WELCOME TO MODERN PHYSICS LAB

http://www-meg.phys.cmu.edu/physics_33340/
MPL MEETING ROOMS

> Every Tuesday at 8:30 AM: Doherty Hall A200

> Every Tuesday and Thursday: Doherty Hall “Sutton” Labs
   at 9:30 AM and 1:30 PM

> Thursday this week and next week (special cases): Wean Hall 7316
   at 9:30 AM and 1:30 PM
I. Give 3 purposes for having laboratory notebooks.

II. \( T = 37.8 \pm 0.5^\circ C \) What does \( \pm 0.5^\circ C \) mean? How should it be determined?

ALSO: \( T_1 = 37.8 \pm 0.5^\circ C \) and \( T_2 = 38.4 \pm 0.1^\circ C \) Do these numbers agree?

III. If I thought that data was described by \( y = f(x) \), how would you plot the data in each case to make it easiest to see by eye whether this is true?

a) \( f(x) = A x^2 \)  
b) \( f(x) = A x^B \), where \( A \) and \( B \) are constants

IV. What is the difference between systematic and random uncertainties? How can you determine each?

V. What makes a technical talk successful? Give 3 important practices which will produce a successful technical talk.

VI. What makes a scientific paper successful? Give 3 important practices which will produce a successful scientific paper.

VII. Does this graph prove the device is ohmic?
$y = 4 \, x^2$

$y = 0.1 \, x^{0.4}$

$y' = \ln(y) = \ln(0.1) + 0.4 \ln(x) = 0.1 + 0.4 \, x'$
Current vs. Voltage

Voltage (V)

Current (A)
SKILLS TO BE LEARNED IN MODERN PHYSICS LAB

By the time you complete this course, you should be able to:

**Physics**

- State the fundamental principles underpinning each of the 3 experiments you do
  - Connect the principles you have learned or will learn in other classes to your MPL experiments

- Explain how the instrumentation in your experiments works and how it reveals the phenomena you are examining

- Recall the one or two most basic physical principles of as many of the other experiments as possible
SKILLS TO BE LEARNED IN MODERN PHYSICS LAB

By the time you complete this course, you should be able to:

Doing experiments

- Keep a notebook that allows another person, skilled in the art of that type of experiment, to reproduce your detailed results

- Use statistics correctly
  - Determine a valid uncertainty on a measured quantity
  - Propagate that uncertainty into an uncertainty in other quantities, by algebraic propagation of errors or least-squares methods

- Draw a conclusion from less than perfect data
  - Express agreement and conclusions in appropriate probabilistic terms
SKILLS TO BE LEARNED IN MODERN PHYSICS LAB

By the time you complete this course, you should be able to:

Communication

- Develop the habit of analyzing the audience and purpose before starting on any communication task

- Give a talk that makes it possible for the audience to learn the major points of the talk

- Write a scientific article that convinces a general physics reader of the conclusions of your scientific work
SKILLS TO BE LEARNED IN MODERN PHYSICS LAB

By the time you complete this course, you should be able to:

**Independence**

- Study a subject on your own until you know it well enough to guide your experimental work

- Know when you do not know something
  - Formulate specific questions
  - Know where to seek out the answers
SKILLS YOU WON’T LEARN IN THIS COURSE

For the Future

- Designing and building up an experiment from scratch
  - You are free to explore, but mostly you are following in the footsteps of “the masters” at this stage of your education
  - Not a “research course”; to get a hint of this, sign up for “Undergraduate Research”

- How to write grant proposals or otherwise get funding for your work
  - Learn from a mentor in a research lab
Welcome to Modern Physics Laboratory. We hope the course will teach you new skills, but we also hope you will have some fun in a relatively informal setting. The syllabus is rather lengthy but READ IT THOROUGHLY; it's all important stuff. It describes the course and gives you some notes on important topics such as keeping lab books and writing scientific articles. The sections in the syllabus are as follows:
OVERVIEW

Modern Physics Laboratory will give you the opportunity to learn about doing experimental physics. By working through experiments chosen from several sub-fields, we hope you will gain experience in some of the techniques of scientific research and learn some new physics along the way. The issue at hand is not to merely mimic old experiments, but rather to have a chance to explore physical phenomena in a laboratory setting, making careful measurements, and drawing your own conclusions about the models and theories which are supposed to describe these phenomena.

COURSE REQUIREMENTS

Each student will perform three experiments, prepare three scientific articles, give one seminar-length talk, and do recitation exercises. During class periods, you will actually make measurements, do data analysis, and discuss your work with the instructors. Background reading, further analysis, and report preparation will be done outside of class hours. By the last lab period of any experiment, all data analysis must be finished and conclusions must be drawn. When class sessions on one experiment are complete, the student immediately begins the next experiment.

Experiments - including set up, measurements, and data analysis - will be worked on by pairs of students. However, each individual is expected to turn in an independently-written lab notebook and article. While you should work on all data analysis and drawing of conclusions with your partner, articles should be written independently.

Given the number of effective lab days in the semester, each experiment will take about 8 sessions. However, the actual end of an experiment will be mutually agreed upon by the student and the instructor. Attendance for two full lab periods each week is required. Sessions must be scheduled to make up all absences. Extra time in the lab may also prove useful. The due date for the third written report is nominally the last day of classes. Oral presentations may be scheduled during finals week in lieu of a final exam.
PROGRESS REPORTS AND BRIEF ORAL REPORTS

During the course of experiments, progress reports are required. Once a week, a short progress report summarizing the past week's work must appear in the lab book. These reports help you take a bird's eye view of your experiment and track your progress.

Twice during the semester, each student will give a 7 minute oral presentation to the class discussing his/her progress or describing a particular aspect of the experiment. These are typical of reports you would make in a professional setting. They will give you practice in important communication skills. These “short” talks will be not be graded, but will give you crucial experience for organizing your “long” seminar-style talk at the end of the semester.

RECITATION

In addition to the laboratory periods, there will be one lecture hour per week on Tuesday at 8:30 AM, in room Doherty Hall A200. We will discuss a number of topics relevant to experimental physics including: keeping lab books, communication techniques, and statistical treatment of experimental data. This part of the course is intended to be very applied and pragmatic. Student participation is REQUIRED. Several pencil-and-paper homework assignments will be made during recitations. There will be a weekly open-book quiz on material from the previous week. Some of the material covered discusses simple procedures to be used in your work. Other material is more complex. Most of the material is not found in the texts, so you must take notes and pay attention in class. You will be expected to incorporate all subject matter covered in these lectures into your reports and lab work, and you will be graded on how well you accomplish this. Failure to incorporate the simple procedural material and turn in all summaries will result in a significant decrease in your grade!
GRADES

- For course
  - 20% 1st experiment
  - 25% 2nd experiment
  - 30% 3rd experiment
  - 15% final oral presentation
  - 10% recitation participation: quizzes, short talks

- Late penalties for missed deadlines on article hand-ins **
  - 0.2 / weekday for 1st 5 days (on a scale of 10)
  - 0.5 / weekday for 2nd 5 days
  - >10 weekdays: averaged as R in final grade
  ** Ask us early enough for extensions and you are likely to get a sympathetic hearing

- Cannot pass the course without:
  - being there for 3 full experiments
  - 3 lab notebooks handed in
  - 3 articles completed
  - final “long” talk given
Modern Physics Lab Grading Standard

Each experiment gets 3 scores, weighted as follows:

1) Doing the experiment & learning the physics  50%
2) Scientific Journal Article  25%
3) Notebook  25%

For items (1) and (2) the scale is:

10  - everything done exceptionally well, carrying all aspects of the work beyond typical expectations, no errors of any significance
9   - everything done very well and at least one thing done beyond typical expectations; no major errors
8   - everything done well; a few small errors but no major errors
7   - everything done well but one thing done not so well (but not terribly)
6   - everything done but one thing done not so well; some other small errors allowed
5   - everything done with some number of errors
4   - some major element missing or incorrect
3   - two or three major elements missing or incorrect
For the Notebook the scale is:

10 - everything done exceptionally well, no errors of any kind
9  - everything done very well; no significant errors
8  - everything done; a few small errors but no major errors
7  - everything done but one thing done not so well (but not terribly)
6  - one major element missing or incorrect
5  - two major elements missing or incorrect
≤4 - three or more major elements missing or incorrect

“Errors” above do not refer to the standardized deductions from the check-off list you will use. These standardized deductions (0.5 per instance) come off your score before the grading above is applied.

Final letter grades will be assigned using the following nominal cut-offs:

9, 10 → “A”
7, 8  → “B”
5, 6  → “C”
3, 4  → “D”
GENERAL COMMENTS
Key points we want to stress throughout the course:

1. **Come to the lab prepared** in advance. Read the handouts and answer the exercise questions contained therein. Study the physical principles behind each.

2. It is equally important to **keep up** with data analysis as the experiment proceeds. Some of this may be done during the lab and some outside of lab. Don't wait until after the experiment is over to start working on the data!

3. Keeping **good lab books** is an essential part of the work. As will be discussed, this means much more than merely taking down tables of numbers.

4. A sophisticated approach to the **comparison of experimental results with theory and/or previous experiments** is also very important. It is not enough to say "they agree" or "they disagree". Rather, valid scientific conclusions are: "they agree well" or "they disagree badly" or something in between. **Make the comparison quantitative**.

5. Conclusions are important. Many students (as well as some professionals) write excellent articles but **shortchange stating** their scientific conclusions. Give them their proper due!

6. The essence of **experimental physics** is to maintain the closest possible contact with the physical phenomena occurring. Observe what's happening. Note carefully what you see and your ideas about those direct observations. Make preliminary graphs or sketches which reflect what you see as closely as possible. Don't let instrumentation and computers take over, preventing your eyes and brain from connecting with the actual experiment.

REQUIRED BOOKS AND BOOKS IN THE LIBRARY
The first book is required, while the second one is very useful but optional.

1) *Data Reduction and Error Analysis for the Physical Sciences*, Philip R. Bevington and D. Keith Robinson, 3rd Edition, (McGraw-Hill, 2003); (A few copies of this book are available to borrow in the lab.)

2) *Experiments in Modern Physics 2nd Ed.*, Adrian C. Melissinos & Jim Napolitano (Academic Press, 2003); (A few copies of this book are available to borrow in the lab.)
MPL EXPERIMENTS

GROUP 1: NUCLEAR AND PARTICLE / COUNTER
COMPTON SCATTERING
NEUTRON ACTIVATION
MUON LIFETIME
MOSSBAUER EFFECT

GROUP 2: ATOMIC/MOLECULAR
ELECTRON SPIN RESONANCE
NUCLEAR MAGNETIC RESONANCE
OPTICAL PUMPING
RAMAN SCATTERING
ZEEMAN EFFECT

GROUP 3: CONDENSED MATTER AND CLASSICAL PHYSICS
CHAOOS
LIGHT SCATTERING
MAGNETIC SUSCEPTIBILITY
X-RAY DIFFRACTION

DO ONE EXPERIMENT FROM EACH GROUP (e.g. not both ESR and NMR)
<table>
<thead>
<tr>
<th>Group</th>
<th>Students</th>
<th>Experiment 1</th>
<th>Experiment 2</th>
<th>Experiment 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Compton</td>
<td>Mag. Suscep.</td>
<td>Zeeman</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Neutron Activ.</td>
<td>Light Scattering</td>
<td>Optical Pumping</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Mössbauer</td>
<td>Chaos</td>
<td>Raman Scattering</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Muon Lifetime</td>
<td>X-Ray Diffract.</td>
<td>NMR or Electron Spin Res.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Optical Pumping</td>
<td>Compton</td>
<td>Light Scattering</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Raman Scattering</td>
<td>Mössbauer</td>
<td>Chaos</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Zeeman</td>
<td>Neutron Activ.</td>
<td>Magnetic Suscep.</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>NMR or Electron Spin Res.</td>
<td>Muon Lifetime</td>
<td>X-Ray Diffract.</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Magnetic Suscep.</td>
<td>Raman Scattering</td>
<td>Mössbauer</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Light Scattering</td>
<td>Zeeman</td>
<td>Compton</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Chaos</td>
<td>NMR or Electron Spin Res.</td>
<td>Muon Lifetime</td>
<td></td>
</tr>
</tbody>
</table>