

# Intermediate Physics Laboratory

PHYS 3304 Spring 2013

Draft Version 0

Rooms 1 and 32, Science Building

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**Office Hours:** Tue-Thu 2:00-5:00 PM or by appointment, SC039.

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**Office Hours:** Tue-Thu 2:00-5:00 PM or by appointment.

**Course Textbook:** I have prepared a draft of a book (*Notes*) for this course and we will use it to guide our work. There will be updates and correction to these notes as we go along. There are several reference books we will also make use of for this course.

1. John R. Taylor, *An Introduction to Error Analysis*, Ed. 2, University Science Books, 1997.
2. Leo, W. R., *Techniques for Nuclear and Particle Physics Experiments*, Springer-Verlag, 1987.
3. Lyons, Louis, *Statistics for Nuclear and Particle Physicists*, Cambridge University Press, 1992.
4. Melissinos, A. *Experiments in Modern Physics*, Academic Press, Second Edition, 2003.

**Topics covered:** All experiments will draw upon your knowledge gained in lecture courses and some will require learning anew. The first order of business is to complete the online lab safety training and the installation of MATLAB on your laptop. In *Notes*, there is a discussion of each topic and a set of questions that follow each experiment. You must perform the experiments and answer these questions in your logbook. We also have an electronic eelog (<http://pollux.phys.ttu.edu>). This eelog is our central documentation repository.

## Goals:

This course is a hands-on survey of modern physics. Some of the goals are:

- To allow you to reproduce and understand the experimental results that are the underpinnings of modern physics.
- To familiarize you with experimental techniques employed in research and industrial laboratories.
- To provide you with an opportunity to develop critical writing skills and effectively present your scientific work to a larger audience.
- To give you an experimental survey of modern physics.

- To expose you to the realities of the laboratory experience, where things don't always work, where the issues are not always clear, and where progress depends on perseverance and ingenuity.
- To learn and appreciate the ethical and social issues that are involved in scientific research. These include the handling of proprietary information, respect for colleagues and adherence to high standards of honesty in reporting scientific results.

You should be prepared for a fundamental difference in difficulty and philosophy in this course compared to what you may have experienced before. This is going to be a "problem solving" experience and not a "cook-book" laboratory. You may have to teach yourself how to calibrate and use different kinds of test equipment. You may have to search for weak signals in the presence of noise. You may have to use statistical techniques to extract results from poor data sets. Your success with the experiments, and with the course, will depend on the dedication and initiative that you apply to solving problems. This is simply a part of the reality and joy of experimental science.

### Requirements:

1. **Logbook:** Each student will record his/her work in a logbook. All work, description of equipment, measurements, calculations, analyses, plots, *etc.* will be contained here (including the answers to questions at the end of each experiment). The instructors will check your logbook every two weeks when you rotate to new experiments.

Keeping a detailed laboratory logbook is an essential part of experimental physics. Students taking PHYS3304 are expected to record their laboratory procedures and observations during the course of their experiments. What goes into a useful laboratory log? The answer is basically everything. Write down, in an informal 1st-person narrative style, what you did step-by-step, include sketches of the apparatus, wiring diagrams, *etc.*, note the relevant experimental conditions and record any unusual events that might affect the experimental data, like someone accidentally turning on a light when your experiment was supposed to be done in a darkened room.

The following are some guidelines on how to write an effective log of your experiments:

- Always try to write the log as you are doing the experiment, not in the evening after you leave the lab. The purpose of such a log is to help you, the experimenter, to recall at a later date exactly how the experiment was performed, what the precise experimental conditions were, and to note any unusual events that might impact the analysis of the experimental data. Its value is in the details.
- Experimental data and observations are recorded in the log and should be accompanied by sufficiently detailed notes so that you could reproduce the data, if so required. You can never write too much in the lab book. Also note that you should never erase or remove pages. Mistakes in the lab book should have a single line or "X" through them.
- If you are taking data by hand (rather than using a computer data acquisition interface), record your data in the log book, making sure to clearly label the different columns of data with the quantity that is being measured, including the units of measurement.
- It is a good idea to make some rough plots or charts of the data as you are recording them, or immediately after, to help you decide if the data are valid and to detect problems with the apparatus. The square grid pattern on which all good logbooks are printed is useful for this

purpose. These rough plots are also useful in deciding if you need to take data at finer intervals so as not to miss some important behavior. It is also a good idea to do a rough, order of magnitude, calculation of the results at this point to check if everything is going as expected. If not, at least you won't have wasted the whole afternoon because of some artifact you haven't taken care of.

Professional scientists and engineers routinely maintain detailed log books of their experiments. In industry, these records are used as legal documents to substantiate claims of original discoveries and subsequent patent rights. In the research lab, many a Nobel Prize has been won based on unexpected findings that were first recorded in a log book as an odd- ball observation and later found to be important. The results in this class probably won't get you a trip to Stockholm, but we are going to get you into the habit of keeping a good experimental logbook so you will be ready when that "eureka" moment arrives.

2. **Attendance:** Attendance is required for the weekly meeting on Wednesdays. You will need to work in the lab outside class hours. Labs will be open from 8 AM to 5 PM during the week. Keys to the labs (Rooms 1 and 32 in Science Building) will be available in the main office.
3. **Final Grade:** 60% will be based on the grading of your logbook. The remaining 40% will be based on two papers which includes detailed analyses of a particular experiment, chosen in consultation with the instructor. The first paper will be based on one of the (three) experiments you already have done in the first half of the semester (15%). The second paper is similarly based on one of the experiments from the second half of the semester (25%). This will be written as a formal scientific paper (APS RevTeX format). The final grading metric is 100-85:A, 85-70:B, 70-55:C, 55-40:D and 40-0:F.

The first paper draft is due on March 20, 2013. You will get comments on the paper in a few days and you will submit the final version of the first paper by March 31, 2013. The first draft of the second paper is due by April 24, 2013, and the final version is due by May 5, 2013. Here are the ingredients of a paper:

- (a) The paper should have a title and a concisely written abstract. The abstract is not a summary but a short paragraph that highlights the important results. You should make an effort to write the abstract such that the reader should be able to understand the abstract in a few seconds. Normally, if the reader finds the result interesting, he/she will read the rest of the paper.
- (b) Make sure the paper is written grammatically correctly abiding by the common rules of capitalization and punctuation. Make sure English is good. Communicating your results in the best possible way is part of good science.
- (c) The paper format is given by the RevTeX style file and you already have an example.
- (d) The first part of the paper should have a brief introduction of the concept(s) with appropriate diagrams and equations, if needed.
- (e) The majority of the paper must contain your analysis of data and the results you draw from them. What do your data mean? What important physics results they prove? What are the statistical and systematic errors associated with your data? Discuss the significance of errors.
- (f) Include a section where you expand on possible extensions of the experiment. In what ways can we improve and extend the experiment such that we can explore new ideas? Perhaps we

can test a new theory, perhaps a different way of performing the measurements will improve precision. How much more physics can we extract from this set up?

- (g) Include plots and tables. Make sure you have clearly written captions. Do not repeat the caption in the text. Be economical. Be precise.
- (h) Make sure your plots represent the data and the results as best as possible. Think about the message you want the figure to convey. Include legends with units. Use color and different types of markers if they help to communicate information better.
- (i) Write a “Conclusion” section where you summarize the main results and discuss the significance of what you wish to communicate.
- (j) Always include properly cited “References” at the end.

The University Writing Center offers 30-minute tutorials to help you write better. You need to make an appointment in advance (<http://uwc.ttu.edu/>). I suggest you use this service to improve your writing and communication skills. I strongly recommend it.

**Outcome and Assessment:** Understanding of modern physics phenomena at a deeper level by conducting experiments; appreciating the tasks of an experimental scientist where the issues range from designing an experiment and making sense of the results; proficiency in error analyses; understanding of basic principles of an experiment from which a proposal for a Senior Thesis can be developed; solid grasp of experimental instrumentation and analyses tools (use of oscilloscopes, data acquisition cards, LabView, MatLAB, *etc.*).

Assessment is achieved by discussions of theory and measurements with students throughout the semester in meeting periods on Wednesdays, review of students’ logbooks, and discussions of students’ presentations.

## PHYS 3304 Outcome and Assessment

Outcome	Assessed by
Understanding of physics concept	Discussion of theory before lab work
Grasp of experimental methods	Review of papers and texts on topic Discussion of experiment at weekly meetings Review of logbook
Principle design criteria of experiments	Discussion of project and plan Discussion of instrumentation Review of logbook
Error analyses	Discussion of mathematical techniques Working together on computer and discussing results Review of logbook

**Disability:** Any student who, because of a disabling condition, may require some special arrangements in order to meet the course requirements, should contact the instructor as soon as possible, so that the necessary accommodations can be made. Proper documentation must be presented from the Dean of Students’ Office.

# PHYS 3304 Schedule

Table 1: Spring 2013 Experiment schedule. Each group/person is labeled by a capital letter. The first group (ABCD) will finish the Steam Engine project by March 1st. The second group (EF) will be finished by April 19th. The Observatory experiment is scheduled for the night of Monday, March 4. The backup date is Thursday, March 7.

Date	Blackbody	Double Slit	Zeeman	Microwave	Semiconductor	Optical Pumping	Steam Engine
1/16 to 2/1	A	B	C	D	E	F	ABCD
2/1 to 2/15	F	A	B	C	D	E	ABCD
2/15 to 3/1	E	F	A	B	C	D	ABCD
3/1 to 3/22 Observatory	→	→	→	→	→	→	EF
3/22 to 4/5	D	E	F	A	B	C	EF
4/5 to 4/19	C	D	E	F	A	B	EF
4/19 to 5/3	B	C	D	E	F	A	

Table 2: Spring 2013 paper schedule.

	Date
1st paper 1st draft	March 20
1st paper Final	March 31
2nd paper 1st draft	April 24
2nd paper Final	May 5