

The Physics 211–212 Laboratory

The laboratory portion of PHYS 211-212 consists of one 3-hour lab per week. You will perform a different experiment each week according to the schedule available on the PHYS 211 Lab Info website. For each laboratory, be sure to bring your lab notebook (spiral bound, quad-ruled), a writing utensil, and a scientific calculator, all of which may be purchased at the Bookstore.

Attendance

Attendance at each of the lab sessions is mandatory. Make-up permits will be issued only in case of family emergency, accident, illness, or some other uncontrollable, legitimate circumstance. With the large number of students taking PHYS 211-212, it is impossible to handle exceptions, so please do not ask. If you must miss a lab for a legitimate reason, you should, if possible, obtain the make-up permit from your lab instructor **before** the lab period. If your lab conflicts with your sports activity (either practice or a scheduled game), you should register for another lab section. If you miss a lab, you **must** contact your lab instructor **immediately**. If you cannot reach your lab instructor, contact Cheslee Hibler (ch058@bucknell.edu).

If you feel ill (i.e., have a fever or respiratory symptoms), you should NOT come to lab. In this case, you must email your lab instructor BEFORE your lab section begins to explain your circumstance. This will be considered an excused absence. If you email your instructor after your lab section ends that day, the absence will not be excused.

Any lab left unfinished by the end of the semester will receive 0 points.

Goals of the Laboratory

Physics is an experimental science. The only reason we really ‘know’ anything about the world around us is by making observations and measurements. It is only when these measurements corroborate physical theories that we say we ‘understand’ and that the theories are accurate. In the laboratory portion of this course, you will certainly be applying the ideas you develop in the lecture part of this course. But more importantly, the goal of the laboratory is to learn how to be a good

experimentalist: (1) how to make careful observations, (2) how to interpret the data of your observations, and (3) how to make an accurate and clear record of your observations and conclusions. (A more exhaustive list of goals for the laboratory is given below.) To maintain a clear record of your work, you will record your work in a laboratory notebook.

Laboratory Experiment Instructions

We expect each experiment, including the write-up in your lab notebook, to require no more than 3 hours. It is important to read the laboratory instructions for the lab you will be doing *before coming to lab*. Each lab will be available as a PDF file on the PHYS 211 Lab Info page the week before the next lab for you to access. The instructions will tell you what the experiment is about and give you a general idea of what to do. They are not like a “cookbook”; we want to leave room for your own cleverness, ingenuity, and even blunders!

Continuing Objectives

We have identified ten essential skills and abilities that we would like you to develop throughout the course. Several of the following recurring objectives are listed at the beginning of each experiment, together with certain objectives specific to individual labs.

1. Be able to identify sources of experimental uncertainty in a measurement.
2. Know how to determine experimental uncertainties (multiple measurements of the same quantity, propagation of errors, etc.).
3. Be able to write an experimental result (including correct number of significant digits, uncertainty, units).
4. Be able to make careful measurements to ensure reproducible results.
5. Know how to keep a clear and organized record, including an introduction (with purpose of lab and appropriate laws or equations), apparatus sketch, table of raw data and calculated quantities, and a good conclusion or summary.
6. Be able to make a good graph either in your notebook or with a computer (label, scales, units, dependent, and independent variables).
7. Know how to make comparisons: are two measured quantities equal? Is a measured quantity statistically equivalent to a theoretical value?
8. Use a computer to collect and analyze data.

9. Use a computer to simulate physical systems using numerical methods.
10. Be able to work with physical vector quantities.

The Importance of the Laboratory Notebook

Of all the materials you bring to lab, the laboratory notebook is the most important. An essential part of experimental physics is learning how to keep a clear and accurate record of all your activities in the laboratory. If you go on in any field of research in the physical sciences, engineering, or medicine, you will be expected to maintain thorough and accurate lab notes. Issues of patent rights have been settled in court based on entries in laboratory notebooks!

Therefore you will be required to keep a good lab notebook with the following requirements:

- All entries should be made in permanent ink.
- All pages in the lab notebook will be numbered and **no pages are to be torn out.**
- The entries you make for each laboratory exercise will follow the ‘**Core Elements**’ given below.

Keeping a good lab notebook will benefit you throughout the semester as labs will often rely on information learned in earlier labs. A good lab notebook will also be key when it comes time to prepare for lab-related questions on the exams and also for the lab practica. Your lab notebook will be your primary source of information for studying lab-related information. It is recommended that you record *everything* (including questions to yourself, answers to lab questions, data, graphs, etc.) in your notebook.

Lab Grades

The laboratory attendance grade will contribute 150 points to your total course grade (15 points for the completion of each lab). You are required to make lab notebook entries for each of the 10 experiments. **In order to receive the full 15 points credit for each of the labs, you must show up on time to your assigned lab and be checked out of lab by your instructor.** Your lab instructor will tell you more details about the checkout procedure, but in general it will consist of checking the major points in your lab notebook (according the ‘Core Elements’ given below) and also answering questions to test your understanding of the lab you just completed. If your lab notebook is missing important information at checkout time, you will be asked to go back and complete what is missing.

Required Documentation For Entries in your Lab Notebook

The goal for making entries in your lab notebook is that another person could, in principle, reproduce the experiment solely from your lab notebook. Therefore, we give the following list of ‘Core Elements’ that each laboratory notebook entry must have regardless of the specific laboratory exercise. For an example of a laboratory notebook entry, see Appendix B.

Core Elements of Lab Notebooks

The following items #1 through #9 are required to be included in your lab notebook documentation for each laboratory exercise.

1. **Lab Header:** Title of lab, date/time, lab partner(s)
2. **Purpose/Goal:** A brief and precise statement indicating what is to be measured or demonstrated in the lab exercise.
3. **Apparatus:** Simple and accurate explanation and/or sketch (e.g. block diagram) of the experimental setup used to make the measurements.
4. **Procedural Details:** Simple and accurate descriptions of important steps undertaken during the experiment, such as equipment settings. Explanations of choices made during data collection, such as distances, sizes, trials, etc.
5. **Data:** All measured values should be in the lab notebook (either hand-written or printed from Excel) and clearly labeled as to what quantity the values represent and how they were measured.
6. **Analysis:** Explicit demonstration of any calculations using the measured data, including error propagation and statistical analysis. If repetitive, then show one representative calculation. This is especially important if Excel formulas are to be used in the lab exercise.
7. **Graphs:** Graphs of data must have properly labeled axes with the range of the axes adjusted to the range of the data.
8. **Computer Files:** Any data or analysis which exists on the computer, such as Excel workbooks or Logger *Pro* files, must be named appropriately, and the name recorded for later retrieval.
9. **Conclusion:** A statement summarizing the results including any conclusions based on the measured data and error analysis. If measuring a specific quantity, the conclusion should make a comparison between measured and expected or accepted values, including a statement about the statistical relevance of the difference, if any. If measurements are to demonstrate a specific principle, then the conclusion should discuss how well the principle was demonstrated.

Lab Practicum

During the semester, there are two lab practica scheduled during your normal lab session. Instead of doing a full 3-hour lab, you will come in for one hour and 15 min (75 minutes) during your regular lab session (that 75-minute timeslot will be assigned to you). During these 75 minutes, you will perform an experiment individually to showcase your learned lab techniques and experimental method.

You MUST come to your assigned time. If you have a legitimate conflict that will prevent you from attending the lab practicum, you must follow the same procedure as making up a lab session. If you are unable to make up the lab practicum during the week it is being administered, you must arrange with your lab instructor a time outside of lab to complete the practicum. **A missed practicum will result in a score of 0 for that practicum.**

One week before a scheduled lab practicum, you will be given the prompts that you may be asked to work on during the practicum as well as assessment criteria that detail what you are being graded on.

A lab practicum is a short experiment meant to test your skill and knowledge in a lab setting, based on what you have learned and practiced thus far. You will be given a physics question to investigate that is related to labs you have already seen and performed. For example, in the first lab practicum, you may be asked to find the drag coefficient of a given object, which would be a small extension of what you already did in lab in the Air Drag experiment. During the lab practicum, you may bring your lab notebook to guide you on good techniques and lab practices and specific details. For this reason, taking good, detailed notes during the semester in lab will be extremely valuable.

As part of the practicum, you will produce a short lab report that you will hand in at the end of the 75 minutes. Therefore, throughout the practicum, you must keep a log of your experimental procedure and reasoning to be handed in as a final report for the lab practicum grade.

- Use the Core Elements for a lab notebook entry to guide your write-up. The write-up should include appropriate elements such as a lab header, purpose, apparatus (if applicable), data, graphs (if applicable), analysis, and a conclusion.
- We will scan up to 5 pages (front and back) of your submission, including the cover page. Ideally, your written description should be 1-2 pages, with any Excel or other printouts included as separate sheets, labeled, and referred to in your write-up. Do NOT cut-and-paste print-outs into your report pages; simply add them as additional pages at the end of your submitted report. Do not staple.

- Include your name on each page of your report.

REMEMBER: You only have one 75 minutes to perform the experiment AND produce a short report, so begin working on the report as soon as you begin the experiment and work on it as you progress.

During the practicum, you will be supervised by your lab instructor. You may not ask them to help you unless it is a technical issue (e.g., the stopwatch batteries are dead).

The report you produce will then be graded according to provided assessment criteria. There will be feedback to help you understand how you performed and what improvements there may be for you to work on and practice in lab.

There will be two lab practica during the semester:

1. The first practicum aims to be developmental. This practicum will be worth 25 points and is geared to give you feedback. It will allow you to see which lab techniques you have mastered and which need additional work. You will then use the remaining labs to improve those skills.
2. The final lab practicum will be more evaluative and will be worth 40 points. The assumption is that by the end of the semester, you will have attained sufficient proficiency in lab techniques to work independently in a lab setting.

The idea is that the first lab practicum will allow you to see what lab techniques you may still need practice with via feedback from the instructor and you may use future labs to improve those skills. Then, in the final lab practicum, you will have a better grasp of the lab techniques you are being tested on as you have now had an entire semester to practice and improve. These practica are intended to be learning experiences! It is hoped that they help you better solidify your lab skills and become more confident in a laboratory setting.