PHYSICS 191
FOUNDATIONS OF PHYSICS I
Fall 2009

INTRODUCTION

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e-mail: cgearhart@csbsju.edu. I check my e-mail at home, and will try to answer any questions about homework and the like the same evening—try to send them before 9 or 9:30. In general, e-mail is a faster and more reliable way of getting in touch with me than voice mail.

Course web site: http://faculty.csbsju.edu/cgearhart/Courses/Physics191/physics_191.htm.

You may also go to the Physics Department web site and follow the links.

Office Hours: Before and after class, by appointment, and whenever I am in—most of the time. I sometimes work at home on even mornings, and I will often be in the Twin Cities on Friday afternoons.

Foundations of Physics I is the first in a sequence of three introductory physics courses (Physics 191, 200, and 211) that survey “classical” physics—that is, physics as it had developed up to about 1900. But I will also try to say a word or two about the developments that have taken place since then. The sequence is required for physics and pre-engineering majors; it lays the foundation for future study of physics and engineering. The sequence is also useful and strongly recommended for chemists, mathematicians, computer scientists, and others needing a strong foundation in physics.

Prerequisites include high school mathematics (algebra, geometry, and trigonometry) and concurrent registration in Calculus I (Math 119). If you are not registered for calculus and have not taken calculus previously, **please see me immediately**. Do not be discouraged if your high school background is weak; you are not alone. We will try to develop much of the mathematics we need as we go along, and will introduce the calculus gradually. Appendix B in the text gives a brief review of elementary mathematics—don't forget it's there!. Other mathematics review texts are available—for example, the review texts in the Schaum outline series have proven useful to many students in the past.

You should have a calculator that at minimum has the following functions: trigonometric functions, exponential function, and logarithms (natural and base 10).

TEXTS

- Hugh Young and Roger Freedman, University Physics (12th ed) (required). (I will often abbreviate this title as "YF".)

  This text does have a web site, but it is expensive (about $45). It has tutorials for some of the problems in the text, but they did not strike me as especially useful. But feel free to ask me about it, or try it yourself; the link is http://www.masteringphysics.com.

There is another, free web resource, ActivPhysics, geared to YF, that you may find useful. I will mention it class from time to time, but feel free to give it a try yourself. The link is http://wps.aw.com/aw_young_physics_11/. I have put this link on the course web site.

- Laboratory Manual (required)
- John R. Taylor, *An Introduction to Error Analysis* (recommended) We assign this book in physics laboratory courses in the sophomore year. For now, it is a useful and recommended supplement to the Appendices of our Laboratory Manual.

SUPPLEMENTAL READING

It is an unfortunate truth that there is no one physics text that is best for everyone. And often, when you cannot understand one text's explanation of a point, it is more effective to read another book's treatment than to reread the first over and over. There are many physics texts on about the same level as Young and Freedman. You will find some of these texts in the Physics Department library (room 104, across the hall from my office)—feel free to browse. You are welcome to use this room for studying.

One book I particularly recommend is the *Feynman Lectures on Physics*. Feynman, a Nobel Prize winner in physics who died in 1988, is one of the best known physicists of the twentieth century. He is also known for his proficiency on the bongo drums—see the picture on the title page—and for picking the locks on safes at Los Alamos, during World War II! The Feynman Lectures were written when he taught the introductory physics course at Cal Tech. The lectures are not so much a text as a guided tour through physics, written by a master at it. It is useful at all levels, from beginner through graduate student, and most physicists and physics majors find it helpful. There are three volumes, and all three are available both in hard cover and in paperback.

Taylor's book on error analysis is one of the better introductory treatments I have seen—we use it as a text starting in our sophomore laboratories. It is not an easy book, but it will repay careful study. It should be helpful in understanding the error analysis we will do in laboratory, and in supplementing the discussion of error analysis in the laboratory manual.

COURSE FORMAT

Physics 191 is a lecture-demonstration-discussion course with a laboratory. Here, in broad outline, is what I hope you will accomplish:

- Begin to understand the beautiful and elegant conceptual and mathematical structure that physics uses to describe our world—in particular, what we variously call “classical mechanics,” “Newton’s laws,” and sometimes, “matter and motion.”
- Develop the ability to solve physics problems—how we use this beautiful and elegant structure to *do* physics! One needs to understand the laws of physics, of course. But one also needs to combine this understanding with practical mathematical skills and problem-solving techniques.
- Become acquainted with the principles of experimental physics, including instrumentation and the analysis of experimental data.

For most class meetings, I will hand out (and post on the web site) assignment sheets that summarize important points, make homework assignments, and the like. Homework assignments are to be worked carefully and turned in at the beginning of the class period following their assignment. **Late work will NOT be accepted**. In addition, I ask you to follow the following format:

FORMAT FOR HOMEWORK ASSIGNMENTS

1. Please include enough work to show how you arrived at your answer.
2. Please write clearly, and organize your work logically and neatly.
3. Please write **on only one side** of the page.
4. Please do no more than **two problems per page**.
5. Please staple or clip problems together. Loose papers, or papers folded together, often get lost. If you turn in problems on paper torn out of a spiral notebook, **please trim the edges**.

I request this format for the convenience of the grader, who is also a student, and who needs to get through a lot of papers rapidly. It should also help you, when you use your homework to review. I tell the grader that s/he need not grade or give credit for illegible work, or work that does not conform to the above format. I will post solutions to the homework problems on the course web site.

I plan to cover the first 11 chapters and parts of chapters 12 and 13 this semester. There will be three or four tests during the semester, announced well in advance, and a final, comprehensive examination, which will cover the entire course, at the end. The first examination will come after we complete chapter 3.

Your final grade will be determined *roughly* as follows:

- 75% — semester exams and final examination. The exams will consist primarily of problems similar to the homework problems and worked examples in the text.
- 10% — homework. Here is where you learn to do the kinds of problems you will see on the exams.
- 15% — laboratory work

LABORATORIES - Rooms 102 and 106

The laboratories are designed to develop your ability to work with experimental apparatus and to analyze experimental data. Descriptions of the experiments will either be in the laboratory manual, or will be handed out in class. Please see me if you are not sure what lab section you are in. A schedule of experiments and dates will either be in the lab manual, or will be announced in class.

I do expect you to read the write-up for the lab before you come in. On some labs, I may ask you to do an initial problem, or take a short quiz, before you begin the lab. Please feel free to talk to your laboratory teaching assistant or to me if you have questions about the lab, or need help writing it up.

HOW TO STUDY PHYSICS

Especially for first-year students: Most of you will find that college courses in general, and this course in particular, will demand *much* more time and effort from you than your high school courses required. Take these demands seriously—it can take a while to get used to them—and be careful not to take on too many activities outside class until you are sure you have time for your courses. We do not make these demands arbitrarily—in this course, you are starting to develop the knowledge and skills you will need as a professional scientist or engineer. Learning them takes enthusiastic commitment and a lot of hard (and sometimes frustrating) work. But if you enjoy science and mathematics, and want to make a career of it, it will also be a lot of fun. Einstein once said that "God is subtle, but not malevolent."

In this section I make some suggestions on how to approach this course.

1. **Plan to spend a lot of time**—a *minimum* of three or four hours of study for each class period.

2. **Physics texts cannot be read quickly.** You may find an initial skimming of a section or chapter useful, but by and large you should read *with paper and pencil in hand*. Don't just read derivations, but work them through yourself, and try to understand every step. Try both to develop an intuitive, qualitative grasp of the material, and to understand how the intuitive picture is expressed and developed mathematically.

   It can also be helpful to look at the chapter summaries in YF. Some people like to look them over before they begin to read the chapter.

3. **The worked examples in the text are extraordinarily important.** They will, more often than not, show you how to approach the problems at the end of the chapter. Don't just read these examples—***work them through, with pencil and paper***! When you're done, try closing the book and seeing if you can work out the example without help. Also, try explaining the example to yourself or someone else—not just the mathematical steps and equations, but why you are using those equations, and what physical principles are involved.

   You may also it helpful to read (and reread) the "Test Your Understanding" exercises at the end of each section in YF.

4. **Work large numbers of problems**; think of the assigned homework problems only as a warm-up. You should do a substantial fraction of the problems in the text for each chapter. There are at least three reasons for this extraordinary demand. First, working problems helps you understand the physics more thoroughly. It is a common experience (among physicists as well as physics students!) to read through new material carefully, think you understand it, and then be stumped when you try to do a calculation. Second, it develops your mathematical skills. Finally, there are specific techniques that are involved in solving problems. I will lay out some general guidelines below, but the more practice you get, the more you will improve.

5. **Work with others.** It often helps to study and work problems with one or two others in the class. And by working in groups, you can often work more problems, and cover more material, than you can working alone.

   Especially for first-year students: It may take you a while to get to know the others in the class, particularly if they are in a different section. Let me know if I can be of any help in setting up informal study groups—just say something to me after class, or send me a note by e-mail.

6. **Don't get behind in your work.** Physics is a cumulative subject; the material you will study later in the semester (and the year) builds on what you have learned earlier.
7. **GET HELP WHEN YOU NEED IT.** I expect you to have a lot of questions about this material, and to experience a certain amount of confusion and frustration at times. It is a necessary, if unfortunate, part of learning. One of the most important functions of the faculty is to be available for individual help; in addition, I will conduct frequent late afternoon review sessions to work problems and answer questions. The only stupid questions are the ones you don't ask.

HOW TO SOLVE PHYSICS PROBLEMS

The following suggestions are a long-winded way of illustrating the advice of John Wheeler, a prominent 20th century physicist:

"Never begin to solve a problem until you know the answer."

Wheeler means that you should not simply stuff numbers blindly into equations. Rather, try to have a clear mental picture of the problem, understand where the equations come from and what they mean. It also can help to have a general idea of what the order of magnitude of the numerical answer should be.

These suggestions come not only from my own experience, but are the results of considerable research conducted in recent years on how successful scientists and engineers solve problems.

1. First, get an intuitive idea of what the problem involves. Describe the problem to yourself. Make a careful sketch. Ask yourself what the qualitative features of the solution are likely to be. Learning physics involves combining an intuitive understanding and a mathematical description of nature. If you jump too quickly to the mathematical description, it is easy either to head off in a wrong direction, or to get a result that you don't understand fully—even if it's correct.
2. Once you understand the problem intuitively, plan a solution. What information are you given, and what do you need to calculate. What physical laws pertain to this problem?
3. Now, proceed to a mathematical description of the problem. What equations will you need? How will you use them? Try not to think of the equations as "formulas," but rather ask yourself what they tell you about nature.
4. Carry out your calculations algebraically at first; that is, don't put in numerical values until the end. If you substitute in numbers too soon, it is easy to lose sight of how various quantities affect each other. Suppose, for example, that you are considering a ball tossed into the air. How does the maximum height depend on the initial velocity? If you put in numbers too soon, you can easily lose sight of relations of this sort, which are often the main point of the problem! And as a practical matter, the earlier one puts in numbers, the more likely an arithmetic mistake.

5. Finally, check your answer. Is it "reasonable," both numerically or algebraically? Or have you, for example, calculated a velocity that is faster than light, or inadvertently predicted that a ball thrown into the air will accelerate upwards? Checks of this sort can either give you confidence in your solution, or point out possible mistakes.

All of this, of course, is more easily said than done. As you begin studying physics, both your intuition and your mathematical skills are relatively undeveloped; it can be hard to know what to trust, or where to begin. Nor can the above suggestions be followed mechanically, or by rote. Try things. You may think you know the right equation, but aren't sure. Try it. You may get the "right" answer; so far, so good. But don't stop there! Go back and understand the equation, where it comes from, how it's derived, what it says about nature, why it applies to this problem. Talk to one another, and to me, and get help if you need it. Then you'll have learned some physics.