# Physics 442/842 Advanced Experimental Physics II Spring 2023

***Meeting Time***

Lecture: Monday 1130-1220, JH 247 (Lecture); Laboratory: Monday 1330-1630 (Section 152) or Tuesday 1230-1530 (Section 151), JH 233.

***Instructor***

Timothy Gay, JH 073, 402-770-6437, tgay1@unl.edu. TJG office Hours: 24/7; appointments recommended.

***Teaching Assistant***

Nathan Ray, JH 244H, nathan.ray@huskers.unl.edu

***Prerequisites***

Physics 441

***Course Objectives***

This course is an extension of PHY 441, with an added emphasis on independent work on topics that will be explored in greater depth and more detail. Nonetheless, the course objectives are essentially the same as those in PHY 441, namely, that the student 1) develops skills and practices needed for work in experimental physics, 2) gains a deeper understanding of what is involved in making measurements, 3) develops written and oral communication skills for the presentation of scientific work, and, 4) gets hands-on experience with phenomena and principles of physics through laboratory work. The course will comprise two labs: a short project to review and improve error analysis skills, and a long project focusing on in-depth work in a single topic.

***Useful Reference texts (listed in Order of Usefulness, most first)***

Bevington and Robinson, *Data Reduction and Error Analysis for the Physical Sciences*
Moore, Davis, and Coplan, *Building Scientific Apparatus*
Monk, *Light: Principles and Experiments*
Young, *Statistical Treatment of Experimental Data*
Walter Fox Smith (ed.), *Experimental Physics*
Melissinos, *Experiments in Modern Physics*
Scherz and Monk, *Practical Electronics for Inventors*
Essink, *Labview*
*The CRC Handbook of Chemistry and Physics*
Saleh and Teich, *Fundamentals of Photonics* (2nd ed.)
Rosebury, *Handbook of Electron Tube and Vacuum Techniques*

There are also many useful texts and manuals in the lab room; these must remain there, except for the copying of brief excerpts.

***Format***

There is one in-person lecture each week for the instructor to present and discuss experimental techniques, procedures, and background information for the experiments, and, for the students to present talks. There are two scheduled three-hour laboratory sessions (each associated with a Section Number) that are held on the Monday and Tuesday of each week. Each student is assigned to a section, and will normally work in the lab on the day associated with their section. However, more hours in the lab can be scheduled in consultation with Prof. Gay or Messrs. Ray or Saw. The course will comprise two labs: a short project to review and improve error analysis skills, and a long project focusing on in-depth work in a single topic. The long project will require 13 weeks to complete, and will require significantly more in-depth understanding and analysis than did the typical 441 experiment.

The short project will be the measurement of the period of a quasi-simple pendulum. It will require careful analysis using a variety of graphical and error propagation techniques. The available long projects are:

*Hall Effect*
*Vacuum System Experiments*
*Compton Scattering from Magnetized Samples*
*Vortex Light*
*Ellipsometry*
*Steady State Orbits in a Quadrupole Trap*
*Microwave Optics*
*Atomic Spectroscopy and the Isotope Shift*
*Experiments with the Torsional Oscillator*
*The Faraday Effect with Optical Fibers and Lock-In Techniques*
*Optical Monitoring of Piezoelectricity*
*Acoustical Analogs of Quantum Mechanics*

If you worked on a simpler version of these labs in PHY441, you may not choose the long version for your project. For the first lab, you can pick your own partner, but people who were partners in 441 cannot be partners in 442. You can switch partners after the first lab if you wish but, again, you may not choose your old 441 partner.

***Grading: Overview***

In addition to the mandatory first lab on the measurement of the period of a pendulum, students are required to complete a long format project. Written reports are due at 11:59 pm on the days indicated on the accompanying schedule. Students are encouraged to give Prof. Gay first drafts of their reports so that they

can receive constructive criticism before the final report is handed in; the turnaround time for Prof. Gay to provide such feedback is 24 hours. You should not expect this first feedback to be extremely detailed, but it will point out the most apparent qualitative problems the report draft has.

The long project will comprise several parts: a written theoretical analysis of the project exactly 5 pages long, a written progress report at least 5 pages in length, a 10-minute oral presentation given by lab partner "A" discussing the experiment's theory, a 10-minute oral progress reports given by lab partner "A", a final 20-minute oral report given by lab partner "B", and a final written report of 20 – 40 pages in length. You are encouraged to give a "practice talk" to Prof. Gay or Messrs. Ray or Saw several days before your presentation is scheduled. ***All grades given to the components of the long project (e.g. the second oral progress report) will be awarded to both lab partners.***

Points (out of 1000 possible) will be assigned as indicated in the table below. *T**he instructor's expectations are high. Given that each student has a partner and that only four written reports are required for the course, these reports should be detailed and well-thought-out. They should be informative and well-written. Neatness counts.*** See also the discussion below and the Lab Report documents on Canvas.

For late reports, grades will be reduced as follows. For each day that the lab is late, the final grade will be lowered by one-third of a letter grade. For example, if the first lab report is turned in at 0053 h according to its email timestamp on the Tuesday morning after the Sunday it is due, and it receives a grade of B+ (3.33) based on merit, the actual grade given will be a B- (2.67). If the final lab report is late, it will receive no credit.

| **Activity** | **Possible Points** |
|---|---|
| Pendulum/Error Lab Report | 220 |
| Written Theory Paper | 125 |
| Oral Theory Presentation | 60 |
| Written Progress Report | 125 |
| Oral Progress Report | 50 |
| Final Oral Report | 120 |
| Final Written Report | 300 |

*Lab Reports*

The written lab reports, the written progress report, and the written theory paper will be the primary output of your work. Both lab partners will collaborate on these reports and hand in one report; they will thus get the same grade for a given experiment. See the accompanying Canvas documents for more details on what these reports should include. The pendulum lab report should be about 10-12 pages long, including figures (all clearly labeled with captions!), tables, and references. The final lab report should be between 20 and 40 pages in length. Neatness and clarity of presentation count (a lot). Typos will lower your grade. The use of good English is mandatory. Your reports should begin with an appropriate title and by-lines. There should then be an introduction with a discussion of the relevant physics, and a specification of the goals of your work. For the lab and progress reports, following the introduction, there should be sections on the experimental apparatus you used, the data you obtained, the data analysis, and the conclusions you reached. Since you will be writing a separate paper on the theory of the experiment, you needn't say much about the theory, except when it is needed to explain specific measurements. Schematic apparatus diagrams including electrical and/or vacuum schematics should generally be included, and, where appropriate, tables of raw data (the latter possibly in an Appendix). One or more photographs of the apparatus, properly labelled, can be very helpful to the reader. It is always good to err on the side of including too many figures rather than too few. A general thought to keep in mind as you write the report is "What should I put in this report that will allow a person reading it to substantially replicate what we did?"

The theory paper should be exactly 5 pages in length, and should discuss clearly the basic physics underlying the phenomena being studied, and/or the reasons for measuring specifics quantities you are measuring.

*Lab Notebooks and Good Experimental Practice*

You should use a bound laboratory notebook to record all data taken in the laboratory. One notebook will suffice for a given experiment. ***All handwriting in the notebook should be in ink. Do not record data on loose paper and copy it into your notebook later!*** To this end, it is best to have a notebook with "graph paper" pages, which will make it easier to draw plots and make tables. A printer is available in the lab if you wish to make plots on a computer and paste them into your notebook.

***It is also best to perform your preliminary data analysis and to make some rough plots in this notebook while you are taking your data.*** This practice

(which should become a habit!) will allow you to see if the incoming data make sense. If they don't, you can adjust your experimental plan accordingly. Plotting data ***by hand*** as you go also gives you a better sense of the relationships between various experimental parameters, and will facilitate decisions you need to make about what to measure next. Generally speaking, it is best to first determine the range of experimental parameters you wish to explore, and to make measurements on a "course grid" first before searching for possible, more detailed features.

***Talks***

The theory and progress report talks should be 10-12 minutes long. This means that you should prepare 10 – 11 PowerPoint slides for each talk. The final report talk will be 20 minutes long, corresponding to about 15 – 18 slides. All talks will be in person. Practice your talk several times, so that you won't go over time. Give one of these practice talks to Prof. Gay or Messrs. Ray or Saw. For the progress and final lab reports, your talk should have a title slide, followed by one or two slides on the physics of the experiment, then one or two slides about the apparatus you used. It never hurts to discuss one or two problems you encountered in taking the data, and ways that you solved these problems. Make sure that it's clear to your audience the methods you used to take your data. Show a sample of the data, and perhaps an example of any calculations you did to analyze these data. The results, attendant error analysis, and conclusions come last. The theory talk should present clearly the underlying theory for the phenomena you are studying. In this talk, brief derivations from first principles to justify the equations describing these phenomena are appropriate.

Evaluations and grades for your talk(s) will be given by Prof. Gay and Messrs. Ray and Saw. Grading will be based on the answers to the following.

*Did the student give a polished presentation?*
*Did they speak clearly and audibly?*
*Were the slides neat and informative and not too "crowded"?*
*Did they contain appropriate illustrations, pictures, and/or drawings?*
*Were text portions of the slides readable?*
*Were the basic physics principles of the experiment and the motivation for doing it clearly discussed?*
*Were the results clearly indicated in tabular or graphical form?*
*Was error analysis and propagation handled properly and presented appropriately?*
*Did the result obtained agree with accepted physical principles or values?*

*Were any obvious problems with the results discussed and/or explained adequately? Was the student able to answer questions put to them by the other students and/or the instructors?*
*In the case of the progress reports, had adequate progress been made in the experiment?*
*In the case of the theory talks, was the theoretical development from first principles well laid out? Did the speaker give a clear explanation for why the relevant phenomena occur?*

The final grade for the talk will be the average of the grades given by the instructor and the TAs.

## ADDITIONAL INFORMATION

### *Academic Integrity*

Refer to the Student Code of Conduct and Academic Integrity, which can be found at http://stuafs.unl.edu/ja/code/. The first violation of the code will result in at least a failing grade for the assignment and notification of university officials. Further action may be taken. Subsequent violations will result in failure for the course, along with notification of university officials. To avoid situations of cheating, plagiarism or academic dishonesty, contact the instructor in advance if a course-related issue is unclear.

### *Students with Disabilities*

Students with disabilities are encouraged to contact the instructor for a confidential discussion of their individual needs for academic accommodation. It is the policy of the University of Nebraska-Lincoln to provide flexible and individualized accommodation to students with documented disabilities that may affect their ability to fully participate in course activities or to meet course requirements. To receive accommodation services, students must be registered with the Services for Students with Disabilities (SSD) office, 132 Canfield Administration, 472-3787 voice or TTY.

### ACE Certification for PHYS 441 and 442

(i) the ACE Outcome(s) for which the course is certified

Student Learning Objective 10: Generate a creative or scholarly product that requires broad knowledge, appropriate technical proficiency, information collection, synthesis, interpretation, presentation, and reflection.

(ii) the opportunities the course will give students to acquire the knowledge or skills necessary to achieve the Learning Outcome(s)

The students are required to plan, execute, analyze, and report on a series of laboratory experiments that illustrate both key principles of physics and the practice of laboratory research. The creative scholarly product is the complete process from planning through reporting and is evaluated as such by the instructor(s). This process teaches the following skills. 1) Develop skills and practices needed for work in experimental physics. 2) Gain some understanding of what is involved in making measurements. 3) Develop written and oral communication skills for the presentation of scientific work. 4) Provide hands-on experience with phenomena and principles of physics through laboratory work. The process requires the development and application of broad knowledge and information collection in both the planning and reporting activities, development and demonstration of appropriate technical proficiency in the execution, and finally, interpretation, synthesis, and reflection in the analysis and reporting of results.

(iii) the graded assignments which the instructor(s) will use to assess the student' achievement of the Outcome(s)

Student achievement will be assessed from the quality of the student's preparation for and conduct of the laboratory work, four written experiment reports, and an oral presentation on one of the experiments. The students will receive timely written and or oral feedback on each graded component.

For even more information, see http://go.unl.edu/coursepolicies regarding university-wide course policies and resources.