

# 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 212 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 the lab coordinator, Cheslee Hibler (cheslee.hibler@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 explaining 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.

**Each unfinished lab will receive 0 credit (0 out of 15 points per lab) for that particular lab toward your total lab grade.**

## 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. PDFs of each lab will be available on the PHYS 211 Lab Info page up to one 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 you should 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 a thorough and accurate lab notebook. 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 documents and save those documents at the end of each lab.

## 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 to 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 #8 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:** 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. **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.
5. **Graphs:** Graphs of data must have properly labeled axes with the range of the axes adjusted to the range of the data.
6. **Computer Files:** For any data stored in computer files, the name of the data file and contents must be documented in the lab notebook so that it could be retrieved at a later date.
7. **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.
8. **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 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 min) during your regular lab session (that 75min- time will be assigned to you). During these 75 min, you will perform an experiment individually to showcase your learned lab techniques and experimental method. **You MUST come to your assigned hour.** 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 unless you present a legitimate excuse for your absence and arrange to make it up either through attending another lab section or scheduling a time to perform it with your lab instructor.**

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 a rubric that details what you are being graded on.

A lab practicum is a short experiment meant to test your skill and knowledge in lab 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 of PHYS 211, 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
- Any data or graphs produced in Excel or Logger Pro should be printed as separate sheets, labeled, and referred to in your write-up. Aim for no more than one sheet (front and back page) for write-up (this does not include any print-outs from Excel or Logger Pro data and/or graphs). **Do NOT cut-and-paste print-outs into your 2-page report; simply add them as additional pages at the end your submitted report.**

- Include your name on each page of your report.

**REMEMBER: You only have 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 one 75 min practicum, you will be supervised by your lab instructor and TAs as usual, but you may not ask them to help you unless it is a technical issue (e.g., the stopwatch batteries are dead). If there is any part of an experiment where you simply need an extra pair of hands to do a measurement, you can ask the TA to help you, but only if you instruct them clearly about what you want them to do (e.g., instructing them exactly how they must drop an object so you can time it).

The report you produce will then be graded according to a rubric. 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, worth 30 points each.** It is expected that you will look back at your experiences and practica feedback from PHYS 211 as you continue to improve your lab skills and reports.

Note that these lab practica are not the only places where you will be evaluated on what you do in lab. There will also be lab-related questions on all of the exams for PHYS 211-212, including the final.