

**Princeton University
Physics Department**

**Physics 103/105
Lab Manual**

Fall 2010

Physics 103/105 labs start Monday September 27, 2010. It's important that you go to the lab section that you signed up for. We will be expecting you!

You should have a lab book and a scientific calculator when you come to your first lab. (See details in the Orientation section following.)

Each week, before you come to lab:

Read the procedure for that week's lab, and any additional reading required.

The **Prelab problems** are **optional**, but please work them if it appears that they will be of help to you.

Also, for the first week:

Read the "Orientation to Physics 103/105 Lab" and Appendices A and B.

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PHYSICS 103/105 LAB MANUAL

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LAB SCHEDULE

Date	Topics	Experimentation	Equipment
Sept 20-24	NO LAB		
Sept 27-30	Experiment # 1 Motion in 2 Dimensions	Analyze motion of a bouncing ball, using VideoPoint and Excel.	PC & CCD camera. Ball & launcher
Oct 4-7	Experiment # 2 Fluids	Forces in fluids and fluid flow	
Oct 11-14	Experiment # 3 Collisions	Collisions in two dimensions Conservation laws	PC & CCD camera Air table, with pucks
Oct 18-20	Experiment # 4 Friction	Friction during constant acceleration on an inclined plane	PC & CCD camera. Cart, tilted ramp
Oct 25-29	NO LAB	--- MIDTERM EXAMS ---	
Nov 1-4	NO LAB	--- MIDTERM BREAK ---	
Nov 8-11	Experiment # 5 Loop-the-Loop		
Nov 15-18	Experiment # 6 Measurement of g	Use a precision pendulum to make an accurate measurement of g	Pendulum, photogate timer
Nov 22-25	NO LAB	--- THANKSGIVING ---	
Nov 29-Dec 2	Experiment # 7 Coupled Pendula	Study coupled motion of two pendula connected by a spring	Physical pendulum, spring
Dec 6-9	Experiment # 8 Speed of Sound	Measure the speed of sound, density, and specific heat of gasses.	Gas column, frequency generator, vacuum pump, scale.
Dec 13-16	Make-up labs		

Orientation to Physics 103/105 Lab

WELCOME TO PHYSICS 103/105 LAB!

Physics 103/105 labs start the **SECOND** full week of classes. It's important that you go to the lab section that you signed up for. We will be expecting you!

You should have a lab book and a scientific calculator when you come to your first lab. (See details in the Orientation section following.)

Each week, before you come to lab:

Read the procedure for that week's lab, and any additional reading required.

The **Prelab problems** are **optional**, but please work them if it appears that they will be of help to you.

Also, for the first week:

Read the "Orientation to Physics 103/105 Lab" material below.

I. What Physics 103/105 labs Are Like

You will soon find that Physics 103/105 Lab is not like any lab you've had before. You will be expected to think and be creative, not just follow instructions. The lab manuals for each experiment will step you through many of the new techniques that you will need, but you will not generally be given recipes to follow for each experiment. The manual for each week will typically describe a basic experiment that all students will be expected to complete. Beyond that, the manual will suggest a variety of additional experiments and extensions that you may find interesting and challenging. You can pick one or more of these to work on, or you can invent a new experiment on your own. The lab employs versatile equipment that will allow you to do the "standard" experiment quickly and then branch out to new challenges that match your interests and expertise.

In Physics 103/105 Lab, you will work in teams of two or three students. (Larger groups become unwieldy.) Your AI will randomly assign teams. Students may work in the same groups each week, but there will likely be changes in the groups during the term. Please be flexible about letting others work with you, or splitting up your existing team if it makes the groups more even. Your AI may mix reassign groups occasionally to give people a

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labs are like**
II. Notebooks
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chance to work with other individuals.

You will find that learning how to plan and work together will be crucial to the effectiveness of your team. Among your responsibilities in physics 103/105 is to be sure that all of the people in your team contribute to your success. Take turns performing the experiment and using the computer so that every team member gets a chance to “drive”. If one or more of your team members seems lost, take a few minutes to get them up to speed—you’ll need their input later when things get tougher! You will also find that you learn a lot by discussing problems with others, *even when you think you’re the one doing the teaching*. Most scientists and engineers today work in teams, some large and some small, depending on the size of the task.

Periodically, your AI will come by your lab bench and ask you questions about what’s going on. Of course, you can ask your AI questions about what’s going on too. You will find that your AI is a great resource. On the other hand, you shouldn’t be surprised if your AI doesn’t answer all of your questions directly. Your AI’s job is to help you learn, and sometimes the best way to do that is by making you struggle on your own for a while.

Sometimes, you will learn things in lab before you see them in lecture or precept. In other cases, you will see topics in lab that won’t be covered in the lecture at all. While physics labs are good for helping you solidify what you learn in lecture (either before or later), they are also great for going beyond the lecture, showing you additional techniques and phenomena that you won’t see in other parts of your physics course.

Among the important techniques you will learn in lab that won’t be covered in lecture are data analysis and error analysis (= analyzing the uncertainty in your measurements). These are critically important skills that you will need in your professional lives as scientists and engineers, and things you may not learn any place else. In many cases, estimating the uncertainty on your measurements will be the most difficult part of a lab.

The process you will go through in this lab closely approximates the working experience of professional scientists and engineers. It goes something like this: your team decides on an interesting investigation, makes a plan, organizes to do the work, gets and analyzes data, thinks about the results, and repeats or improves the experiment until you are satisfied with your accomplishments. The most valuable tool that you have in the lab (or anywhere else) is your common sense. A good scientist or engineer is always asking: Do we have a clear idea of what are we trying to do? Do our results so far make sense? Is there a better way to do it? Practicing scientists almost never get their final results the first time they do an experiment. Don’t just go through the motions: plan, think, and understand. Try to get to the result quickly, think about it, and then do a better experiment or try a variation to test a “what if?” idea. Along the way you will learn a lot of physics, especially if you are thinking and discussing (or arguing about) ideas with your teammates.

II. Notebooks

For physics 103/105 labs, you will not turn in any formal laboratory reports. Instead, you will be required to keep a notebook. You can get one at the U-Store. The spiral bound 5X5 QUADRILLE RULED (80 Sheets 11" X 8.5" Green tint) is recommended (cheap and adequate). If those are not available, try to get something close; quadrille paper is particularly important.

Start each week's lab on a new page; write the date at the top, and who your other team members are. If you attend a different lab session than the one to which you are formally assign, also write your formal lab section. From that point on, your notebook should be a comprehensive record of everything you do and think in 103/105 lab that day; sort of like a diary or a journal.

Your lab notebook is not the same as a "lab report." It contains similar information, but in much less polished form. DO NOT waste time making your notebook look pretty. It should be neat enough to be easily understandable, BUT NOT NEATER. Feel free to cross things out, draw arrows, make freehand sketches, and cuss. Use scissors and tape to include printouts in your notebook whenever you use a computer to make a diagram or a graph. Also, include all of the things you tried that didn't work out how you planned; they're an important part of what you are learning too. Just be sure that your notebook is easily readable, and always take some time to write some understandable sentences explaining what you are about to do, what you've just done, and what you have learned from it.

Suppose, for instance, that you have just measured the speed of a car that has rolled down a ramp, and it didn't come out like you expected it to. You might write:

"The value we came up with for the speed of the car was 4.2 m/sec; that's about 15% lower than we expected. Maybe friction (while rolling) is more important than we thought? Jen suggested we try raising the ramp: that way the speed of the car should be greater, and the effect of friction should be (relatively) smaller."

You could then try the experiment again, including the new data and a new graph in your notebook, along with your conclusions:

"Dang! The speed increased to 6.7 m/sec, but now that's 25% lower than we expected it. The problem didn't get better, it got worse! So much for that idea: we can conclude that friction while rolling down the ramp probably isn't the problem...."

Notice that although the problem isn't solved yet, the student was able to draw a partial conclusion: that the discrepancy in speed is not due to rolling friction. These conclusions are vital for your notebook. Without them, your notebook is just a bunch of meaningless numbers. Of course, a final paper based on this experiment might never include this degree of detail, especially about this part of the experiment that seems to be producing inconsistent results. But solving these difficulties is an important part of your experience in lab, and your description of your experience is what your notebook is all about.

Students are often unsure about how much detail to put in the notebook. What we most want to see in your notebooks is evidence of thinking, and not just “correct” results.

At the end of your lab period, leave your notebook on the shelf in your lab room for your AI to grade. DO NOT REMOVE your notebook from the lab room. This rule is for your own benefit. When students take their notebooks home, it starts a sort of arms race for who has the prettiest colored graphs and the best spelling. Don't waste time beautifying your notebook; it's a record, not an artwork.

Professional researchers rely heavily on their notebooks for reference when they write the papers or reports describing their work. Notebooks are the means to recall and check, sometimes years later, what went on in the lab. Many researchers have their notebooks regularly notarized, in case they are needed for patent verification. It's important to learn how to keep a good lab notebook. Someday your job may depend on it.

III. Prelab work

Please read (and think about) the lab instructions before coming to lab. Otherwise you will waste a lot of time in getting up to speed. If your lab partners aren't reading the write-ups ahead of time, ask them to do so. Many of the writeups refer you to Appendix materials which you will be expected to read carefully.

You can also complete the optional “prelab problems” at the end of each set of lab instructions before coming to lab. The prelab problems are not too hard or time consuming, but they can be helpful in getting you prepared for each week's material.

IV. Grading

The main intent of Physics 103/105 lab is to offer you a chance to be scientifically and technically creative. We want you to form and pursue ideas. Our evaluation of your work will depend a lot on your creativity and understanding, and very little on “getting the right answer.” Experimentation is hard, and even good experiments don't always turn out how you plan them to be.

Golden rule of 103/105 lab grading: *In general, we won't hold it against you if an experiment doesn't produce the answer you think it should or doesn't quite get finished, as long as you worked hard and were intellectually and creatively engaged for your entire lab period. The flip side of the pact is this: In general, you are required to be intellectually and creatively engaged for your entire lab period, even if your experiment goes well. If you finish one experiment, then think of another.*

Whatever you do, don't just sit around doing nothing. Your grade will suffer, and you will attract unwanted attention.

For Physics 103, the Lab grade is worth 15% of your course grade in the class (Physics 105 will announce its grading scheme in class). But for both classes, your lab grade is calculated as follows:

75% Notebooks: Graded after each lab for completeness, thoughtfulness, and readability.

25% Participation: Graded for each lab for creativity and industry.

V. Attendance

Attendance each week is vital in Physics 103/105 Lab. If you must miss your regular lab section due to illness, University-related travel, or religious reasons, contact the Ph103 Lab Manager: Prof. Kirk McDonald (kirkmcd@princeton.edu) by email to arrange to go to another lab section.

Not Completing one lab will lower your PHY 103/105 course grade by one full letter grade. Not Completing two labs will result in automatic failure of the entire course.

If you realize that you have missed a lab because you have slept through it or have forgotten what day it was, then you can make it up later that week in another lab section. If you realize you have missed your lab, try to contact Prof. McDonald. However, if you have only one time slot left that you can make up the laboratory, don't wait to hear from the department office; just show up, explain the situation to the AI, and we'll sort the paperwork out later.

Makeup labs will offered, by appointment with Prof. McDonald, during the last full week of class, Dec. 13-17. However, it is strongly recommended that in case of schedule difficulties some week, you attend some lab session that week, and work with other students on the lab.

VI. Feedback

Physics 103/105 Labs are always changing. As always, we think we've nailed it, but chances are we've missed some things. To help us do better in future weeks and future years, we want to hear feedback from you.

If you have any questions, comments, or concerns about Physics 103/105 Lab, please bring them up with your AI, the lab manager, or the course head. Thanks!

**Physics 103/105 Labs start on Monday, September 27, 2010.
See you there!**