Materials, Mechanical Behavior of, Advanced	228
Linguistics, Mathematical Models in	359	Management, Economics for, Seminar in	297	Materials, Mechanics of	220, 235
Linguistics, Programming	249	Management Environment	299	Materials of Music	348
Liquids, Properties of Gases and	277	Management Experience	361	Materials, Polymeric, Synthesis and Properties of	278
Literary Analysis	339	Management, Financial	302		

SUBJECTS INDEX

Materials Processing	236	Mechanics, Solid, Laboratory	310	Middle Ages, Architecture in the	243
Materials, Research in	229	Mechanics, Statistical	246, 268	Middle East, Transitional, Politics in the	317
Materials Research Laboratory	234	Mechanism, Structure, Bonding and, Introduction to	245	Migration and Political Development	317
Materials Science	235	Media, and Interactions, Electrodynamics of Waves	255	Military History, World	361
Materials, Science of	235	Medicine, Chemical Engineering in	277	Military Institutions of the Modern State, War and the	344
Materials, Special Studies in	220	Medieval Europe, Culture and Society in	342	Military Law and Administration, Principles and Applications of	362
Materials, Structural	219	Memory, Seminar in Psychophysiology of	272	Military Management and Logistics, Principles of	362
Materials, Structural, Strength of	219	Metabolic Aspects in Inherited Disease	336	Military Tactics and Communications	362
Materials, Thermodynamics of	234	Metabolism, Nutritional Biochemistry and, Advanced	333	Military Systems, World	361
Mathematical Analysis of Fundamental Physics	326	Metabolism, Nutritional Biochemistry and, Advanced	333	Military Systems, World, Airpower and the	361
Mathematical Approach to Economics	293	Metal, Fracture Mechanisms in	237	Military Teaching and Leadership, Principles of	362
Mathematical Backgrounds for Communication Sciences	359	Metal Structures, Behavior of	220	Mind, Philosophy of	348
Mathematical Behavioral Science	301	Metallurgical Systems, Dynamic Behavior of	238	Mineral Engineering	238
Mathematical Learning Theory	328	Metallurgy, Advanced X-ray	237	Mineralogy, Theoretical	283
Mathematical Logic	330	Metallurgy and Materials Science, Kinetics in	236	Minerals, Rock Forming	285
Mathematical Logic, Introduction to	330	Metallurgy, Chemical	234	Missiles, Naval Guided	362
Mathematical Models in Linguistics	359	Metallurgy for Nuclear Engineers	354	Model Building in Political Science, Seminar in	322
Mathematical Models in the Social Sciences, Introduction to	322	Metallurgy, Physical	235, 236	Model Building, Statistics for	298
Mathematical Optimization Techniques	215	Metallurgy, Process, Thermodynamics in	238	Model Laboratory or Structural Design	220
Mathematical Politics	322	Metallurgy, Special Problems in	238	Modeling and Simulation of Dynamic Systems Models and the Metropolis	226
Mathematical Price Theory	293	Metallurgy, Thermodynamics in	236	Models, Complex, of Social Systems, Seminar on	322
Mathematical Programming	305	Metals at Elevated Temperatures, Behavior of	237	Models, Computational	252, 253
Mathematical Psychology, Seminar in	274	Metals, Properties of	238, 289	Models for Computation, Theoretical	250
Mathematical Reading	331	Metals, Phase Transformations in	236	Models, Marketing	308
Mathematical Theory of Computation and Symbol Manipulation	253	Metals, Strengthening Mechanisms in	236	Models, Mathematical, in Linguistics	359
Mathematical Theory of Computation, Introduction to	325	Metals, Structural Properties of	219	Models, Mathematical, in the Social Sciences, Introduction to	322
Mathematical Theory of Modern Physics	328	Metals, Structure and Properties of	236	Models, Theory of	330
Mathematics, Applied, Introduction to	328	Metaphor	341	Modern Algebra	326
Mathematics, Applied, Methods of	328	Metaphysics	347	Modern Architecture in Germany from 1895 to the Bauhaus	243
Mathematics, Applied, Methods of, for Engineers	325	Meteoritics and Geochemistry, Research in	285	Modern Art from Post-Impressionism to Cubism	242
Mathematics, Applied, Principles of	324	Meteoritics, Current Research in	245, 287	Modern Art, Introduction to	242
Mathematics, Applied, Seminar in	298	Meteoritics Seminar	285	Modern Art, Symbolism in	243
Mathematics, Applied, Topics in	328	Meteorological Seminar	332, 333	Modern Control Theory and Applications	226
Mathematics, Combinatorial, Applications of	250	Meteorology, Descriptive	331	Modern Drama	340
Mathematics for Economists	292	Meteorology, Dynamic	331, 332	Modern French Poetry	357
Mathematics for Management	298	Meteorology, Dynamical, Introduction to	331	Modern German Drama	356
Mathematics, Philosophy of	348	Meteorology, Physical	332	Modern German Fiction	356
Mathematics, Review of	324	Meteorology, Special Problems in	333	Modern German Novel, The	356
Mathematics, Seminar in	326	Meteorology, Special Subject in	333	Modern Optics Project Laboratory	260
Mathematics, System	304, 305	Meteorology, Statistical Methods in	331	Modernism, Sources of	340
Mathematics, The World of	324	Meteorology, Statistical Problems in	331	Modes of Heat and Mass Transfer	276
Matrix Methods of Structural Mechanics, Variational and	311	Meteorology, Synoptic	331	Modulation Theory, Detection, Estimation, and	254
Matter, Structures and Properties of	275	Methods of Applied Mathematics, for Engineers	325	Molecular Configuration in Biological Systems Seminar	265
Mayakovsky and Pasternak	360	Methods of Engineering Analysis	225	Molecular Fluid Mechanics	227
Measurement and Analysis, Physical	231	Methods of Harmonic and Statistical Analysis	291	Molecular Genetics	265
Measurement and Control, Instruments for	226	Methods of Planetary Astronomy	286	Molecular Spectra and Molecular Structure	246
Measurements, Electronic Components and	259	Methods of Research in City Planning	282	Molecular Structure and Reactivity	246
Measurements, Electronic Light	249	Methods of Theoretical Physics	268	Molecules, Physics of Atoms and	266
Mechanical Behavior of Crystalline Material	285	Metropolis, American, The	343	Monetary and Banking Policy	294
Mechanical Behavior of Materials	228	Metropolis, Models and the	280	Monetary Economics	295
Mechanical Behavior of Plastics	220	Metropolitan and Regional Planning in Developing Countries	281	Monetary Policy, Seminar in Fiscal and	295
Mechanical Behavior of Materials, Advanced	228	Metropolitan Planning Administration	282	Moral and Social Philosophy, Introduction to	338
Mechanical Processing of Materials, Research in the	233	Mexico, Cultures and Societies of	342	Moral Issues, Contemporary	337
Mechanical Vibration	291	Microbial Physiology	264	Morality and the Law	350
Mechanics, Advanced	224	Microbiology, Experimental, Genetics and	263	Morality, Responsibility in Law and	346
Mechanics, Analytical	268	Microbiology, Food	334	Moral Philosophy	346
Mechanics and Optics of Polymers	233	Microbiology, General	264	Moral Responsibility, Free Will and	346
Mechanics and Thermodynamics, Statistical	248	Microbiology, Industrial	334	Motion, Fields, Forces, and	248
Mechanics, Applied, Seminar in	225	Microbiology Laboratory	334	Motivation, Neural Mechanism of Learning and	273
Mechanics, Continuum	276	Microeconomic Theory, Intermediate	292	Multistage Transistor Amplifiers	251
Mechanics of Fluids	277	Microelectronics	257	Multivariable System Dynamics	310
Mechanics of Materials	220, 235	Microscopy, Electron	265	Multivariate Political Analysis	322
Mechanics of Sediment Transport	222	Microscopy, Electron, Introduction to	219	Music, Introduction to	348
Mechanics of Solids	223	Microscopy Laboratory, Electron	265		
Mechanics of Two-Phase Flow	313	Microwave Circuits	257		
Mechanics, Quantum, Introductory	246	Microwave Magnetics	258		
Mechanics, Solid	310	Microwave Physics, Introduction to Optical, Radiofrequency, and	269		

Music, Materials of	348	Novel, The Modern German	356	Operations Research, Probabilistic Models in Systems Engineering and	252
Music Research, Problems and Techniques of	349	Nuclear Chemical Engineering	352	Operators, Elliptic	330
Music, Seminar in	349	Nuclear Engineering for Space Applications	352	Optical Channels, Communication Systems and	254
Music Theory	348, 349	Nuclear Engineering, Seminar in	354	Optical Methods in Biophysics	265
Music, Twentieth-Century	349	Nuclear Engineering, Special Problems in	354	Optical, Microwave, and Radiofrequency Physics, Introduction to	269
Music, Twentieth-Century: Schoenberg, Berg and Webern	349	Nuclear Engineers, Metallurgy for	354	Optical Properties of Ceramics, Electrical and	238
Music, Western, in the Baroque Era	349	Nuclear Fuels	238, 354	Optics of Polymers, Mechanics and	233
Music, Western, in the Classic Era	349	Nuclear Physics	270	Optics Project Laboratory, Modern	260
Music, Western, in the Middle Ages and the Renaissance	349	Nuclear Physics, Elementary	351	Optics Project Laboratory, Particle	260
Music, Western, in the Romantic Era	349	Nuclear Physics for Engineers	270	Optics, Statistical, and Spectroscopy	269
Musical Form and Analysis	349	Nuclear Physics, Introduction to	267	Optimal Control, Theory of	256
<b>N</b> arrative and the Novel	339	Nuclear Physics, Special Problems in	271	Optimization of Structures	221
Narrative Fiction	339	Nuclear Plant Dynamics	352	Optimization Techniques, Mathematical	215
National Economic Control, The Politics of	317	Nuclear Power, Economics of	352	Oral Biology Laboratory, Research Approaches to	336
National Security, Research and Development and	319	Nuclear Radiation, Biological Effects of	354	Oral Biology, Research Approaches to	336
Nationalism in Africa	321, 344	Nuclear Reactor Design	352	Oral Science, Seminar in	336
Natural Products, Organic Chemistry	246	Nuclear Reactor Engineering	352	Orchestration	349
Nature and Justification of Liberty	346	Nuclear Reactor Engineering, Introduction to	351	Ordinary Differential Equations	324
Nature of Literature, The	355	Nuclear Reactor Operations	353	Organ and System Physiology	264
Naval Architecture and Marine Engineering, Computer Systems for	290	Nuclear Reactor Physics	352	Organic Chemistry	245, 246
Naval Architecture and Marine Engineering, Special Problems in	291	Nuclear Reactor Physics Laboratory	352	Organic Chemistry, Advanced: Synthesis	246
Naval Engineering	362	Nuclear Rockets	313	Organic Chemistry: Natural Products	246
Naval Guided Missiles	362	Nuclear Structure, Theory of	270, 271	Organic Chemistry: Physical	246
Naval Industrial Management and Leadership	362	Nuclear Systems, Strategic, Evolution of	318	Organic Chemistry, Seminar in	247
Naval Ordnance Laboratory, Industrial Project at the	262	Nuclear Theory, Selected Topics in	271	Organic Chemistry, Special Topics in	246
Naval Ordnance Laboratory, Research and Development at the	262	Nucleic Acid Structure, Seminar in Protein and Number Theory, Algebraic	263	Organization	301
Naval Organization and Management	362	Number Theory, Elementary	323	Organization Change, Seminar on	301
Naval Orientation and Leadership	362	Numbers, Theory of	329	Organization Development, Practicum in	300
Naval Ship Design, Principles of	290	Numbers, Topics in the Theory of	329	Organization, Industrial, and Public Policy	293
Naval Ship Propulsion	289	Numerical Analysis	324, 325	Organization, Doctoral Seminar in	302
Naval Ship-System Design	290	Numerical Methods of Engineering Analysis	215	Organizational Psychology	301
Naval Ships, Conceptual Design of	290	Numerical Methods of Reactor Analysis	353	Organizations, Comparative Analysis of	301
Near Eastern Archaeology: The Foundations of Civilization	342	Numerical Solution of Problems in Chemical Engineering	276	Organizations, Complex	300
Negotiation and Force in International Relations	319	Nutrition and Food Science Projects Laboratory	333	Organizations, Surveys and Experiments on	301
Network Synthesis	253	Nutrition and Food Science, Selected Topics in	334	Orientation and Sea Power	362
Network Theory, Introductory	248	Nutrition and Food Science, Seminar in	335	Origins of Contemporary Architecture in the Eighteenth Century	243
Neural Mechanisms of Learning and Motivation	273	Nutrition and Physiological Chemistry, Advanced	334	Origins of Modern and Post Modern	351
Neuroanatomy, Mammalian, Outline of	272	Nutrition, Experimental	333	Origins of Modern Scientific Thought	347
Neurobiology, Light and Electron Microscope Techniques in	273	Nutrition, Human	334	Outline of Mammalian Neuroanatomy	272
Neuroelectric Potentials, Biophysics of	252	Nutrition Research, Techniques in Food and Nutritional and Food-Borne Diseases, Epidemiology of	334	<b>P</b> ainting	240
Neuroendocrine Control Mechanisms	335	Nutritional Biochemistry and Metabolism	333	Painting and Sculpture in the Middle of the Nineteenth Century	242
Neurophysiology, Advanced	264	Nutritional Biochemistry and Metabolism, Advanced	333	Painting in the Twentieth Century	243
Neutral Particle Transport	353	Nutritional Pathology	335	Paleontology	284
Neutron Diffraction	269	<b>O</b> ak Ridge Station, School of Chemical Engineering Practice	279	Paris, Great Cities	243, 350
Neutron Physics and Applications	353	Ocean Engineering, A Survey of	291	Partial Difference Equations	327
New Enterprises	308	Ocean Engineering and International Affairs	292	Partial Differential Equations	327
Nietzsche, Friedrich: Major Authors	340	Ocean Engineering Structural Design	289	Particle Devices and Plasma, Engineering Physics of	353
Nineteenth Century European Liberalism: Its Decline and Transformation	345	Ocean Engineering Structures	289	Particle Optics Project Laboratory	260
Nineteenth Century, Painting and Sculpture in the Middle of the	242	Ocean Engineering Systems	292	Particle Physics	271
Nineteenth Century, The, Identity and Autobiography	336	Oceanic Circulations	332	Particle Physics, Selected Topics in	271
Noise and Fluctuations, Physics of	267	Oceanic Variability	332	Particle Physics, Special Problems in	271
Noise, Flow	224, 292	Oceanography, Chemical, Research in	287	Particle Physics, Theoretical	271
Nomography	232	Oceanography, Dynamic	332	Particle Transport, Neutral	353
Nonassociative Algebras	329	Oceanography, Physical	284, 332	Particles, Charged, in Space	271
Non-Linear Dynamical Systems	256	Oceanography, Physical, Research in	287	Pasternak, Mayakovsky and	360
Non-Western Literature	340	Oceanography, Physical, Seminar in	287, 332	Patents, Inventions and	250
Northern Renaissance and the Reformation, The	343	Oceanography, Seminar in	287	Pathology, Comparative, Seminar in	335
Novel, Narrative and the	339	Oceanography, Special Problems in	287, 332	Pathology, Nutritional	335
		Oceanography, Special Subject in	333	Pavements, Structural Design of	220
		Opera, The	349	Peasant Society	342
		Operational Methods, Application of	290	Perception and Knowledge, Biological Bases of	351
		Operations Analysis, Flight Transportation	314	Perception, Psychology of	273
		Operations Management	299, 307	Perception, Seminar on Sensation and	273
		Operations Planning and Control Systems	307	Personality, Social Stability, and Social Change	326
				Personality, Society, and Politics	316
				Personality Structure and Development	274
				Personality Theory and Assessment	300

SUBJECTS INDEX

Perspectives in Life Science	263	Physics, Crystal, X-rays and	269	Planets, The Earth and the	283
Petroleum, Economics of Eastern Hemisphere, Seminar in the	293	Physics, Electron	267	Planning Administration, Metropolitan	282
Petrology	384	Physics, Experimental	267	Planning and Control, Advanced Concepts in Managerial Information for	303
Petrology, Experimental	285	Physics, Fundamental, Mathematical Analysis of	326	Planning and Poverty	281
Petrology, Experimental, Special Topics in	285	Physics, Group Theoretical Methods in	267	Planning, City and Regional	279
Petrology, Sedimentary, Research in Sedimentology or	285	Physics, Introduction to Optical, Microwave, and Radiofrequency	269	Planning, City and Regional, Introduction to	280
Petrology, Special Topics in	285	Physics Laboratory, Nuclear Reactor	352	Planning, City, Methods of Research in	282
Phase Transformations in Metals	236	Physics, Macromolecular, Principles of	233	Planning, City, Problems in	279
Phenomenology	346	Physics, Mathematical Theory of Modern	328	Planning Design, Community	279
Philosophical Anthropology	347	Physics, Neutron, and Applications	353	Planning, Metropolitan and Regional, in Developing Countries	281
Philosophical Psychology	274, 347	Physics, Nuclear	270	Planning of Structural Systems	220
Philosophies and Religions of Asia	347	Physics, Nuclear, Elementary	351	Planning Process, Theory of the	282
Philosophy, Analytic	347	Physics, Nuclear, for Engineers	270	Planning, Regional, Problems in	280
Philosophy and Scientific Method	338	Physics, Nuclear, Introduction to	267	Planning, Site	280
Philosophy and the Life Sciences	347	Physics, Nuclear Reactor	352	Planning Techniques, City	280
Philosophy and Theology, Contemporary	350	Physics, Nuclear, Special Problems in	271	Planning, Urban, and Social Policy	281
Philosophy, Classical	345	Physics of Atoms and Molecules	266	Plasma and Particle Devices, Engineering Physics of	353
Philosophy: Classic and Contemporary	337	Physics of Atoms and Radiation, Special Problems in	269	Plasma Dynamics	257
Philosophy, Contemporary, Background of	347	Physics of High Speed Gas Flows	309	Plasma Effects, Solid-State, Seminar on	258
Philosophy, Contemporary, Introduction to	338	Physics of Noise and Fluctuations	267	Plasma Kinetic Theory	270, 354
Philosophy from Antiquity to Copernicus, Science and	347	Physics of Quantum Electronics	269	Plasma Kinetic Theory, Advanced Topics in	313, 354
Philosophy, History of	345	Physics of Solids	237, 259	Plasma Kinetic Theory, Introduction to	314
Philosophy in Literature	347	Physics of Solids, Laboratory in	237, 258	Plasma Laboratory	353
Philosophy, Introduction to Moral and Social	338	Physics of Solids, Theoretical Methods in, Introduction to	237	Plasma Physics, Selected Topics in Fluid and	270
Philosophy, Moral	346	Physics of Strength and Plasticity	228	Plasma Physics, Special Problems in Fluid and	270
Philosophy, Natural, in Chinese Tradition, Science and	343	Physics of the Atmosphere, Elementary	332	Plasmas and Controlled Fusion	353
Philosophy of History	345	Physics of the Earth	286	Plasmas, Introduction to Physics of Fluids and	270
Philosophy of Language	348	Physics of the Galaxy	271	Plasmas, Kinetic Theory of Gases and	227
Philosophy of Language, Problems in the, Seminar	348	Physics of the Stars	271	Plasmas, Wave Propagation in	270
Philosophy of Logic	346	Physics of the Upper Atmosphere	332	Plasmas with Electromagnetic Waves, Interactions of	270
Philosophy of Mathematics	348	Physics, Particle	271	Plastic Analysis of Structures	288
Philosophy of Mind	348	Physics, Particle, Selected Topics in	271	Plastic Composition	241
Philosophy of Physics	348	Physics, Particle, Special Problems in	271	Plasticity and Anelastic Deformation, Solid Mechanics —	225
Philosophy of Religion	347	Physics, Particle, Theoretical	271	Plasticity, Physics of Strength and	228
Philosophy of Science	348	Physics, Philosophy of	348	Plasticity, Viscoelasticity and Creep	310
Philosophy of the Arts	347	Physics, Planetary, and Chemistry	244, 267, 284	Plastics, Mechanical Behavior of	240
Philosophy, Religious, in the West	347	Physics, Planetary, Special Problems in	287	Plates and Shells, Theory of	288
Philosophy Seminar	338	Physics, Polymer, Laboratory	234	Plates, Stability and Thermoelasticity	310
Philosophy, Special Advanced Topics in	348	Physics Project Laboratory	266	Playwriting	338
Philosophy, Special Topics in	348	Physics, Quantum, Introduction to	267	Poetic and Scientific Discourse in Classical Literature	350
Phonology, Introduction to Linguistics	358	Physics, Quantum, Principles of	266	Poetic Form, Seminar on	357
Photography, Advanced	240	Physics, Reactor, Advanced	352	Poetics, Linguistics and	357
Photography, Creative	240	Physics, Reactor, Fast	353	Poetics, Russian, Studies in Comparative and	357
Photography, Evaluating	240	Physics, Readings in	267	Poetry, French, Modern	357
Photography, Problems in	240	Physics, Solid-State, Introduction to	267	Poetry, German, Seminar in	356
Physical and Engineering Systems, Computer Models of	225	Physics, Solid-State, Special Problems in	270	Poetry, Goethe's	355
Physical Applications of Group Theory	268	Physics, Special Problems in Undergraduate	267	Poetry, Russian, Modern, Seminar in	360
Physical Ceramics	235, 238	Physics, Theoretical	266	Poetry, The Writing of	338
Physical Chemistry	246	Physics, Theoretical, Methods of	268	Policy Analysis, Systematic, Principles of	319
Physical Chemistry of Macromolecules	264	Physics, Theoretical, Special Problems in	269	Policy Analysis, Systematic, Seminar in	319
Physical Chemistry of Polymers	278	Physics, Twentieth-Century, Tradition and Innovation in	351	Policy Decisions, Power, Influence and	316
Physical Chemistry, Seminar in	247	Physiological Chemistry, Advanced Nutrition and	334	Policy Determination, Business Practice and	308
Physical Components of Control Systems	312	Physiological Modeling in Manned Systems, Life Support and	227, 312	Political Analysis, Multivariate	322
Physical Measurement and Analysis	231	Physiological Psychology	272, 273	Political and Economic Development of Tropical Africa	321
Physical Metallurgy	235, 236	Physiological Psychology, Practicum in	273	Political Change in Developing Areas, Social Organization and	321
Physical Meteorology	332	Physiological Psychology, Seminar in	272	Political Development, Field Research in	321
Physical Oceanography	284, 332	Physiology, Experimental	264	Political Development in India: Comparative Asian Politics	317
Physical Oceanography, Research in	287	Physiology, General and Cell	263	Political Development, Migration and	317
Physical Oceanography, Seminar in	287, 332	Physiology, Microbial	264	Political Development, The U.N. System and Problems of	320
Physical Organic Chemistry	246	Physiology, Organ and System	264	Political Development, Theories of	321
Physical Principles of Solid-State Devices	251	Physiology, Systemic	335	Political Ideas and Industrial Society	321
Physical Processes, Statistical Fluctuations in	270	Planetary Astronomy, Methods of	286	Political Organizations, The Development of	321
Physical Properties of Sea Water	287	Planetary Atmospheres	245, 286	Political Parties	318
Physics	265, 266	Planetary Fluid Dynamics	332		
Physics, Advanced Atomic	269	Planetary Physics and Chemistry	244, 267, 284		
Physics and Chemistry of Surfaces	277	Planetary Physics, Special Problems in	287		
Physics and Engineering Use of Adhesives	228	Planetary Surfaces	286		
Physics, Atomic, Experimental	266				
Physics, Chemical, Special Topics in	246				

Political Process, The American	316	Principles of Materials Separation	235	Psychology, Physiological, Practicum in	273
Political Processes, Theory of	322	Principles of Military Management and Logistics	362	Psychology, Physiological, Seminar in	272
Political Psychology	316	Principles of Military Teaching and Leadership	362	Psychology, Political	316
Political Science Laboratory	323	Principles of Naval Ship Design	290	Psychology, Political, Graduate Seminar in	316
Political Science Seminar	321	Principles of Quantum Physics	266	Psychology, Proseminar in	272
Political Science, Seminar in Model Building in	322	Principles of Ship Design	290	Psychology, Research in	274, 275
Political Socialization	315	Principles of Systematic Policy Analysis	319	Psychology Seminar, Advanced	274
Political System, Soviet	318	Principles of Systems	304	Psychology, Social	274, 300
Political Systems, Comparative	317	Principles of Transistors	251	Psychology, Social, Advanced Seminar in	300
Political Theory, Topics in	322	Private Organizations and the Political Process	318	Psychophysiology of Memory, Seminar in	272
Politics, African, Comparative	317	Probabilistic Models in Systems Engineering and Operations Research	252	Public Finance	294
Politics and Government of Sub-Saharan Africa, Seminar	317	Probabilistic Systems Analysis	251	Public Management of Science	319
Politics, Chinese	317	Probability	325, 347	Public Opinion and Propaganda	315
Politics, Comparative, Theories and Approaches to the Study of	318	Probability and Random Variables, Applications of	324	Public Policy and Use of the Seas	292, 320
Politics in the Transitional Middle East	317	Probability Theory and Linear Systems	254	Public Policy on Labor Relations	296, 306
Politics, International, Seminar in	320	Probability Theory and Random Processes	254	Public Policy, Prediction in Social Science and	322, 323
Politics, Mathematical	322	Probability, Time-Dependent	294	Puskin and Russian Romanticism	360
Politics of East Europe, Domestic and Foreign	318	Problem Solving	274	<b>Quantitative Analysis, Case Studies in</b>	306
Politics of National Economic Control, The	317	Process Control	256	<b>Quantitative Analysis, Research Seminar in</b>	306
Politics of Urban Education	323	Process Design	276	<b>Quantitative Methods</b>	299
Politics, Personality, Society, and	316	Process Metallurgy	238	<b>Quantitative Methods in Management</b>	298
Politics, Urban, Seminar in	323	Processing, Information, Introduction to	282	<b>Quantum Electronics</b>	258, 267
Pollution, Air, Control, Seminar in	278	Production, Prices and	292	<b>Quantum Electronics, Physics of</b>	269
Pollution, Fluid Mechanics of	228	Production, Ship, Analysis	291	<b>Quantum Mechanics, Advanced Topics in Spectroscopy and</b>	247
Polymer Materials Science	233	Professional Officer, Principles and Techniques of Leadership, The	361	<b>Quantum Mechanics, Introductory</b>	246
Polymer Physics Laboratory	234	Professional Writing Tutorial	305	<b>Quantum Physics, Introduction to</b>	267
Polymeric Materials, Synthesis and Properties of	278	Programming, Heuristic, and Artificial Intelligence	325	<b>Quantum Physics, Principles of</b>	266
Polymerization Processes	278	Programming Linguistics	249	<b>Quantum Theory</b>	268
Polymers, Mechanics and Optics of	233	Programming, Mathematical	305	<b>Quantum Theory of Magnetism</b>	259
Polymers, Physical Chemistry of	278	Programming Systems, Digital Computer	250	<b>Quantum Theory of Matter, Topics in</b>	267
Polymers Seminar, Fibers and	234	Project Seminar	249	<b>Quantum Theory, Relativistic, Topics in</b>	271
Polymers, Structure and Properties of	278	Project Study	261	<b>Questions, The Logic of</b>	346
Populations, Finite, Sampling of	298	Proof Theory	330	<b>Radiation and Radioisotope Applications</b>	354
Porous Media, Flow in	222	Propaganda, Communist	318	<b>Radiation Damage in Crystalline Solids</b>	239, 354
Portland Cement Concrete	220	Propaganda, Public Opinion and	315	<b>Radiation, Energy Transmission and</b>	248
Poverty, Planning and	281	Properties of Gases and Liquids	277	<b>Radiation Heat Transfer</b>	230
Power, Economics of Fuel and	293	Properties of Metals	238, 289	<b>Radiation, Nuclear, Biological Effects of</b>	354
Power, Influence and Policy Decisions	316	Propulsion, Electric	313	<b>Radiation, Selected Topics in Physics of Atoms and</b>	269
Power, Space	313	Propulsion Hydrodynamics	289	<b>Radiation Shielding</b>	353
Power System Engineering	253	Propulsion, Naval Ship	289	<b>Radiation, Special Problems in Physics of Atoms and</b>	269
Power System Engineering, Special Topics in	253	Propulsion, Ship	289	<b>Radiations, Ionizing, Food Applications of</b>	335
Power Systems Project Laboratory	260	Propulsion System Reliability and Control	289	<b>Radiative Transfer</b>	278
Power, The Analysis of	316	Prose Fiction, French	357	<b>Radical and Revolutionary Ideologies</b>	318
Practice, Industrial	234	Prose, Russian, Seminar in	360	<b>Radio Astronomical Signals, Detection and Measurement of</b>	257
Practice of Structural Engineering, The	221	Prose, The Writing of	338, 339	<b>Radio Astronomy, Fundamentals of</b>	257, 272
Practicum in Organization Development	300	Proseminar in Psychology	272	<b>Radio Corporation of America, Industrial Practice at</b>	261
Practicum in Physiological Psychology	273	Protein and Nucleic Acid Structure, Seminar in	264	<b>Radio Corporation of America, Industrial Project at</b>	264
Practicum in Survey Research Methods	282	Protest, Mechanisms and Forms of, Seminar	321	<b>Radiochemistry</b>	241
Precipitation Processes, Atmospheric	332	Psychoanalysis, History and	344	<b>Radiochemistry Laboratory</b>	244
Prediction in Social Science and Public Policy	322, 323	Psychological Functions of Environmental Form	280	<b>Radioisotope Applications, Radiation and</b>	354
Preliterate Cultures	338	Psychology, Comparative	273	<b>Random Processes, Advanced Topics in</b>	254
Preparation for Thesis	283	Psychology, Comparative, Seminar in	273	<b>Random Processes, Introduction to</b>	254
Price Theory, Mathematical	293	Psychology, Developmental	275	<b>Random Processes, Probability Theory and</b>	254
Prices and Production	292	Psychology, Developmental, Seminar in	275	<b>Random Variables, Applications of Probability and</b>	324
Principles and Applications of Military Law and Administration	362	Psychology, Introductory	272	<b>Random Vibration</b>	224
Principles and Problems of American Foreign Policy	320	Psychology, Managerial	298	<b>Rationalists, The Continental</b>	347
Principles of Applied Mathematics	324	Psychology, Mathematical, Seminar in	274	<b>Raytheon Company, Industrial Practice at the</b>	262
Principles of Automatic Control	311	Psychology of Language and Communication, Seminar in	274	<b>Raytheon Company, Industrial Project at the</b>	262
Principles of Combustion	278	Psychology of Perception	273	<b>Reacting Gas Dynamics</b>	228
Principles of Communication	253	Psychology of the Environment	280	<b>Reaction Kinetics of Gases and Plasmas</b>	227
Principles of Control Systems	352	Psychology, Organizational	301	<b>Reactivity, Molecular Structure and</b>	246
Principles of Crystallography and X-ray Diffraction	235	Psychology, Philosophical	274, 347	<b>Reactor Analysis, Advanced Methods of</b>	353
Principles of Flight Guidance	312	Psychology, Physiological	272	<b>Reactor Analysis, Numerical Methods of</b>	353
Principles of Inorganic Chemistry	244			<b>Reactor Design, Chemical Kinetics and</b>	276
Principles of Instrumentation and Control	311			<b>Reactor Design, Nuclear</b>	352
Principles of Macromolecular Physics	233				
Principles of Management	361				

SUBJECTS INDEX

Reactor Engineering, Nuclear	352	Romanticism, German	355	Semantics	348
Reactor Kinetics, Space-Time	352	Rome: Reality and Idea	342	Semiconductor Device Research, Topics in	258
Reactor, Nuclear, Engineering, Introduction to	351	Rotating Fluids	327	Semiconductor Devices Project Laboratory	260
Reactor, Nuclear, Physics	352	Rotating Machine Systems, Control of	226	Semiconductor Electronics	257
Reactor Operations, Nuclear	353	Russia and the Modern Age: Dostoevsky, Tolstoi Chekhov	340	Seminar, Undergraduate	363
Reactor Physics, Advanced	352	Russia, Gogol and Literary Methodology in	360	Sensation and Perception, Seminar on	273
Reactor Physics, Fast	353	Russia: Orthodoxy, Autocracy, and Rebellion	343	Sensorimotor Processes, Seminar in	273
Reactor Physics Laboratory, Nuclear	352, 353	Russian, Advanced	360	Sensory Communication	252
Reactors, Fast Power	352	Russian, Elementary	359	Sensory Inputs, Analytical Models for Human Processing of	255
Reactors, Thermal Power	352	Russian, Intermediate	359	Sensory-Neural Systems	255
Reading, French	357	Russian Literature, Introduction to	360	Separation, Materials, Principles of	235
Reading, German	355, 356	Russian Literature, Soviet	360	Set Theory	330
Reading Seminar in Economics	292, 293	Russian Poetics, Studies in Comparative and	357	Shakespeare	339
Reading Seminar in Social Science	321	Russian Poetry, Modern, Seminar in	360	Shakespearean Tragedy	339
Reading, Spanish	356	Russian Prose, Seminar in	360	Shell Structures	310
Reading, Russian	360	Russian Reading	360	Shell Structures, Analysis and Design of	221
Readings in Physics	267	Russian Romanticism, Puskin and	360	Shells and Plates, Theory of	288
Readings in Power and Responsibility	299	Russian Short Story, The	360	Ship Design, Advanced Hydromechanics of	288
Real Estate Economics	282	Russian, Spoken	360	Ship Design, Introductory	290
Real Gas Dynamics	309	Russian, Structure of	358	Ship Design, Naval, Principles of	290
Real Variables, Functions of	326	Sampling of Finite Populations	298	Ship Design, Principles of	290
Reason and Revelation: Religious Visions in the West	337	Sanskrit, Introduction to	358	Ship, Naval-System Design	290
Reconstruction of Europe, 1945-65	345	School of Chemical Engineering Practice — Bound Brook Station	279	Ship Operation and Construction, Decision Processes in	290
Recursion Theory	330	School of Chemical Engineering Practice — Oak Ridge Station	279	Ship Production Analysis	291
Recursion Theory, Higher	330	Schools of Economic Thought	293	Ship Propulsion	289
Reformation, The Northern Renaissance and the	343	Science, American, and Its Development: Current Issues and Problems	320	Ship Propulsion, Naval	289
Refrigeration	231	Science and American Foreign Policy	319	Ship Structural Analysis and Design	289
Refrigeration, Low Temperature	231	Science and Natural Philosophy in Chinese Tradition	343	Ship Structural Design	289
Regional Geophysics, Interpretation Methods in	286	Science and Philosophy from Antiquity to Copernicus	347	Shipping Economics	290
Regional Planning, City and	279	Science of Materials	235	Ships, Naval, Conceptual Design of	290
Regional Planning, Problems in	280	Science, Philosophy of	348	Shock Response of Marine Structure, Acoustics and	291
Regional Planning Research	283	Science, Public Management of	319	Short Story, The	339
Regulation, Government, of Industry	293	Scientific and Engineering Writing	338	Signal Transmission and Coding in the Auditory System	255
Relativistic Quantum Theory, Topics in	271	Scientific Development and Government Policy	319	Signals, and Systems, Circuits	248
Relativity	272	Scientific Discourse in Classical Literature, Poetic and	350	Signals, Bioelectric	255
Reliability and Control, Propulsion System	289	Scientific Experiments, Design and Analysis of	294	Signals, Digital Processing of	257
Religion and Society in America	350	Scientific Method, Philosophy and	338	Signals Laboratory, Electronic Circuits and	259
Religion, Philosophy of	347	Scientific Thought, Modern, Origins of	347	Signals, Radio Astronomical, Detection and Measurement of	257
Religions of Asia, Philosophies and	347	Sculpture in the Middle of the Nineteenth Century, Painting and	242	Simulation Methods	216
Religious Philosophy in the West	347	Sculpture in the Twentieth Century	243	Simulation Methods for Analysis and Control	256
Religious Visions in the West: Reason and Revelation	337	Sculpture, Metal, Techniques of	236	Singular Integrals	327
Renaissance, English, Literature of the	339	Sea Instruments, Air and	331	Sino-Soviet Relations and International Communism, Research Seminar on	318
Renaissance, Italian, The	343	Sea Power, Orientation and	362	Site Planning	280
Renaissance, The Northern, and the Reformation	343	Sea Water, Physical Properties of	287	Social Anthropology, Introduction to	342
Renaissance, Western Music in the Middle Ages and the	349	Seas, Public Policy and Use of the	320	Social Aspects of Development	281
Representation	279	Seas, Use of the, Public Policy and	292	Social Change, Intellectuals and	351
Representations of Lie Groups	330	Security, National, Research and Development and	319	Social Change, Urban Settlement, Squatters, and	281
Research	247	Sediment Transport, Mechanics of	222	Social Criticism in America From Tocqueville to Riesman	343
Research and Development and National Security	319	Sedimentology and Sediment Movement	284	Social Development of Children, Seminar in	274
Research and Development at the Air Force Cambridge Research Laboratories	262	Sedimentology of Sedimentary Petrology, Research in	285	Social Organization and Political Change in Developing Areas	321
Research and Development at the Naval Ordnance Laboratory	262	Sedimentology Seminar	285	Social Philosophy, Introduction to Moral and	338
Research Problems	265, 335	Seismology, Advanced	286	Social Policy, Urban Planning and	281
Responsibility in Law and Morality	346	Selected Problems in Soviet Literature	360	Social Policy, Urban, Seminar	281
Review of Mathematics	324	Selected Topics in Astrophysics	272	Social Psychology	274, 300
Revolution and Totalitarianism, The Twentieth Century	337	Selected Topics in Biology	265	Social Psychology, Advanced Seminar in	300
Revolution, Communism and	317	Selected Topics in Fluid and Plasma Physics	270	Social Research, Logic of	322
Revolution, The American	344	Selected Topics in Nuclear Theory	271	Social Science and Public Policy, Prediction in	322, 323
Revolutionary Ideologies, Radical and	318	Selected Topics in Nutrition and Food Science	334	Social Science, Reading Seminar in	321
Riemannian Geometry	326	Selected Topics in Particle Physics	271	Social Sciences, Concept Formation and Research Technique in the	321
Rock Forming Minerals	285	Selected Topics in Physics of Atoms and Radiation	269	Social Sciences, Introduction to Mathematical Models in the	322
Rock Mechanics	219	Selected Topics in the History of Art and Architecture	244	Social Sciences, Introduction to the	322
Rocket Propulsion	313	Selected Topics in the Theory of Solids	269	Social Sciences, Statistics for the	322
Rockets, Nuclear	313				
Romantic Era, Western Music in the	349				
Romanticism, French	357				

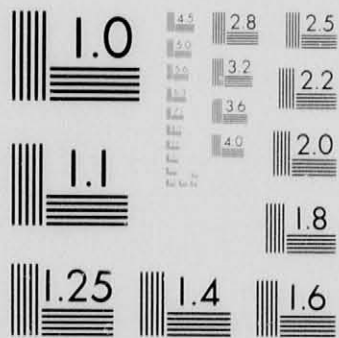
Social Stability and Change, Seminar in	321	Space Communications	254, 312	Stochastic Systems	305
Social Stability, and Social Change, Personality	321	Space Dynamics and Gyroscopic Instruments	312	Story, Russian Short, The	360
Social Structure, Urban, and Process	281	Space, Hilbert	326	Story, The Short	339
Social Systems, Seminar on Complex Models of	322	Space Operations, Seminar in	361	Stratigraphic Research	285
Social Theory from Marx to the Present	345	Space Power	313	Strength and Plasticity, Physics of	228
Social Vision in Literary Art: Shaw, Lawrence, Faulkner	340	Space Systems Engineering	314	Strength of Structural Materials	219
Socialism, Capitalism, and Growth	297	Space Systems Engineering, Advanced	314	Strengthening Mechanisms in Metals	236
Socialization, Adult, Doctoral Seminar on Career Development and	302	Space-Time Reactor Kinetics	352	Stress Analysis, Experimental	231
Socialization, Adult, Seminar on Influence, Attitude Change and	300	Spacecraft Design, Aircraft and	314	Stress Analysis, Research in Experimental	231
Socialization, Political	315	Spanish Civil War, 1936-39	345	Structural Analysis, Advanced	221
Society and Man	315	Spanish Drama	356	Structural Analysis and Design	214, 220
Society, and Politics, Personality	316	Spanish Literature, Introduction to	356	Structural Design of Pavements	220
Society, Education and	350	Spanish Literature, Masterpieces of	356	Structural Design, Model Laboratory for	220
Sociology, Industrial	301	Spanish Literature, Twentieth-Century	356	Structural Dynamics	221
Sociology, Urban, Contemporary, Seminar in	323	Spanish Reading	356	Structural Engineering, Special Problems in	220
Soil Behavior	218	Spanish, Spoken	356	Structural Engineering, The Practice of	221
Soil Dynamics	218	Spanish, Structure of	358	Structural Information Systems	221
Soil Engineering, Special Studies in	219	Special Problems	284	Structural Materials	219
Soil Mechanics	214	Special Projects	314	Structural Materials, Strength of	219
Soil Mechanics, Advanced	218	Special Projects, Advanced	314	Structural Mechanics, Advanced	221
Soil Mechanics, Experimental	219	Spectra, Molecular, and Molecular Structure	246	Structural Mechanics, Advanced Topics in	311
Soil Mechanics, Theoretical	218	Spectroscopy and Quantum Mechanics, Advanced Topics in	247	Structural Mechanics, Introduction to	288
Soil Technology	218	Spectroscopy, Interpretive	245	Structural Mechanics, Variational and Matrix Methods of	311
Soils, Improvement of Engineering Properties of	219	Spectroscopy, Statistical Optics and	269	Structural Properties of Metals	219
Solar System, Dynamical Problems of the	272, 286, 312	Speech and Hearing, Sound	251	Structural Reliability	221
Solid Mechanics	310	Speech Communication	259, 359	Structural Research	285
Solid Mechanics — Elasticity	225	Spoken French	357	Structural Stability	221
Solid Mechanics — Introduction to	224	Spoken German	355	Structural Systems, Planning of	220
Solid Mechanics — Introduction to Mechanics of Continuous Media	225	Spoken Russian	360	Structural Vibration, Sound and	224
Solid Mechanics Laboratory	311	Spoken Spanish	356	Structure and Properties of Interfaces	239
Solid Mechanics — Plasticity and Anelastic Deformation	225	Squatters, and Social Change, Urban Settlement	281	Structure and Properties of Metals	236
Solid State and Its Application, Special Topics in the	258	Stability and Control, Flight Vehicle, Advanced	310	Structure and Properties of Polymers	278
Solid State Chemistry, Advanced Topics in	247	Stability and Motion Control of Ocean Vehicles	288	Structure, Bonding and Mechanism, Introduction to	245
Solid-State Chemistry, Introduction to	235	Stability and Thermoelasticity, Plates	310	Structure of American Law	299
Solid-State Devices, Physical Principles of	251	Stability and Turbulence, Hydrodynamic	328	Structure of Arabic	358
Solid-State Physics, Introduction to	267	Stagecraft, Elementary, and Production Studies, Theatre Arts	339	Structure of Computing Systems	252
Solid-State Physics, Special Problems in	270	Staged Cascades in Chemical Processing	275	Structure of English	358
Solid-State Plasma Effects, Seminar on	258	Stars, Physics of the	271	Structure of English: Advanced Syntax	358
Solidification Processing	237	State and Local Politics	317	Structure of German	358
Solids, Conduction Processes in	258	Statistical Analysis, Methods of Harmonic and Statistical Analysis, Multivariate, Applications of	291	Structure of Matter, The	236
Solids, Crystalline, Radiation Damage in	239, 354	Statistical Analysis, Multivariate, Applications of	215	Structure of Russian	358
Solids, Defects in	236	Statistical Decision Theory	298	Structure of Spanish	358
Solids, Electric and Magnetic Properties of	249	Statistical Fluctuations in Physical Processes	270	Structure of Urban Life	323
Solids, Electronic Properties of	258	Statistical Mechanics	229, 246, 268, 327	Structures	242
Solids, Electrons and Atoms in	235	Statistical Mechanics and Kinetic Theory, Advanced Topics in	247	Structures and Properties of Matter	275
Solids, Laboratory in Physics of	237, 258	Statistical Mechanics, Thermodynamics and	234, 248, 308	Structures, Dynamics of	315
Solids, Mechanics of	223	Statistical Method	294	Structures, Earth	219
Solids, Physics of	237, 259	Statistical Methods in Meteorology	331	Structures, Marine	288
Solids, Selected Topics in the Theory of	269	Statistical Optics and Spectroscopy	269	Structures, Ocean Engineering	289
Solids, Theory of	269	Statistical Problems in Automatic Control	312	Structures, Optimization of	221
Sound and Structural Vibration	224	Statistical Problems in Meteorology	331	Structures, Plastic Analysis of	288
Sound, Speech and Hearing	251	Statistical Theory	294	Studies in Comparative and Russian Poetics	357
Sources of Modernism	340	Statistical Theory of Communication	254	Studies in Literature and National Values	340
Soviet-American Diplomacy	345	Statistical Thermodynamics, Introduction to	246	Studies in Manufacturing Analysis	307
Soviet Foreign Policy and the Communist World	318	Statistics, Experimental, for the Biological Sciences	336	Studies Toward a Theory of Architecture	243
Soviet Literature, Contemporary	360	Statistics for Behavioral Science	300	Study and Research in Management System Dynamics	308
Soviet Literature, Selected Problems in	360	Statistics for Model Building	298	Surface and Colloid Chemistry	277
Soviet Political System	318	Statistics for the Social Sciences	322	Surface and Internal Waves	332
Soviet Russian Literature	360	Statistics, Industrial	297	Surface-Gas Interactions	309
Soviet Union, Economics of the	295	Stellar Dynamics and Galactic Structure	328	Surface Science and Engineering	278
Soviet Union, The: An Industrial Society in Historical Perspective	344	Stellar Evolution	271	Surfaces, Physics and Chemistry of	277
Space Applications, Nuclear Engineering for	352	Stochastic Dynamic Systems	256	Survey of General Linguistics	359
Space, Charged Particles in	271	Stochastic Processes, Estimation and Control of	312	Survey of Ocean Engineering, A	291
		Stochastic Processes, Introduction to	325	Survey Research Methods	316

SUBJECTS INDEX

Synoptic Laboratory.....	331	Theories and Approaches to the Study of Comparative Politics.....	318	Transmission Systems, Image.....	252
Synoptic Meteorology.....	331	Theories of International Relations.....	320	Transport Phenomena.....	276
Syntax, Advanced, Structure of English:.....	358	Theories of Political Development.....	321	Transport Processes, Fluid Mechanics and.....	276
Syntax, English, Seminar on.....	358	Theory and Method in the History of Art and Architecture.....	244	Transport Systems Analysis.....	217
Syntax, Introduction to Linguistics:.....	358	Theory and Practice of Community Action.....	323	Transportation and Urban Form.....	280
Synthesis, Advanced Organic Chemistry:.....	246	Theory Formation, Problems of Explanation and.....	346	Transportation Engineering, Case Studies in.....	218
Synthesis and Properties of Polymeric Materials.....	278	Theory of Approximation Methods.....	327	Transportation Engineering, Special Studies in.....	218
Synthesis, Network.....	253	Theory of City Form.....	282	Transportation, Flight.....	217, 303, 314
System Dynamics and Control, Advanced.....	226	Theory of Computers.....	325	Transportation, Flight, Facilities.....	217
System Dynamics, Introduction to.....	224	Theory of Economic Development.....	297	Transportation, Flight, Operations Analysis.....	314
System Dynamics, Multivariable.....	310	Theory of Functions.....	326	Transportation, Flight, Seminar.....	217, 303, 314
System Engineering, Power.....	253	Theory of Income and Employment.....	294	Transportation in the United States, History of.....	342
System Engineering, Power, Special Topics in.....	253	Theory of Knowledge.....	346	Transportation Planning, Advanced.....	218
System Mathematics.....	304, 305	Theory of Material Interface Phenomena.....	233	Transportation Systems, Urban.....	217
System Physiology, Organ and.....	264	Theory of Models.....	330	Transportation, Urban, The Problem.....	280
System Theory, Control.....	256	Theory of Modern Kinematics.....	232	Turbines, Gas.....	230
Systematic Policy Analysis, Principles of.....	319	Theory of Nuclear Structure.....	270, 271	Turbulence and Random Phenomena in Fluid Mechanics.....	332
Systematic Policy Analysis, Seminar in.....	319	Theory of Numbers.....	329	Turbulence, Hydrodynamic, and Stability.....	328
Systemic Physiology.....	335	Theory of Optimal Control.....	256	Turbulent Flows, Advanced Viscous and.....	228
Systems Analysis, Elements of.....	215	Theory of Plates and Shells.....	288	Turbulent Flows, Viscous and.....	227
Systems and Computation, Elements.....	247, 248	Theory of Political Processes.....	322	Twentieth-Century America, Dissent and Reform.....	343
Systems and Design, Advanced Projects in.....	232	Theory of Probability.....	327	Twentieth-Century Art Theories.....	243
Systems and Design, Special Problems in.....	232	Theory of Solids.....	269	Twentieth-Century Music.....	349
Systems, Circuits, Signals, and.....	248	Theory of the Planning Process.....	282	Twentieth-Century Music: Schoenberg, Berg and Webern.....	349
Systems, Computer, Seminar.....	283	Theory of Traffic Flow.....	218	Twentieth Century, Painting in the.....	243
Systems, Computing, Structure of.....	252	Thermal Power Reactors.....	352	Twentieth-Century Physics, Tradition and Innovation in.....	351
Systems, Digital, Introduction to.....	250, 251	Thermodynamics.....	229	Twentieth Century, Sculpture in the.....	243
Systems, Distributed.....	226	Thermodynamics, Advanced.....	229	Twentieth-Century Spanish Literature.....	356
Systems, Dynamic.....	224	Thermodynamics, Advanced Projects in Heat and.....	229	Twentieth Century, The: Consciousness in Industrial Society.....	338
Systems, Dynamic, Control and Optimization.....	249	Thermodynamics and Statistical Mechanics.....	234, 308	Twentieth Century, The: Identity and Autobiography.....	336, 337
Systems Engineering and Operations Research, Probabilistic Models in.....	252	Thermodynamics, Applied.....	230	Twentieth Century, The: Revolution and Totalitarianism.....	337
Systems Engineering, Space.....	314	Thermodynamics, Chemical.....	246	Twentieth Century, The: Revolution, War, and "Totalism".....	355
Systems Engineering, Special Studies in.....	216, 227, 256, 290, 323	Thermodynamics, Chemical Engineering.....	275, 276	Two-Dimensional Hydrofoil Theory.....	288
Systems, Information.....	249	Thermodynamics, Elements of Classical and Statistical.....	229	Two-Phase Flow and Boiling Heat Transfer.....	230
Systems, Linear, Probability Theory and.....	254	Thermodynamics of Materials.....	234	Two-Phase Flow, Mechanics of.....	313
Systems, Man-Machine.....	226	Thermodynamics in Metallurgy.....	236	Uncertainty, Analysis of.....	214
Systems, Non-linear Dynamical.....	256	Thermodynamics in Process Metallurgy.....	238	Undergraduate Physics, Special Problems in.....	267
Systems, Power, Project Laboratory.....	260	Thermodynamics, Statistical, Introduction to.....	246	Undergraduate Research Problems.....	335
Systems, Principles of.....	304	Thermodynamics, Statistical Mechanics and.....	248	Undergraduate Seminar.....	362, 363
Systems, Probabilistic, Analysis.....	251	Thermoelasticity, Plates, Stability and.....	310	Undergraduate Teaching Seminar.....	361
Systems Simulation.....	304	Thesis Presentation, Undergraduate.....	261	Undergraduate Thesis Presentation.....	261
Systems, Stochastic.....	305	Thesis, Preparation for.....	283	U.N. System and Problems of Political Development, The.....	320
<b>T</b> axation and Business Management.....	303	Thesis Reports.....	275	U.S. Foreign Policy — Plans and Strategies.....	320
Teaching Electrical Engineering.....	261	Thesis Research.....	241	U.S. Foreign Policy — Process and Problems.....	320
Teaching Seminar, Undergraduate.....	363	Three-Dimensional Hydrofoil Theory.....	288	United States, History of Technology in the.....	342
Techniques in Food and Nutrition Research.....	334	Tides, Waves and.....	287	United States, History of Transportation in the.....	342
Techniques of Metal Sculpture.....	236	Time-Dependent Probability.....	294	University, American, Seminar on the.....	350
Technology and Economic Growth.....	341	Tolstoi's "War and Peace".....	360	Urban American History, Seminar on.....	282
Technology and Innovation, Economics of.....	293	Tool Fundamentals, Machine.....	233	Urban Design.....	241
Technology and Policy.....	319	Topical Studies in the History and Theory of Art.....	242	Urban Design, Computer-Aided.....	244
Technology and Society, Seminar on.....	350	Topology.....	330	Urban Design, Problems in.....	280
Technology, Government, Politics and.....	319	Topology, Advanced.....	330	Urban Development Patterns and Economic Growth.....	282
Technology in the United States, History of.....	342	Topology, Differential.....	330	Urban Development Policy, Seminar on.....	281, 323
Technology, New, Legal Aspects of.....	234, 306, 315	Topology, Graduate Seminar.....	330	Urban Economics.....	295
Technology, Values, and Social Choice.....	350	Topology, Introduction to.....	326	Urban Economics: Positive Analysis.....	282, 295
Tensor Calculus.....	329	Totalitarianism, Revolution and, The Twentieth Century.....	337	Urban Economics: Positive and Normative Analysis.....	282, 295
Textile Materials and Processes, Elements of.....	233	Toxicology, Food.....	335	Urban Education, Politics of.....	323
Theatre Arts: Elementary Stagecraft and Production Studies.....	339	Toxicology, Food, Laboratory.....	335	Urban Education, Seminar in.....	351
Theology, Contemporary Philosophy and.....	350	Trade, International.....	295	Urban Environment, Components of the.....	280
Theoretical and Applied Elasticity.....	329	Tradition and Innovation in Twentieth-Century Physics.....	351	Urban Evolution, Elements of.....	243, 350
Theoretical Hydrodynamics.....	327	Traffic Flow, Theory of.....	218	Urban Form, History of.....	243
Theoretical Methods in Physics of Solids, Introduction to.....	237	Transfer, Heat and Mass.....	229	Urban Form, Transportation and.....	280
Theoretical Mineralogy.....	283	Transfer, Radiative.....	278		
Theoretical Models for Computation.....	250	Transistor Amplifiers, Multistage.....	251		
Theoretical Particle Physics.....	271	Transistors, Principles of.....	251		
Theoretical Physics.....	266	Transmission of Information.....	254		
Theoretical Physics, Special Problems in.....	269				
Theoretical Soil Mechanics.....	218				

Urban Landscape.....	280	Vibration, Mechanical.....	291	Wave Propagation in Plasmas.....	270
Urban Life, Structure of.....	323	Vibration, Random.....	224	Waves and Coastal Processes.....	222
Urban Planning and Social Policy.....	281	Vibration, Structural, Sound and.....	224	Waves and Tides.....	287
Urban Politics and Problems.....	323	Vibrations.....	224	Wave, Internal, Surface and.....	332
Urban Politics, Research Seminar in.....	323	Vibrations, Continuum.....	315	Waves, Media, and Interactions,	
Urban Politics, Seminar in.....	323	Vibrations, Structural, Acoustics and.....	291	Electrodynamics of.....	255
Urban Settlement, Squatters, and Social		Vienna and Versailles.....	344	Weapons Systems, Special Problems in.....	313
Change.....	281	Virology, Topics in.....	264	Weather Prediction, Numerical.....	331
Urban Social Policy Seminar.....	281	Viscoelasticity.....	220	Welding Engineering.....	237, 289
Urban Social Structure and Process.....	281	Viscoelasticity and Creep, Plasticity.....	310	Western Tradition, The: The Classical	
Urban Sociology, Contemporary, Seminar in.....	323	Viscous and Turbulent Flows.....	227	Heritage.....	336
Urban Systems Analysis Techniques.....	217	Viscous and Turbulent Flows, Advanced.....	228	Western Tradition, The: The European	
Urban Transportation Problem, The.....	280	Viscous Fluids, Aerodynamics.....	309	Heritage.....	336
Urban Transportation Systems.....	217	Visual Design, Advanced.....	240	Western Music in the Baroque Era.....	349
Utopian Literature.....	339	Visual Design Problems.....	239	Western Music in the Classic Era.....	349
<b>V</b> ariability, Oceanic.....	332	Visual Design Projects.....	239	Western Music in the Middle Ages and the	
Variable, Complex, Functions of a,		Visual Processes.....	273	Renaissance.....	349
Introduction to.....	326	Visual System, Electrophysiology of the.....	273	Western Music in the Romantic Era.....	349
Variables, Complex, Functions of.....	326			Wings and Bodies, Aerodynamics of.....	310
Variables, Real, Functions of.....	326	<b>"W</b> ar and Peace," Tolstoi.....	360	Workshop in Astronomy.....	284
Variational and Matrix Methods of Structural		War and the Military Institutions of the		World Affairs, Changing Outlooks and	
Mechanics.....	311	Modern State.....	344	Identities in.....	316
Varieties of Fascism: Origins and Comparative		War, Limited, Evolution of Forces for.....	319	World Military History.....	361
Development in Germany and France,		War, Spanish Civil, 1936-39.....	345	World Military Systems.....	361
1900-1945.....	345	War Systems and Strategies, General,		World of Mathematics, The.....	324
Vehicle Environmental Control.....	231	Development of.....	319	Writing of Fiction, Introduction to the.....	338
Vehicle, Flight, Engineering.....	314	War Systems and Strategies, Limited,		Writing of Fiction, The.....	338
Vehicle, Waterborne, Design of a.....	290	Development of.....	319	Writing of Poetry, The.....	338
Vehicles, Automotive.....	230	War Systems, Concepts of General and		Writing of Prose, The.....	338
Vehicles, Flight.....	315	Limited.....	362	Writing, Scientific and Engineering.....	338
Vehicles, Flight, Aerodynamics of.....	310	Water Quality Control.....	223	Writing Tutorial.....	338
Vehicles, Flight, Automatic Control of.....	311	Water Resource Systems.....	223	Writing Tutorial, Professional.....	305
Vehicles, Hydrospace.....	291	Water Resources, Introduction to.....	221	<b>X</b> -ray Diffraction.....	269
Vehicles, Ocean, Stability and Motion		Water, Sea, Physical Properties of.....	287	X-ray Diffraction, Principles of	
Control of.....	288	Waterborne Vehicle, Design of a.....	290	Crystallography and.....	235
Versailles, Vienna and.....	344	Wave Motion.....	328, 329	X-ray Metallurgy, Advanced.....	237
Vertical Take-Off Aircraft.....	313	Wave Propagation.....	224	X-rays and Crystal Physics.....	269





MICROCOPY RESOLUTION TEST CHART  
 NATIONAL BUREAU OF STANDARDS-1963-A