Laura Fermi's Notes on Preliminary Meeting December 7, 1956

LAURA FERMI'S NOTES ON PRELIMINARY MEETING DECEMBER 7, 1956

Subject matters:

1. Optics and waves - Purcell, Friedman, Phil Morrison, Ingard, Rossi, Steve White
2. Mechanics - Rossi, Gottfried, Caldwell, Ferin, Rossi, Ingard
3. Electromagnetism - very little: Little, Rossi, Ferin
4. Submicroscopic physics - Caldwell, Osborne

Second thoughts:

1. Outline
2. Outline
3. Almost nothing
4. They are working with it now, will come afternoon

— If optics starting point we should see it, so as to see how course may develop.

— Though: mechanics may come first,

Waves vs particles, pictorial

Mechanics developed fast through dynamical theories, little Kynematic

Reason for optics before mechanics: extremely rich in phenomena. Gives concrete before abstraction. Leads to concrete about light. From mechanics definition, point of view, math. If optics first, they will see the need of mechanics.

Though: light complicated. Almost all experience comes from eyes. Lot of people have _____ for quantative reasoning; think qualitative reason no good. Speed of sound depends on distance. Qualitative, order of magnitude.

Mistake is to handle pieces separately. Tie together: wave: spring: compression and acceleration.

Dynamics if built up to it. You have a lot of the concepts already in optics, like velocity.

Qualit vs quantitatives.

Qualit; the bad is _____ But if presented clearly, dist inguish concepts from definition, sharpness, then quantitative is not necessary

OPTICS

Film presentation staying close to school situation. Talking and filming as if in a classroom even thought not stay there.

Even though skip many things, we go over things they know, we show them from different point of view, rectilinear propagation, diffraction, velocity

of light (they know figure). So we start out with a rapid summary, there are lots of things you know already, angle, plain observation. Some of things to find out how you ever knew it. Purpose is not to teach what is in the books, but why.

Should we or should you not tell them that they know already

Pedagogic approach

Objectives

Observation - it leads to light

The advantage of a film is not to rely on words. So you show what we are saying. In film many rapid shots to show a lot of phenomena.

Then we'll go systematically, and look one pheonmenon at a time.

Don't show end results, but how they happened. Frank spent a full lecture showing how some things happened which they though happened differently, look closer, it did not happen this way. You have to puzzle them.

Optics Outline

1. Rectilinear _____ propagation, shadows, echyps, pinholes, cameras.
2. Reflection, specular not much time. Virtual image where the light comes from, so we tie with rectilinear propagation; as if the source were there, what defines a surface. How the distrubance feels out and finds out what a surface is. When we do mathematically. Beams instead of rays. Angle to respect to what?

~~Opportunity box~~

Opportunity to make a beam ~~xxxxxx~~ come to a focus. Build up a surface by putting mirrors at angles. Elypt and parabol mirros. You can get the light back together. Frank asks which is forward and which is backwards?

Which is the source and which is where it goes to. Trap is; have you seen direction?

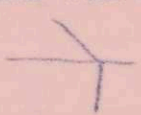
We are in room with many lights that do not interfere. Reflections sends them back without arguing symmetry.

Meaning of straight line. Zacharias wants prize ~~prove~~ for best student's essay on what is a straight line.

Take things on faith vs boring them with things which seem obvious. Not everything obvious.

Not too long either in textbooks or films. Rather in problems. Student will do some of the work. Presumption; student have had plane geometry just before.

The question of too fast or too slow. Fast pace means gaps. Students filling if you are very careful how you prepare questions for students. Experiments on refraction.

3. Refraction - Sin of angle? Some will not. Refraction experiment large block of plastic with scattering. First pl where we go toward a law of physics.  See how 2 angles related. Have the student plot one things vs another, see what get. Regularities, but

not enough, eventually ratio comes out not by definition but by trying. You vary parameters, find law; not by definition. Is physics caract you try to unbury. Predict from this Snell's law. We do not assume they know sine function.

Prism we see bending synthetic lens out of prism, correct shape of mirrors. See in principle we can devi se surfaces to see in focus, parallel light to a focus.

Something like an image, as empirical. We do not spend time on lens, classify or find, but since useful But lens can be shown as application digression, not physics.

Rabi says lens gets away from physics for practical end. But practical end, says Frank to study more physics. Still student must understand that it is not physics.

Rabi: Student already familiar with concept of angle. You have the law. Next question is how to make it more simple. Somehwere slow, and show the simplification. Here you are applying math for first time; relation is not obvious; show that simplicity is what we aim at; sufficiently simple, general, and fundamental assumption. Look at the law first, play internal refraction, extrapolation.

Table of sines. Does not know, the significance is he can use the same table for all materials. Gets index, perhaps through triangles, can do without sines; much better.

Rabi: Perhaps lenses not here. Want to take difficult digress into lenses and perhaps charm of basic things will be lost.

Rabi: Spectrum before application? Yes, because has intellectual. With refraction, want to do always coming back, also reflection which goes together with refraction.

Rabi: Tell them very sharply when you make an application. Reflection index: we have to say relative to the 2 matters.
Kids have cameras and eyes. Perhaps lenses before going into more theory to check phenomena already have. Outline of property of light. Interference phenomena before nature or what?

Rabi: All course of phenomena before going into deep

Friedman: Rapid so far, then ask questions.

Michels: Should leave some flexibility to instructor.

Friedman: After 3 questions of what : so wave, check with it phenomena we have already.

Rabi: He has had typical experience and theory up to this point. You can do a lot phenomena without further principles. Laws of lenses, we can make them. Let them do some ray tracing from them. Two surfaces much more difficult than 1 in the beginning. Get $\frac{1}{f}$ in one example, and say you could do it on many other. Vision? Fran wants to stay away from it, only images rather than mechanism of eye. Lens; if we do that have to do ray tracing, Michels for it. Can do a lot of it

with just ruler. Very importnat. Novelty that by drawing he can predict where it will come. Then can see that it is ture. He can determine, define focal lingth, prism is idealistic, you then jump to a curve surface. References for the student here?

AFTERNOON

B Bruno's outline how things happen.

1. General kyn description of nature.

   1. regularity

   2. simplicity

   Materials: Astronomy to ~~Kepler~~ Cofernicus or Kepler

   Optics { geometrical, waves, acoustic } back and forth

   focusing attention on description of nature, phenomenblogic and kynematic, extrapol of glare.

2. Dynamics of motion, why things happen, cause and effect, generality of physical laws, mass impulse. Laws of mechan, magnet grav forces, fields. Coulomb's law. Qualitative mag-

n netism, no quantitave except concept of uniformity of field and motion of magnetic field.

3. Atomistic, integer multiples; atom

   Structure of matter
   Size of atoms } how to measure
   Charge of electrons

4. Fields

   Elementray electrodynamics, develop perhaps dynamics of acoustic wave, dynamical of continuous medium.

   Is field necessary? Empty space has physical property, seems essential to Bruno.

   Build the idea of field and leave it to property of space is not useful. You cannot go vary far, similar potential energy.

   Statics of field.

   Let us decide not to discard it unless we try

      Coulomb's law in mech

      Lawrence; law

      Electromagnetic induction? Is it enough to move current?

      Otherwise you need introduce variation of field. This way we need more about field

Back to Friedman's optics

Wave phenomena, propagation, velocity, reflection on ropes, coil, 2 media, demonstration in wave picture we have trouble with rectilinear propagation. Optics in unhomogeneous media. Light pressure, do it experimentally, long before force and pressure? yes, but not use pressure,

pressure in wave field, sound field. Start to diffract, parallel experiment. Oepn up aperture. Opening and closing gaps, go directly to interference rather than clean up diffraction, ripple tank. Movie comes in beautifully, wave length, acoustical. Now wave phenomena in submicroscopic diffraction of molecules on crystal. Standing waves at this time? Polarization? People would like to see it in here, closes well kynematic optics. Vote against crystal optics.

Bruno wants to start with solar system. Franck says would you feel bad if we posponed - no = but they keep on arguing.

Learn to observe phenomena, pictures behind phenomenological are needed.

We must change the attitude that learn because it is in the book, they should observe.

The 2 ideas of balls and waves, see that both can be used to explain. Introduces model, teaches to collect information and see what is to do next.

Tending toward dynamic description. We have difficulty of simplicity.

You can devise your experiment, etc. This is different from simple kynematics description, mix kynematics as you go toward dynamics.

Rabi says that as modern physicists wave theory is more important than gravitational, he would not start there. It is an accident that planets are there.

Mechanic, Ingard's way is done better not rhrough waves.

Terribly exciting to find that one formula regulates all universe.

For motion you have to define references

One way of presenting mechanics, forces, related, motion they produce all sorts of forces. Other elements in how bodies react to forces. Laws of motion. We develop constant force run into problem of eliminating other forces. Ideal situation. Mass with one substance, final velocity and ratio of mass velocity to define mass, ft, momentum, cleaner to description. dynamic definition of f. All for straight line first. Kynematics negligible at this state. Then other direction, enough of kynematics of vectors to show motion in 3 dimensions. Rotatory motion with string and spring. Geometrical conception with acceleration as vector. Combination of example in 1 ~~dexx~~ dimension of fs not constant, only illustrate graphical decreasing velocity. Also, if I see something moving, deduct there is a f which than I check, planetary motion serves to see force. Constant f with change of direction.

Apply to grandiose discovery of gravitation in planetary. Talk about pulse and momentum and impulse as change.

Conservation of momentum is not as

Action and reaction not law, but we have conservation, so we have that.

Conservation of energy, preparing 2 conservation laws, heat as extension of conservation of energy.

Kinetic idea of heat, as form of energy, adiabatic experiment of pressure, conservation law to tie back to wave, without doing dynamic of wave in detail.

Realistic with electric force after some electricity

Alternative version of Mechanics

Interaction, mutuality

Dynamical laws, momentum and mass definition not through force, bodies thrown apart, momentum conservation experimentally bodies collided, pairs of velocities, restrictions, relative velocities don't increase, conservation of kinetic energy, principle that can be viewed with balls bouncing against wall, Conservation of energy is restricted to conservation of momentum. Law of motion and idea, essentially as differential.

Rossi says more abstract, less connect between cause and effect, though it is closer to what we see.

Interaction, make examples, physics; study of interactions, mechanics; study of motion due to interaction. Have to experiment with impact billiard table with no friction. Statics becomes case of dynamics when acc is 0.

Decide to do both.

Frames of reference description, rotary motion, see in car going around. So laws for standing still by reference to surface of the earth. How to show a Foucault's pendulum in a classroom.

Electricity and Magneticsm

Coulomb's law, then do balistic not with charge but with balls.

No potential.

Then magnetic forces, iron filings, not necessarily field, lines of induction or field lines.

No. 3 run to 25 on pick up.

Atomistic, some of it before balistic of small particles,

Conservation law

Fields

Cosmic ray

Wave phenomena of small particles (without analyzing, then go back and analyzie)

Existence of various kinds in Millikan's and Farady's experience

Atoms and molecules

Dolton

Gay Lussoic

Faraday, chemical atomistic ions, Ion mass as atom mass, mass spectrocopy.

_____ of atomic units, see integers even though

Crystal diffractions and absolute counting, measure wavelength with your own lattice, elementary way, dimensions of atoms, number included in mole

Thickness of film

Electron microscope

Intermolecular forces, liquid vapor equilibrium, why water expands on freezing.

Subject matters

1 Optics & waves – Purcell & Friedman, Phil Morrison, Ingard – Rossi (Steve White)

2 Mechanics → Rossi, Gottfried, Caldwell, Fermi, Rossi, Ingard

3 Electromagnetism – very little: Little Rossi, Fermi talked of it in mechanics

4 Submicroscopic physics – out – Caldwell, Osborne

Second thoughts

1 outline
2 outline
3 almost nothing
4 they are working with it now, will come afternoon

Preliminary meeting

Dec 4

typed up

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- Though: mechanics may come first,

Waves vs particles, pictorial
Mechanics developed ~~fast~~ through ~~Kyn~~ dynamical theories, little Kynematic

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Reason for ~~dynamics~~ optics before mech.: extremely rich in phenomena - gives ~~to~~ concrete before abstraction - Leads to concrete about light - From mechanics definition, point of ~~to~~ view, math-
If optics first, they will see the need of mechanics

Though - light complicated
- Almost all exper comes from eyes

Lot of pop have qr ever for quantitat reasoning; think qualitative reason no good. Speed of sound depends on distance

Qualitative - Order of magnitude

Mistake is to handle pieces seperately Tie together: wave: spring: compression & acceleration -

Dynamics if built up to it You have a lot of the concepts already in optics, like velocity

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Qualit vs quantitatives

Qualit: the bad is sloppiness. But if presented clearly, distinguish concepts from definition, sharpness Then quantitative is not necessary

~~Optics~~

~~Leave the~~

Optics

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Talking & filming as if in a classroom even though not stay there

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Pedagogic approach -

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Observation - it leads to light

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Then we'll go systematically, and look one phenom at a time -

Don't show end results, but how they happened. Frank spent a full lecture showing how some things happened which they thought happened differently: look closer, it did not happened this way. You have to puzzle them

O.K.

Optics outline 6

1 Rectilinear bundle propagat -
shadows, eclyps pinholes, cameras

2 Reflection - specular - not much time - verdual image where the light comes from, so we lie with rectilinear propag: as if the source were there
what defines a surface - How the disturbance feels out and finds out what a surface is - When we do mathematically -- Beams instead of rays. Angle to respect to what?
Opportunity to make a beam come to a focus. Build up a surface by putting mirrors at angles - Elypt & parabol mirrors - You can get the light back together. Frank asks which is forward & which backwards?
Which is the source & which is # where it goes to - Trap is: have you seen direction
We are in room with many lights that do not interfere. Reflections sends them back without arguing symmetry

7 Meaning of straight line

Each wants prize for best student's essay on what is a straight line

Take things on faith vs boring them with things which seem obvious

Not everything obvious

~~No~~ Not too long either in textbooks or films. Rather in problems.

Student will do some of the work

Presumption: stud have had plane geometry just before. Use many places

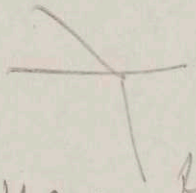
The question of too fast or too slow

Fast pace means gaps.

Students telling if you are very careful how you prepare questions for studs

Experiments on refraction

3 Refraction - Sin of angle? Some will not -
Refraction experiment: large block of
plastic with scattering - First pl
where we go toward a law of physics



see how 2 angles related -
Have the stud plot one thing vs
another. See what get - Regularities,
but not enough: Ratio comes out
not by definit but by trying -
You vary parameters. Find law;
not by definit. Is physic exact
You try to verify - Predict from
this Snell's law - we do not
assume they know sin funct

Prism we see bending
synthetize lens out of prism,
correct shape of mirrors -
See in principle we can devise
surfaces to see in focus

R parallel light to a focus -

Something like an image - as empirical

We do not spend time on lens, classify or find - But time useful

But lens can be shown as application, digression, not physics

B Rabi says lens gets away from phys # for practical end - But practic end, says Frank to study more physics - Still stud must underst that it is not physics

Rabi: stud already familiar with concept of angle. You have the law. Next question is how to make it more simple Somewhere else, and show the simplific - Here you are applying math for first time; relation is not obvious; show purpose that simplicity is what we aim at; sufficiently simple, general, and fundamental assumption - Look at the law first - Play with real refraction — extrapolation

Table of sines - Does not know The significance is he can use same table

for all materials - Yours Gets index -
Perhaps through triangles - Can do without
sines; much better -

Rab Perhaps lenses not here -

Want to take difficult digress into fuss
and perhaps charm of basic things
will be lost

Rab Spectrum before application? Yes because
has intellectual

With refract: want to do always
coming back, also reflection which
goes together with refract

Rab tell them very sharply when
you make an application

reflect index: we have to say relative
to the 2 mabers.

Kids have cameras & eyes
Perhaps lenses before going into
more theory to check phenomena
already have
Outline of properties of light

Interference phenomena before nature & what?

Rabi: all corse of phenomena before going into deeps ~~of phs~~

Freidu: rapid so far — Then ask questions

Michels: should leave some flexibility to ~~the~~ instructor

Freidu: after 3 question of what: so wave — check with it phenomena we have already

Rabi: he has had a typical exper & theory up to this point — You can do a lot phenom without further principles

laws of lenses — We can make them. Let them do some ray tracing from them

2 surfaces much more difficult than 1 in the beginning

get $\frac{1}{f}$ in 1 example, and say You could do it on many other

Vision? Fran wants to stay away from it, only images rather

than mechanism of eye

Lens: if we do that have to do Ray tracing Michels for it - Can do a lot of it with just ruler. Very important

Novelty that by drawing he can predict where it will come. Then can see that it is true. he can determine Defini focal length - Basic is ideal that & you then jump to a curve surface

References for the student here?

Afternoon

Bruno's outline how things happen

1 General Kyn descript of nature

1) regularity

2) simplicity

Materials : astronomy to Copernicus or Kepler

optics : geometrical
waves
acoustic
} back and forth

focusing attention on descript of nature - phenomenologia

2 kynemat - extrapol of geom

2) Dynamics of motion why things happen

Cause & effect

generality of physical laws

mass impuls

Laws of mechan, magnet grav el forces

fields

Coulomb's law
Qualitative magnetism,
no quantitative except concept
of uniformity of field & motion
of magnetic field

3) atomistic
high multiples: atom
Struct of matter
Sum of atoms } how to measure
charge of elec

4) fields
elementary electrodynamics
Develop perhaps dynamic of
acoustic wave _ dynamical
~~consti~~ of continuous medium

Is field necessary?

Empty space has physical property - seems essential to Bruno

Build the idea of field and leave it to property of space is not useful You cannot go very far - Similar potential energy

Statics of field

Let us decide not to discard it unless we try

Coulomb's law is much

Lawrence's law

Electromagnetic induction ? Is it enough to move current ? Otherwise you need introduce variation of field - This way we need more about field

Back to Freedman's optics

wave phenomena

propagat, velocity, reflection on ropes, coil, 2 media - demonstration

in wave picture we have trouble with rectilinear propagation - Rays optics in inhomogeneous media

light pressure - do it experimentally - long before force ∝ pressure? yes - but not use pressure - pressure in wave field sound field -

Start to diffract - parallel experim

Open up aperture - -

Opening & closing gaps - go directly to interference rather than clean up diffraction - ripple tank

Movie comes in beautifully

wave length - acoustical

how wave phenomena in submicroscopic: diffract of molecules on crystal

Polarization ? can do with acoustical
Standing waves at this time?
→ people would like to see it in here - closes
will hypersonic optics
Vote against crystal optics

Bruno wants to start with solar system
Franc says would you feel bad
if we postponed — no — But they keep on
arguing
Learn to observe phenomena
pictures behind phenomenological are
needed
We must change the attitude that learn
because it is in the book — they should
observe
The 2 ideas of balls + waves - see that
both can be used to explain - Introduces
model - ~~Collect~~ Teaches to collect information
and see what to do next

Tending toward dynamic descript -
We have difficulty of simplicity
You can durse your experiment etc -
this is different from simple Kynematics
description - Mix Kyn as you go toward
dynamics -

Rabi says that as modern physicists
wave theory is more important than
gravitational - He would not start
there - It is an accident that planets
are there

Mechanic, Engards' way, is done better not through
waves

Terribly exciting to find that one formula
regulates all universe

For motion you have to define references

One way of presenting mechanics

forces - related - motion they produce
all sorts of forces - Other elements in
how bodies react to forces. Laws
of motion - We develop constant force
run into problem of eliminating other
forces - Ideal situation - Mass with
one substance, final velocity and
ratio of mass-vel to defin mass
ft = momentum - cleaner & sp descrip
dynam defin of f - All for straight
line first - Kynematics negligible at
this state - Then other direction -
enough of Kynem of vectors to show
motion in 3 dimensions - Rotatory
motion with string & spring - Keplers
conception with accelerat as vector
Combinat of - examples in 1 dimens
of fs not constant. only illustrate graphical
decreasing velocity - Also: if I see
something moving, deduct there is a f

which then I check: planetary motion serves to see force - Constant & with change of direction

Apply: to grandiose discovery of gravit in planetary

talk about impulse & momentum, & impulse as change

Conservat of momentum is not as law

Action & reaction not law, but we have conservat, so we have that —

~~If momnt is not = to law of motion~~

Conservat of Energy preparing 2 conservat laws - heat as extension of conservat of energy

~~do~~ kinetic idea of heat, as form of energy adiabatic experiment of pressure - Conservat law to tie back to wave, without doing dynamic of wave in detail

Balistic with electric force after some
electri

Alternative version of Mechanics

Interaction, mutuality

Dynamical laws: momentum & mass difinition not through force

bodies thrown apart
momentum conservation ex permentally bodies collided: pairs of velocties

restrictions: relative velocities dont increase: conservat of Kinetic energy - principle that can be viewed with balls bouncing against wall

conservat of energy is restrict to conserv of momentum

Law of motion & idea ~~description of interaction~~

essentially as differential

Rossi says more abstract, less connect between cause & effect - though

it is closer to what we see

Interaction: make examples
physics: study of interactions
mechanics: study of motion due to interaction
Hard to experiment with impact: billiard table with no friction

Statics becomes case of dynamics when acc is 0

Decide to try both

Frames of reference description
rotatory motion - see in car going around
So laws for standing still by reference to surface of the earth
How to show a Foucault's pendulum in a class room —

Electricity & Magnetism.

Coulomb's law
then do balistic not with charge but with balls
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N° 3 run to 25 on pick up.