Welcome to Advanced Physics Lab

Baris

Advanced Physics Lab, PHYS 3600
Baris Altunkaynak and Don Heiman, Northeastern University, 2021

Don

About the Course

The course material will be presented
in-person and online with PowerPoint slides.

First week will be lecture material
Following 6 weeks are experiments
Homework and Lab Reports for each experiment

Main Webpage

The course webpage
https://web.northeastern.edu/heiman/3600/index.html
has links to the lectures, homework and the 6 experiments.

Introduction to Course

Adv Phys Lab website

Advanced Physics Lab

PHYS 3600 - Summer-1, 2021, https://web.northeastern.edu/heiman/3600/index.html

Baris Altunkaynak and Don Heiman, Northeastern University, 2021

Item	Description
Welcome	Check this webpage often, as it has updated information.
Monday, May 10	Introduction, course structure, estimation, Feynman/Fermi
Tuesday, May 11	Errors, Uncertainties, Optics
Wednesday May 12	Semiconductors, Acoustics
Thursday, May 13	Intro to experiments, worksheets **Homework due by 9:50 am**
Ralph Waldo Emerson	*˝All life is an experiment.* *The more experiments you make the better.˝*
Doc in Steinbeck's *Cannery Row*	Doc (marine biologist Ed Ricketts) is *"interested in knowing something about everything" "His mind had no horizon"*
Check it out	Richard Feynman's 1937 MIT lab report

Group -- Experiment # / Dates (Mon-Thur, 9:50-11:30 am)	**1** May 17-20	**2** May 24-27	**3** MayJun 31-3	**4** June 7-10	**5** June 14-17	**6** June 21-24
1 Jeanne d'Arc, Robyn Hode	AFT	CEO	FUEL	HALL	RUBY	SOL
2 Richard Feynman, Rosalind Franklin	SOL	AFT	CEO	FUEL	HALL	RUBY
3 Millie Dresselhaus, Enrico Fermi	RUBY	SOL	AFT	CEO	FUEL	HALL

Measurement Without an Instrument

Measurement Without a "Ruler"

(Something Enrico Fermi might suggest)

How can we measure something without using the proper tool or instrument?

As an example, we will measure the width of a classroom whiteboard using only an 8.5 x 11 inch piece of paper.

In order to confirm our accuracy, we will measure the width using a metal "tape measure."

We will also estimate uncertainties in the measurements.

Introduction to Course

Syllabus

PHYS 3600 - Advanced Physics Lab - Summer 2021

Don Heiman, Northeastern University, 5/7/2021, http://northeastern.edu/heiman/3600/syllabus.html

Calendar: http://northeastern.edu/heiman/3600/index.html

When: *Course material is* ***Online*** *via the course* ***Calendar*** *on the website*
Original schedule: Mon/Tue/Wed/Thur (9:50-11:30am; 1:30-3:10pm; 4:00-5:40pm)

Instructors: Prof. **Don Heiman -** heiman@neu.edu; Dr. **Baris Altunkaynak** - i.altunkaynak@northeastern.edu
Office Hours: email anytime or Zoom when scheduled
If you have questions about anything, please request help at the earliest possible time.

Description of Course**: CANVAS will be used for turning in all assignments; see Description**

Textbook: None required, but here are some valuable resources.
Useful resource: *Data Reduction and Error Analysis;* P. Bevington and D.K. Robinson (3rd ed. 2003, McGraw-Hill)
Writing: *The ACS Style Guide - Effective Communication of Scientific Information* (Eds. Anne M. Coghill and Lorrin R. Garson). Chapters can be downloaded thru NU access at https://pubs.acs.org/isbn/9780841239999

Lab Experiments: Six lab experiments will be completed during the semester, one each week.
Homework: Homework assignments will be due generally at the **beginning of class** every **Thursday**.
Reports: Lab reports will be due at the **beginning of class** every **Monday** -- *Grades reduced for late reports*.
Poster: A digital poster of one experiment will be completed in place of a final exam.
CANVAS will be used for turning in all assignments.

Lab reports: The written lab reports provide valuable experience in communicating your experimental results. They are graded every week and will contain feedback comments. This feedback guides you toward improving your reports over the length of the semester. In the writing, focus will be on clarity, organization, grammar, style, format and figures. Scientific writing is an important component of the course, providing credit for the **NUpath *Writing Intensive*** and **NU Core *Writing Intensive in the Major***. This training provides experience in writing high-quality documents for your managers, scientific publications, grant proposals, etc.

Grading (percentages are plus or minus 10 %):
Homework: Homework assignments will be handed in electronically. (30 % of grade) **DUE THURSDAYS AT 9:50 AM**
Lab reports and Poster: Six lab reports and one poster are required. (70 % of grade) **DUE MONDAYS AT 9:50 AM**
Late Grading: Homework - minus 2 pts/day (out of 30 possible); Lab Reports - minus 10 pts/day (out of 100 possible).

Experiments: Here are links to the lab instructions
Acoustics and Fourier Transform, Coupled Electrical Oscillators, Fuel Cell, Hall Effect, Ruby Spectroscopy, Speed of Light

Introduction to Course

Course is
DOUBLE Time

This Summer-1 course covers the same amount of material in **7 weeks** that would normally be covered in the usual **15 week** Fall and Spring semesters.

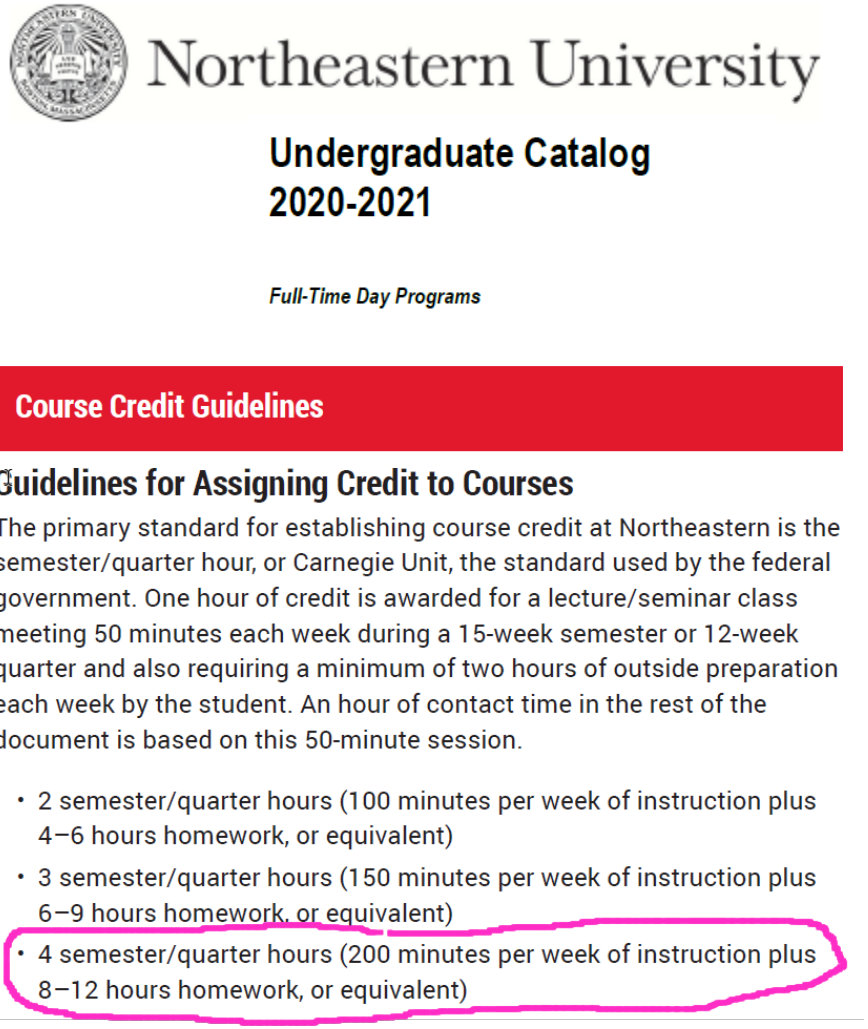
The **federal academic standard** for course work is listed on page 29 of the NU 2020-2021 Catalog on the left.
It states:

11-15 hours per week of in-class plus out-of-class time for a 15-week course.

That leads to in-class plus out-of-class time of

22-30 hours per week

for this 7- week Summer course.



Northeastern University

Undergraduate Catalog
2020-2021

Full-Time Day Programs

Course Credit Guidelines

Guidelines for Assigning Credit to Courses

The primary standard for establishing course credit at Northeastern is the semester/quarter hour, or Carnegie Unit, the standard used by the federal government. One hour of credit is awarded for a lecture/seminar class meeting 50 minutes each week during a 15-week semester or 12-week quarter and also requiring a minimum of two hours of outside preparation each week by the student. An hour of contact time in the rest of the document is based on this 50-minute session.

- 2 semester/quarter hours (100 minutes per week of instruction plus 4–6 hours homework, or equivalent)
- 3 semester/quarter hours (150 minutes per week of instruction plus 6–9 hours homework, or equivalent)
- 4 semester/quarter hours (200 minutes per week of instruction plus 8–12 hours homework, or equivalent)

Advanced Physics Lab

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This Week

1-INTRO: Introduction to the Course
boiler plate (syllabus), exercise
motivation, Feynman Technique, Fermi questions

2-ERRORS: Errors and Uncertainties, exercises
accuracy, precision, round off, propagation of errors

3-OPTICS: Optical Properties
EM spectrum, photo detectors, light emitters

4-SEMICOND: Semiconductors
band gap, Fermi energy, resistivity, Hall effect

5-ACOUSTICS:
sound, beats, Fourier transform, music

6-EXPERIMENTS: Intro to Lab Experiments, exercises
Tour my research lab

Advanced Physics Lab

Advanced Physics Lab, PHYS 3600
Don Heiman, Northeastern University, 2021

This Week

1-INTRO: Introduction to the Course
boiler plate (syllabus/labs), motivation,
Fermi questions, Feynman Technique, homework

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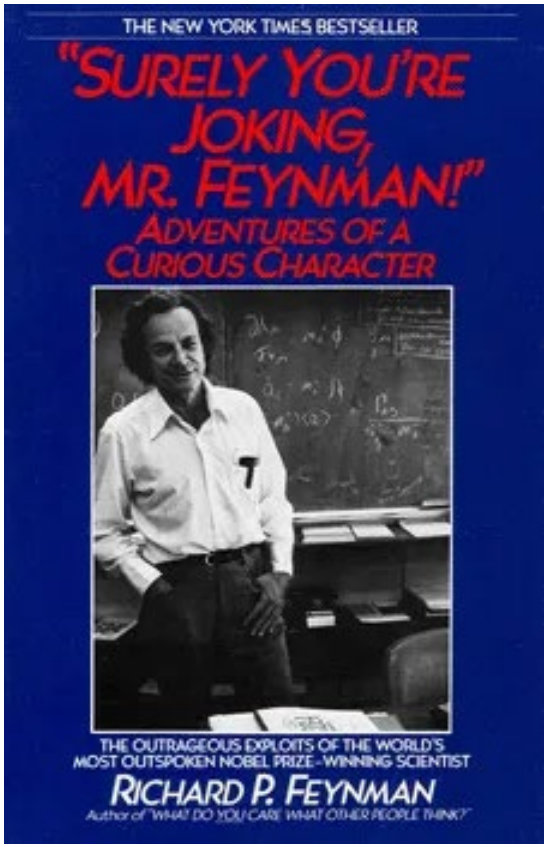
6-EXPERIMENTS: Intro to Lab Experiments
Virtual tour my research lab

Scientists Driven by Intellectual Curiosity



Curiosity Drives Science

Richard Feynman

Adventures of a Curious Character

(Feynman's MIT lab report)

Enrico Fermi

The Fermi Question

Scientists Driven by Intellectual Curiosity

Some Quotations

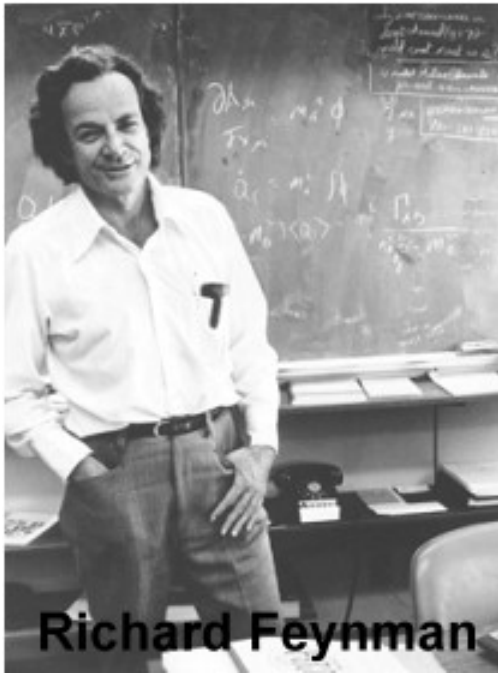
*"**I learned very early the difference between knowing the name of something and knowing something.**"*

- Richard P. Feynman

Feynman was also famous for persuading scientists and mathematicians to explain complex ideas using only simple terminology.

*"**If you can't explain it simply, you don't understand it well enough.**"*

- Albert Einstein



Scientists Driven by Intellectual Curiosity

Some More Quotations

Doc is ***"interested in knowing something about everything"***
Doc, ***"His mind had no horizon"*** - Steinbeck's Cannery Row

"All life is an experiment. The more experiments you make the better."
- Ralph Waldo Emerson

"Even theorists have an advantage when they thoroughly understand experiments."
- Don Heiman

How to develop Intellectual Curiosity (https://www.lifehack.org)

1. Keep an open mind - *Be open to learn, unlearn, and relearn. Some things you know and believe might be wrong, and you should be prepared to accept this possibility and change your mind.*

2. Don't take things as granted - *If you just accept the world as it is without trying to dig deeper, you will certainly lose the 'holy curiosity'. Try to dig deeper beneath the surface of what is around you.*

3. Ask (yourself) questions relentlessly - *A sure way to dig deeper beneath the surface is asking questions: What is that? Why is it made that way? How does it work?* ***Ask Yourself questions!***

4. Don't label something as boring - *Whenever you label something as boring, you close one more door of possibilities. Even if you don't have time to explore it, leave the door open to be visited another time.*

5. See learning as something fun - *If you see learning as a burden, there's no way you will want to dig deeper into anything. So, look at life through the glasses of fun and excitement and enjoy learning.*

6. Read diverse kinds of reading - *Don't spend too much time on just one world; take a look at another world. Pick a book or article on a new subject; let it feed your mind with the excitement of a new world.*

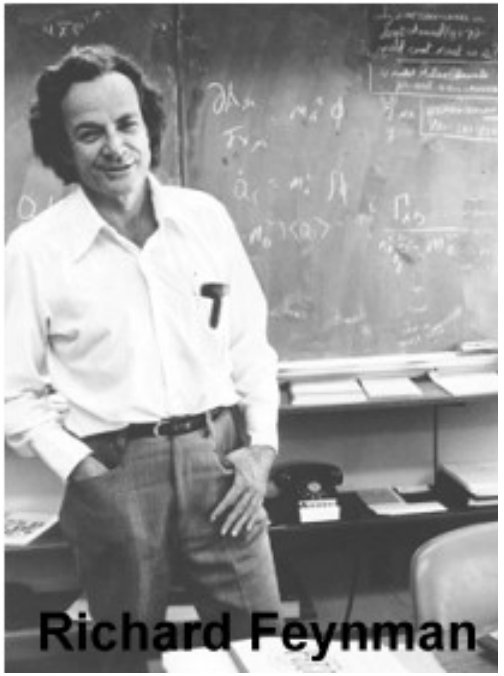
Feynman Technique

A version of the **Feynman Technique** applies to **learning/understanding** something.

It goes back to Einstein's quote about not completely understanding something until you can explain it simply.

1. **Pretend you are explaining it** to a student in the sixth grade or to your non-scientific grandmother.
2. **Identify gaps** in your explanation. Go back to the original material when necessary.
3. **Organize and simplify.** Organize items as bullet-points or numbered items. This can simplify things.

https://fs.blog/2021/02/feynman-learning-technique/



The Great Explainer

Scientists Driven by Intellectual Curiosity

Enrico Fermi

Turn every experience into a question.

"Fermi Questions"

Can you analyze it?

If you can, you'll learn something.

If you can't, you'll also learn something.

Enrico Fermi

Who was Enrico Fermi?

What is a "Fermi Question"?

What is a Fermi Solution?

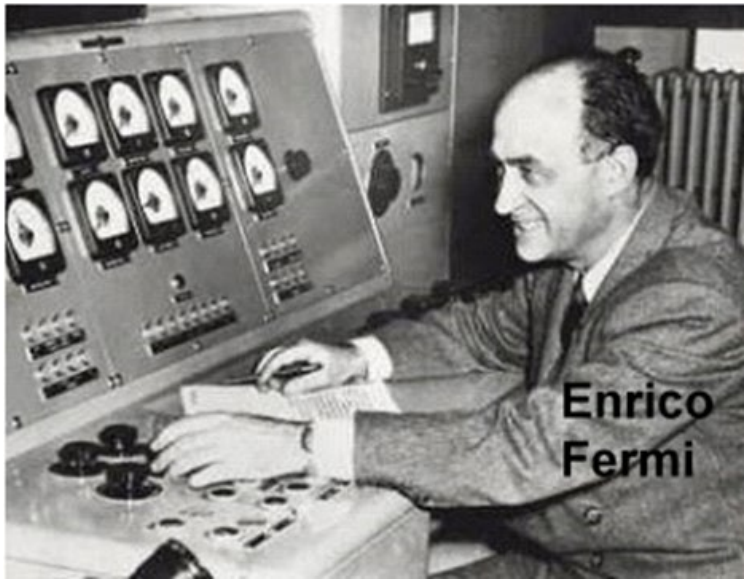
Why are Fermi Questions Useful?

Enrico Fermi – Who and Why

Who was Enrico Fermi?

ENRICO FERMI (1901-1954)
was an Italian physicist who was awarded the 1938 Nobel Prize his contributions to nuclear physics and quantum theory. He was also a noted **experimentalist**.

Fermi was forced to flee Italy and in 1942 he achieved the **first controlled nuclear chain reaction** at the University of Chicago. During World War II he was a leading member of the Manhattan Project that developed the atomic bomb in Los Alamos, New Mexico.



Overpass; bomb test; slow neutrons; lunch walk

Why - Fermi Questions

Examples: Fermi Questions or Fermi Problems

How many piano tuners are there in Chicago?

How many jellybeans are in a container?

How much does 1 million $10 bills weigh?

*1 g * $1E6/$10 = 1e5 g = 100 kg ~* ***220 #***

See http://www.physics.umd.edu/perg/fermi/fermi.htm
for a long list of Fermi Questions

Why are Fermi Questions useful?

They seek to find a fast, rough estimate of a quantity.

Often called a "***Back of the Envelope***" calculation.

What is a Fermi Estimation

A solution requires **estimation** of physical quantities.

Fermi was legendary for being able to **figure out things in his head**, using **information that initially seems too meager** for a quantitative result. He used a process of "zeroing in" on problems by saying that the value in question was certainly larger than one number and less than some other amount. He would proceed through a problem in that fashion and, in the end, have a quantified answer within identified limits. Bracket the answer.

In a Fermi question, the goal is to get an answer to an **order of magnitude** (typically better than a power of ten) by making reasonable assumptions about the situation, not necessarily relying upon definite knowledge for an "exact" answer.

- **A Fermi question is posed with limited information given**
  - How many buckets of water or balloons would fill a swimming pool?
- **A Fermi question requires that you ask many more questions**
  - How big is a bucket or water balloon?
  - What are the approximate dimensions of the pool?
  - What measurement must be estimated using the dimensions of the pool?
  - ... and the list goes on.
- **A Fermi question utilizes estimation, done over and over**
- **Fermi estimations emphasize process**

A Physics Fermi Question

Homework Assignment

How many photons per second enter my retina from a book page illuminated by a "60 W" LED lightbulb?

Q: What is the true power of the lightbulb?

Box says it is uses only 8 W of power.

Q: What is efficiency of an LED versus an incandescent Edison lightbulb?

LEDs are typically ~50 % efficient, versus 10-15%.

Q: What is energy of a single photon?

Visible light is between 2 and 3 eV.

Q: How many SI units (joules) are in an eV.

1.6×10^{-19} J/eV (charge on the electron)

Q: How many photons/s illuminate the page on a book?

- Q: How far away is the ceiling light?
- Q: What is the area of a page?
- Q: How many photons enter the pupil of my eye?
- Q: What is the diameter of my iris?

Example Fermi Questions

1. How many golf balls will fill a small backpack?
2. What is the volume of $1M in $20 bills?
3. How many cells are there in the human body?
4. What fraction of the area of the United States is covered by automobiles?
5. What is the weight of solid garbage thrown away by Americans every year?
6. **How many gallons of gasoline are used by cars each year in the US?**

Homework Assignment: Make a list of the important estimates you need to make in finding a solution for question 6, starting from the population of the US. You can look up a few numbers, but don't be too precise.

Paper Folding Problem

How many times can you fold a standard piece of paper?

First, let's do the experiment.

How many times did you fold it?

What would be the thickness if folded in half 50 times?

Now, let's find an approximate answer by asking questions.

Q: What is the thickness of a piece paper?

Q: Can you relate the thickness to a know quantity?

Q: How do you deal with exponents?

Paper Folding Problem

- Folding a piece of paper 50 times in half -

A ream of paper has 500 sheets

Ream thickness ~ 2", or 50 mm (1"=25.4 mm)

Sheet thickness is t = 50 mm/500 = 0.1 mm

So, thickness after folding is = $0.1\ mm * 2^{50}$

(Recall that $2^{10} = 1024$ or $2^{10} \sim 10^3$)

Now, folded thickness is = $0.1\ mm * (2^{10})^5$

$= 10^{-4}\ m * 10^{15}$

= 100 Mkm

Distance to the sun (1 AU) = 150 Mkm

Homework Assignment: If folded 50 times in half into an approximate square cross section, what would be the dimension of the cross section?

Does that dimension make sense? What is the size of an atom?

Homework Assignments

List of homework assignments for today

Due: Friday by 6:00 PM

Write down estimations for each step.

1. Find Fermi estimation for photons/s from 60 W LED (slide 17).

2. Find Fermi estimation for the gasoline question (#6, slide 18).

3. What is cross sectional dimension of paper folded 50 times (slide 20). Comment on the dimension.

Advanced Physics Lab

"Take Home" for today

Learning versus **Thinking**

Learning is the ***outcome***
but
Thinking is the ***process***

Learning	**Thinking**
* Left-brain, details, math	* Right-brain, big picture, creative
* Google	* Feynman Technique/Fermi Questions
* Ask someone	* Ask **Yourself**

Thinking takes more practice!

END