Physics 3605W, Spring 2019: Modern Physics Laboratory

Syllabus

Instructor: Vlad S. Pribiag
Office: 214 Physics and Nanotechnology Building (PAN)
Email: vpribiag at umn.edu
Office Hours: Mondays 1:30 pm – 2:30 pm (PAN 214 or 216) or by appointment.

Teaching Assistants: Nathan Bosch (bosch088 at umn.edu – sections 002 and 006 and 007), Andrew Evans (evans908 at umn.edu – section 003) and Alex Hamill (hamil483 at umn.edu – sections 004 and 005)

Lecture/workshop: T: 12:20 p.m. to 1:10 p.m., Tate Hall 110

The goals of this course are to introduce students to:

- Quantitative experimentation and the making of measurements.
- The concept of experimental uncertainty and probability
- Keeping a concise, but detailed logbook
- Scientific report writing

General information

The laboratory is located in Room B40 in the Tate Laboratory of Physics. Students will work in groups as assigned on Canvas. The experimental equipment will be assigned to a group for a two-week period, after which it will be reassigned. All data taking must be accomplished within this period. You will carry out five of the available experiments, as assigned by the instructor. **There is no make-up at the end of the semester.**

There will be one classroom meeting per week. Most class meetings will not be used for lectures – lecture material will be posted in video form online. **Assigned video lectures and readings are given in Canvas and must be completed by the specified dates as preparation for class.** Most of the class meetings will be interactive workshops for developing understanding of the concepts and techniques of data analysis techniques. For many of the workshops, you are expected to bring with you a computer with MATLAB installed for carrying out the data analysis exercises. **If you do not have a laptop, please contact the instructor before the second week of class.** You will also be assigned preparatory online homework due before each workshop.

A written guide to the same material is also posted on the course website. **There will be two in-class mid-semester tests** based on the lecture material.

This is a writing-intensive course. You will write two scientific papers during the semester, presenting the results of two of your experiments. The course includes instruction and workshops on writing topics including scientific paper structure and standards as well as the preparation of scientific figures. For each paper, you will submit a draft and participate in a peer-review process with your fellow students. The quality of your drafts and of your participation in the peer-review process are considered part of the grading rubric for each paper. After receiving your graded first paper, you will submit a revised version which addresses the comments from the
grading process. This second version will be graded as well and the score included in the overall writing score.

**Weekly attendance is required. Absences must be discussed with the instructor in advance.**

**Software and texts used in this course**

This course will make use of MATLAB™ linear-algebra software for data analysis and fitting. MATLAB is a commercial product for which all students have access through the college by applying for a CSE Labs account. MATLAB operates on Windows, Mac, and many flavors of Linux.

Obtain CSE Lab account: [https://www.cs.umn.edu/account-management/](https://www.cs.umn.edu/account-management/)

Download MATLAB: [https://www.cs.umn.edu/download_software/matlab](https://www.cs.umn.edu/download_software/matlab)

**Optional recommended book** on measurements and dealing with experimental uncertainties:

“Measurements and their Uncertainties: A practical guide to modern error analysis” 1st Edition by Ifan Hughes (Author), Thomas Hase (Author) Oxford University Press; 1 edition (October 1, 2010)

**Lab logbooks and MATLAB Lab Reports**

All **prelab** work, raw data and as a history of actions taken during the work in the lab are to be recorded in a paper lab notebook. Your TA will review your prelab work before you are allowed to begin each new experiment and will grade you on your record of the lab in your logbook after each lab.

After lab, you will transfer the raw data into MATLAB and carry out data analysis, calculations, and conclusions in the form of a **MATLAB Live Script Lab report**. Examples of lab reports will be posted on the Canvas course website. Each lab report will be due one week after the completion of the lab on Canvas.

The **lab book** must be a bound notebook containing quadrille ruled paper. _Lined logbooks or scraps of paper are not allowed._ You will paste in data, computer generated graphs, etc. when they are taken. You should never tear out pages from your logbook! Whenever you make a mistake (we all do!), just neatly cross out that section of your logbook. Make sure that it is still possible to read whatever is under the cross-out; it is quite common to find out later that what is there is not actually wrong, or includes useful information.

This logbook is very important. It should contain enough information so that, after a period of, say, 6 months, you would be able to completely reconstruct all the steps you took during the experiment. All raw data must be included somehow. For smaller datasets, it is recommended that you write it in your logbook by hand. However, long computer-generated output and fitted graphs can stored in an accessible website (e.g. Google Docs), but must be clearly named and referred to in the logbook at the relevant point. All equipment, settings of instruments, etc., must be included. This does not mean copying what is already in your lab manual, but noting details that are not there, such as voltages or error specs.

The technique of keeping a good lab notebook is a very useful skill to develop. In many companies, such logbooks become the property of the company. Obviously, tidiness and clear writing are essential attributes; it is possible that others may also need to be able to decipher what you’ve done in your experiment.

In your lab report, all axes and tables should be carefully labeled with the correct units; words of explanation should be present wherever necessary, and sources of errors must be noted and estimates of their sizes included. There should be a careful analysis of results with derivations of final uncertainties. It is useful to begin your lab
report by plotting your data as soon as you take it.

This is an important technique to learn; you must be able to identify errant data points as soon as they are taken, not later, after your experiment is finished. An example of such a situation is shown below. It is not very obvious from the table of data that there may be one erroneous data point - often due to a misreading of a scale, or simply a wrong number being written down. (In this case the value of \( y \) for the fifth data point should have been 26.1, not 36.1 cm). In contrast, the problem is immediately apparent from the graph of the data. In other words, a table of your data without an associated graph is insufficient!

Grading

Your final grade will be based on several quantities, weighted as follows:

- Lab (reports (25 pts)/notebooks(5 pts)/prelabs(5pts)) 40% of total score
- 2 Scientific Papers 35%
- Homework Assignments 5%
- 2 in-class exams 20%

You must complete all five labs and both scientific papers in order to pass this course. There are absolutely no exceptions to this requirement. “Incompletes” will be assigned only in cases where serious illness or another documented emergency has prevented you from completing the course requirements. To receive a grade of incomplete, you and the instructor must draw up a signed agreement describing the work to be completed and the time frame for its completion.
<table>
<thead>
<tr>
<th>Week -- Date</th>
<th>Assigned Video Lectures (generally due before class on the indicated week)</th>
<th>Workshop topic</th>
<th>Lab</th>
<th>Assignments (Canvas, due Friday evenings)</th>
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</thead>
<tbody>
<tr>
<td>1. (Jan 21-25)</td>
<td>Keeping a lab notebook</td>
<td>No scheduled lab.</td>
<td>Lab 0</td>
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<td></td>
<td>Working with data in Matlab/Octave</td>
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<td>2. (Jan 28-Feb 1)</td>
<td>(1), (2), (3), (4)</td>
<td>Propagating uncertainties</td>
<td>Conduct first lab</td>
<td>HW1: Uncertainties</td>
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<td>3. (Feb 4 - Feb 8)</td>
<td>(5), (6), (7), (8)</td>
<td>Linear fitting</td>
<td></td>
<td>HW2: Linear fits</td>
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<td>4. (Feb 11-15)</td>
<td>Scientific communication: figures</td>
<td>Sample figures</td>
<td></td>
<td></td>
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<tr>
<td>5. (Feb 18-22)</td>
<td>Poisson and Exponential PDFs, Non-linear fitting</td>
<td>Conduct second lab</td>
<td></td>
<td>HW3: More fits</td>
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<td>6. (Feb 25-Mar 1)</td>
<td>Scientific communication: structure of a paper</td>
<td>First paper scaffold</td>
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<td>7. (Mar 4-8)</td>
<td>Scientific communication: style of a paper</td>
<td>First paper draft</td>
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<td>8. (Mar 11-15)</td>
<td>Peer review of first paper</td>
<td>[None]</td>
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<td>First paper</td>
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<td>9. (Mar 18-22)</td>
<td>Spring Break (no class/lab/homework)</td>
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<td>10. (Mar 25-29)</td>
<td>First quiz</td>
<td>Conduct fourth lab</td>
<td>[None]</td>
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<td>11. (Apr 1-5)</td>
<td>Data analysis challenges</td>
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<td>12. (Apr 8-12)</td>
<td>Hypothesis-testing with Probability Density Functions</td>
<td>Conduct fifth lab</td>
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<td>HW4: Hypothesis tests</td>
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<td>13. (Apr 15-19)</td>
<td>Monte Carlo techniques and the Gaussian distribution</td>
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<td>Second paper scaffold</td>
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<td>14. (Apr 22-26)</td>
<td>Second quiz</td>
<td>[No lab]</td>
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<td>Second paper draft</td>
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<td>15. (Apr 29-May 3)</td>
<td>Peer review of second paper draft</td>
<td>[No lab]</td>
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<td>Second paper (Due May 6th)</td>
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<td>16. (May 6-10)</td>
<td>[No Class]</td>
<td>[No lab]</td>
<td>[None]</td>
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Video Lectures
1. Introduction to experimental data analysis
2. Significant figures and scientific notation
3. Making multiple measurements of a single quantity: histograms, mean, median, mode, and variance
4. Calculating a quantity from different measurements: propagation of uncertainties
5. Optimal combination of multiple measurements: the weighted mean
6. A controlled experiment: varying a control parameter to measure a quantity
7. Linear fitting
8. Interpreting the results of a fit: chi² analysis and outliers
9. Walking the chi² (χ²) surface
10. Non-linear fitting
11. Probability distributions: Poisson and Exponential
12. Probability distributions: The Gaussian and the Central Limit Theorem
13. Hypothesis testing
14. Monte Carlo Techniques
15. Introduction to experimental data analysis

Laboratory topics
Each student will complete 6 experiments from among the list below, as assigned by the instructor.

- Bandgap and Hall effect in Germanium
- Black-body radiation
- Charge-to-mass ratio of the electron
- Compton scattering
- Helium excitation
- Millikan oil-drop experiment
- Photoelectric effect
- Photon counting statistics
- Precision spectroscopy
- Radioactive decay and statistics
- X-ray diffraction
- Zeeman effect
Statement on Academic Honesty
The University has a clear policy on student conduct, including cheating and plagiarism. You can find the guidelines at http://www.oscai.umn.edu/conduct/student/index.html

Here is a specific interpretation for this course:

1. All data reported in your lab book and the Scientific Paper must be your own. They must be taken by you in the 3605 laboratory. In particular, if you miss a lab period, you must come in to take your own data. Under no circumstances can you use data obtained by someone else. Sharing data in violation of this policy will be considered academic misconduct by both parties. The minimum penalty will be an automatic F in this course.

While it is understood that you are working with a lab partner, you may only use data taken in your presence. That common data taken by both of you can certainly be shared and a memory stick is sometimes a useful mechanism to allow both of you to do your own analysis on the same data later on.

2. Fabrication refers to the wholesale creation of data. For example, if you believe that $y$ depends quadratically on $x$ and create a set of points obeying that relation and then claim those points are experimental data, you would be guilty of data fabrication. This is the most heinous crime that one can commit as an experimentalist. The minimum penalty will be an automatic F in this course.

Data manipulation refers to the use of systematic bias in data taking or analysis to obtain a desired result. This can range from outright dishonesty (eliminating all data points that don’t fit your favorite theory) to more subtle cases in which the bias may not be readily apparent. We will discuss this issue in class.

3. All written work must be your own. Each of you will have your own lab-book, carry out your own analysis, and prepare your own papers. Using text or figures prepared by others in a lab-book or written paper without appropriate citation is plagiarism, for which the minimum penalty will be an F in this course. Some collaboration on analysis is expected and encouraged, as long as it is bilateral.

4. You will be consulting external sources, such as textbooks, reference books, journal articles, and web-sites. All external sources, including web sites, must be cited in your lab-book and paper.
DEPARTMENTAL POLICIES

ATHLETES must provide their official University of Minnesota athletic letter containing the approved competition schedule to their instructor and the staff in Tate 130. Away exams will be arranged with the athletic adviser traveling with the team. Accommodations will be made for official university sports only (i.e. no accommodations will be made for intramurals, club sports, etc.)

DISABILITY SERVICES: If you have accommodations for this course, please provide the staff in Tate 130 with a copy of your accommodation letter for the current semester. Exams will be arranged according to accommodations and sent to the testing center for administration.

MANDATORY POLICY INFORMATION [REFERENCES/LINKS VERSION FOLLOWS]

- Student conduct code
- Scholastic Dishonesty
  See student conduct code
- Disability Accommodations
  http://ds.umn.edu/student-services.html
- Use of Personal Electronic Devices in the Classroom
  http://www.policy.umn.edu/Education/STUDENTRESP.html
- Appropriate Student Use of Class Notes and Course Materials
  http://www.policy.umn.edu/Education/studentresp.html
- Makeup Work for Legitimate Absences
  http://policy.umn.edu/Policies/Education/Education/MAKEUPWORK.html
- Grading and Transcripts
  http://policy.umn.edu/Policies/Education/Education/GRADINGTRANSCRIPTS.html
- Sexual Harassment
  http://regents.umn.edu/sites/default/files/policies/SexHarassment.pdf
- Equity, Diversity, Equal Opportunity, and Affirmative Action
  http://regents.umn.edu/sites/default/files/policies/Equity_Diversity_EO_AA.pdf
- Mental Health and Stress Management
  http://www.mentalhealth.umn.edu

MANDATORY POLICY INFORMATION [FULL TEXT VERSION FOLLOWS]

Student Conduct Code
The University seeks an environment that promotes academic achievement and integrity, that is protective of free
inquiry, and that serves the educational mission of the University. Similarly, the University seeks a community that is free from violence, threats, and intimidation; that is respectful of the rights, opportunities, and welfare of students, faculty, staff, and guests of the University; and that does not threaten the physical or mental health or safety of members of the University community.

As a student at the University you are expected adhere to Board of Regents Policy: Student Conduct Code. To review the Student Conduct Code, please see: http://regents.umn.edu/sites/default/files/policies/Student_Conduct_Code.pdf.

Note that the conduct code specifically addresses disruptive classroom conduct, which means "engaging in behavior that substantially or repeatedly interrupts either the instructor's ability to teach or student learning. The classroom extends to any setting where a student is engaged in work toward academic credit or satisfaction of program-based requirements or related activities."

Disability Accommodations

The University of Minnesota is committed to providing equitable access to learning opportunities for all students. Disability Services (DS) is the campus office that collaborates with students who have disabilities to provide and/or arrange reasonable accommodations.

If you have, or think you may have, a disability (e.g., mental health, attentional, learning, chronic health, sensory, or physical), please contact DS at 612-626-1333 to arrange a confidential discussion regarding equitable access and reasonable accommodations.

If you are registered with DS and have a current letter requesting reasonable accommodations, please contact your instructor as early in the semester as possible to discuss how the accommodations will be applied in the course.

For more information, please see the DS website, https://diversity.umn.edu/disability/.

Use of Personal Electronic Devices in the Classroom

Using personal electronic devices in the classroom setting can hinder instruction and learning, not only for the student using the device but also for other students in the class. To this end, the University establishes the right of each faculty member to determine if and how personal electronic devices are allowed to be used in the classroom. For complete information, please reference: http://policy.umn.edu/Education/STUDENTRESP.html.

Makeup Work for Legitimate Absences

Students will not be penalized for absence during the semester due to unavoidable or legitimate circumstances. Such circumstances include verified illness, participation in intercollegiate athletic events, subpoenas, jury duty, military service, bereavement, and religious observances. Such circumstances do not include voting in local, state, or national elections. For complete information, please see: http://policy.umn.edu/Policies/Education/Education/MAKEUPWORK.html.

Appropriate Student Use of Class Notes and Course Materials

Taking notes is a means of recording information but more importantly of personally absorbing and integrating the educational experience. However, broadly disseminating class notes beyond the classroom community or
accepting compensation for taking and distributing classroom notes undermines instructor interests in their intellectual work product while not substantially furthering instructor and student interests in effective learning. Such actions violate shared norms and standards of the academic community. For additional information, please see:


**Grading and Transcripts**

The University utilizes plus and minus grading on a 4.000 cumulative grade point scale in accordance with the following:

- **A** 4.000 - Represents achievement that is outstanding relative to the level necessary to meet course requirements
- **A-** 3.667
- **B+** 3.333
- **B** 3.000 - Represents achievement that is significantly above the level necessary to meet course requirements
- **B-** 2.667
- **C+** 2.333
- **C** 2.000 - Represents achievement that meets the course requirements in every respect
- **C-** 1.667
- **D+** 1.333
- **1.000** - Represents achievement that is worthy of credit even though it fails to meet fully the course requirements
- **D**

For additional information, please refer to:
http://policy.umn.edu/Policies/Education/Education/GRADINGTRANSCRIPTS.html.

**Sexual Harassment**

"Sexual harassment" means unwelcome sexual advances, requests for sexual favors, and/or other verbal or physical conduct of a sexual nature. Such conduct has the purpose or effect of unreasonably interfering with an individual's work or academic performance or creating an intimidating, hostile, or offensive working or academic environment in any University activity or program. Such behavior is not acceptable in the University setting. For additional information, please consult Board of Regents Policy:
http://regents.umn.edu/sites/default/files/policies/SexHarassment.pdf

**Equity, Diversity, Equal Opportunity, and Affirmative Action**

The University provides equal access to and opportunity in its programs and facilities, without regard to race, color, creed, religion, national origin, gender, age, marital status, disability, public assistance status, veteran

Mental Health and Stress Management

As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance and may reduce your ability to participate in daily activities. University of Minnesota services are available to assist you. You can learn more about the broad range of confidential mental health services available on campus via the Student Mental Health Website: http://www.mentalhealth.umn.edu.