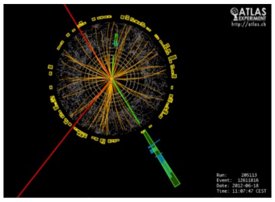
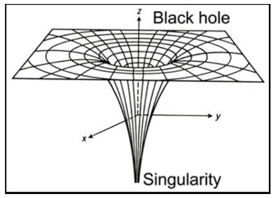
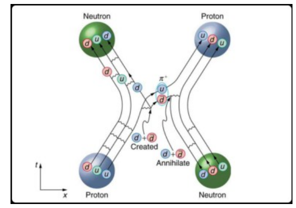
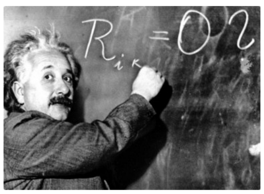


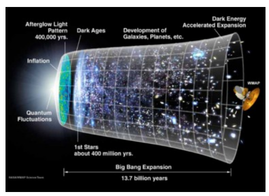


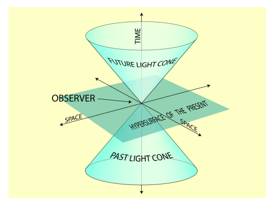


Physics 130
Relativity, Spacetime, and Contemporary Physics

Fall Semester, 2017







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General Course Information

This is the first course in Lafayette's introductory Physics sequence. However, it is not your typical introductory physics course. The goal of this course is to expose you to some of the most exciting contemporary developments in physics and to give you a sense of what we don't know about nature – the fundamental unanswered questions to which we are still seeking answers. Over the course of the semester, we will explore the bizarre and often non-intuitive picture of the natural world that emerges in situations far removed from our everyday experience – phenomena that appear at distances smaller than the size of an atom, at temperatures millions of times hotter than the sun, or at speeds approaching the speed of light.

During the first two weeks of this course, you will be introduced to a few key concepts from classical physics which will serve as a foundation for the rest of the semester. During the next seven weeks, we will come to grips with Einstein's theory of relativity and its strange and seemingly paradoxical implications. In the process, you will develop a geometric understanding of "spacetime" – the union of space and time – and become familiar with the mathematical tools necessary to analyze the motion of objects in spacetime. Finally, during the last six weeks of the course, we will focus on particle physics. We will begin by examining the physical phenomena that appear at progressively smaller and smaller distance scales. This will culminate in the description of nature at the smallest scales ever experimentally probed – a description that has come to be know as the Standard Model of particle physics. We will examine what we currently understand to be the basic building blocks of matter (quarks and leptons) and the fundamental forces (gravity, electromagnetism, and the strong and weak nuclear forces) through which they interact. We will examine what we know about the history of our universe, down to the first infinitesimal fraction of a second. We'll also learn about some of the exciting recent discoveries in physics (neutrino oscillation, the Higgs boson, gravitational waves) and discuss some of the aspects of our universe (dark matter, dark energy) that we still don't fully understand.

In the process of exploring some of the most exciting topics contemporary physics, you'll also get a chance to hone some of the universal skills that are crucial in practically *any* science or engineering field – skills such as setting up an experiment, thinking critically about what you observe, reasoning through problems, and communicating your own knowledge to others. Indeed, by the end of the semester, you can look forward to being able to do all of the following.

- You'll understand the fundamental principles of Einstein's special theory of relativity and be able to apply that understanding in solving quantitative problems.
- You'll be familiar with the particles of the Standard Model, their properties, and how they interact.
- You'll have a sense of what physical phenomena become important at different distance and energy scales.
- You'll have an appreciation of what the most important unanswered questions in physics are and how current research aims to address those questions.
- You'll understand how symmetry informs our understanding of nature and be able to apply symmetry principles and conservation laws in order to solve problems.
- You'll be able to perform experimental measurements relevant for testing a hypothesis and to evaluate whether your data supports, motivates the revision of, or refutes that hypothesis.

The prerequisites for this include an understanding of calculus at the level of Math 161, as well as basic algebra and geometry. You should be aware that calculus is an integral part of this course (no pun intended), and that a solid grasp of these mathematical prerequisites is assumed. Understanding this background material will be your responsibility, and if you don't feel comfortable with this material, it's up to you to seek help from the instructors or from elsewhere. There are plenty of resources on campus available to you in this regard, so if you want to know more about what's available, please ask.

I ask that you join this course with a will to think, to ask questions, to make mistakes, and to try out ideas. Be careful not to confuse understanding with having memorized a lot of facts and formulas. I feel that the former is important while the latter is not – and the former will be far more useful to you in the long run.

Components of the Course

The course will consist of class meetings, reading assignments from a variety of different sources, some questions and problems, some laboratory experience, two mid-term exams, and a final exam. These are described more fully below.

Class Meetings:

Class meetings will be held **from 2:10 PM – 3:00 PM in Hugel 017** each Monday, Wednesday, and Friday during the semester. A schedule of the topics we'll be discussing at each class meeting, along with the corresponding reading assignments, can be found on the course web page. These class meetings are there to help clarify things that you might be confused about after exerting your best efforts at understanding them on your own. However, I emphasize that **not everything can be covered in class; you are responsible for understanding much of the material on your own** by synthesizing what you've learned from your readings, problem sets, lab experiments, exams, and other class activities. It is therefore important that you come to class prepared to ask questions. There are no "dumb" ones. If you don't understand something, chances are there are others who don't understand either or who don't even realize they are missing something.

Class meetings aren't only about lectures either: on most days, we will also have other class activities that are meant to help you understand the material. For example, during class meetings, you will often be working collaboratively in teams of two or three people to come up with solutions to more open-ended problems. These kinds of activities are designed provide you with an opportunity to apply what you're learning in ways that more authentically mirror how practicing scientists and engineers actually work. Moreover, it is not unusual for test questions to be based on these activities, so make sure you understand them. For all of these reasons, **regular attendance in class is expected**. You are responsible for knowing anything covered in class, even if you have to miss class for any reason.

Readings:

There is one required textbook for this course, which is available from the Lafayette College Store:

- Thomas A. Moore, *Six Ideas That Shaped Physics: Unit R – Laws of Physics are Frame-Independent*, 3rd Ed. (McGraw-Hill Education, 2017).

This text is available from the Lafayette College Store. In addition to readings from this textbook, we will be looking at articles and short excerpts from a number of additional texts which will be made available on the course Moodle, including

- Thomas A. Moore, *Six Ideas That Shaped Physics: Unit C – Conservation Laws Constrain Interactions*, 2nd Ed. (McGraw-Hill Education, 2003), Chapters 1 – 6.

- David J. Griffiths, *Introduction to Elementary Particles*, 2nd Ed. (Wiley, 2008), Chapters 1, 2, and 11.

- David J. Griffiths, *Revolutions in Twentieth-Century Physics* (Cambridge University

Press, 2013), Chapters 4 and 5.

- Edwin F. Taylor and John. A. Wheeler, *Exploring Black Holes: Introduction to General Relativity*, (Addison Wesley Longman, 2000), pages 2-17 – 2-49.

- Kenneth Krane, *Modern Physics*, 3rd Ed. (Wiley, 2012), Chapter 12.

Readings from these texts will be assigned for each class meeting, and it is important to do the assigned reading before class. You can't speed-read this stuff; you should go through it with pencil and paper at hand, checking it out as you go.

In addition to the textbook and the excerpts mentioned above, you will also need to acquire the following supplementary materials for this course from the Lafayette College Store:

- **A lab notebook**. Please note the your lab notebook for this course must be one of the black, bound lab notebooks available from the Lafayette Bookstore. You and your lab partner will be sharing a single lab notebook, so you should coordinate this purchase with your lab partner.

Homework Assignments:

Working through problems is an essential part of this course. There's no way of truly understanding the physics without delving in and doing *physics*. For this reason, I will be assigning a number of homework problems each week which I feel provide practice with the most crucial aspects of the material we're covering in the course. Working through problems accomplishes a lot of different things: it gives you practice using the physical principles you're studying, which helps you learn them in a way simple memorization doesn't; it can show you some further interesting consequences of the fundamental ideas; it will teach you how to approach problems; and it will help you discover how well you really understand what you have read. It is essential that you read the relevant sections of the textbook and review your lecture notes thoroughly *before* attempting the homework problems.

A list of the problems included in each homework assignment will be accessible from the course web page. **All problems are due at 4:00 PM on the day (typically a Friday) indicated on the course schedule** on that same web page. I will accept late homework for half credit up until the beginning of the next class meeting. Late homework will not be accepted beyond that point without a Dean's Excuse.

Almost all the physics in a problem comes at the beginning, in the process of setting up the problem – you need to understand the physical principles that apply prior to solving the problem. This means you need to think about the physics, not search for the “right equation” – often there *is* no “right equation.” The important thing is *not* getting the same numerical answer that appears on the solution set, but understanding the physical concepts and how to apply them! In fact, many times, it is a good idea to try and answer the question *qualitatively* prior to plugging numbers into equations. It is also a good idea, once you think you've solved a particular problem, to ask whether your solution seems reasonable – if you have no idea, it probably means that you haven't really understood the problem.

You are encouraged to work on homework problems with other students in the class. This can be a very productive way to study, and working with other people to solve problems is a big part of how science and engineering are really done. However, your written work should reflect your own understanding and not be a copy of another person's efforts.

Laboratory:

You will be performing a variety of laboratory experiments over the course of the semester. These labs are an integral part of this course. Physics is an experimental science and did not really get started in its modern form until people began to do careful, quantitative experiments. The lab associated with this course is designed not only give you a chance to test and develop your understanding of some of the physics you learn in the classroom, but also to introduce you to additional concepts that we won't be covering in lecture. It's also designed to provide you with glimpse of how scientific information – and confidence in that information – is acquired.

The labs for this course will be held on **from 1:10 – 4:00 PM each Thursday** throughout the semester, unless otherwise indicated on the course web page. Further information about the laboratory portion of this course can be found in your lab manual, and further information will be provided by your laboratory instructor during your first lab meeting. Information about the individual labs will be posted on the Moodle for the laboratory section of this course (which is distinct from the Moodle for the lecture section) in advance of the lab meeting.

Mid-Term Tests and Final Exam**:**

There will be two mid-term exams given during the course. These exams are designed give you the opportunity to demonstrate how well you understand the material. In order to proved you with more time to work on these exams (a fifty-minute exam can sometimes feel rushed), we have scheduled them during the laboratory period – **one from 1:10 – 3:00 PM on Thursday, Sept. 28th and one from 1:10 – 3:00 PM on Thursday, Nov. 2rd**. The mid-term exams will focus primarily on material covered since the previous exam (or in the case of the first exam, since the beginning of the course); however, each new topic introduced in this course builds incrementally upon the material we'll have studied previously. In addition, there will also be a final exam at a date and time to be determined by the Registrar.

Grading

Course Grade:

Your grade in the course will be determined by the following criteria:

Homework	18%
Participation	6%
Labs	15%
Mid-term Exam 1	18%
Mid-term Exam 2	18%
Final Exam	25%

Office Hours:

You are encouraged to stop by my office at any time if you have questions about any aspect of the course. You may not always find me, however, if you drop by unannounced. My official office hours, during which you can count on my being in my office (except under extraordinary circumstances), will be held **Monday, Wednesday, and Friday from 3:00 – 4:00 PM and Wednesday from 9:00 – 10:00 AM** unless otherwise noted on the course web page. If you are unable to drop by during these official office hours, you may also call or email me to make an appointment for some other time.

Intellectual Honesty:

All exams in this class are closed-book. Calculators are permitted, and you will also be provided with a sheet of useful equations and fundamental constants at the start of each exam. However, the use of any other resources is not permitted. When studying, working in the laboratory, or working on homework problems, I encourage you to work with other students. However, you may not consult a solutions manual or any other source for answers to the problems, and the write-up that you submit to me for each problem should be your own work.

As always, you are expected to abide by the principles of intellectual honesty and academic integrity outlined in the Lafayette Student Handbook, which can be found at

- http://studentlife.lafayette.edu/resources/

Other Useful Information

Accessibility Services:

In compliance with Lafayette College policy and equal access laws, I am available to discuss appropriate academic accommodations that you may require as a student with a disability. If you are requesting accommodations, you must register with the Disability Services Office (administered by ATTIC) for disability verification and for the determination of reasonable academic accommodations. It is **your responsibility** to provide me with an official letter from Disability Services which clearly outlines what those accommodations are. I cannot provide accommodations until you provide me with such a letter. Requests for academic accommodations must be made within the first two weeks of the semester, except in unusual circumstances, so that suitable arrangements can be made in a timely manner.

Informal Surveys:

Over the course of the semester, I want to hear from you how you feel the course is going, what you like, what you don't like, what your concerns are, and how you think the course could be improved. Therefore, at regular intervals throughout the semester, you'll have the opportunity to fill out a short, informal course evaluation so that we can get feedback from you.

Course Communication:

This syllabus, a list of assigned readings and problem sets, and other course materials will be posted on the course web page, which can be found at

- http://workbench.lafayette.edu/~thomasbd/Phys130-RelativityContempPhys-Fall-2017/Phys130-RelativityContempPhys-Fall-2017.html

In addition to the course web page, there is also a Moodle page for this course which I will frequently use in distributing course materials, communicating with the class, etc. The Moodle page can be found at

- https://moodle.lafayette.edu/course/view.php?id=11686

Occasionally, it may be necessary for me to communicate additional information (scheduling changes, clarifications about homework problems, etc.) to the class as a whole. When I do so, I will use your official Lafayette email addresses for all course-related correspondence, so make sure to check your Lafayette email regularly.

Common Course of Study Outcomes Statement:

This course (and particularly the lab component) will promote the following outcomes for Natural Sciences (NS) within the Lafayette Common Course of Study:

- NS1: Employ the fundamental elements of the scientific method in the physical and natural world.
  (a) Identify and/or formulate a testable scientific hypothesis.
  (b) Generate and evaluate evidence necessary to test and/or revise a hypothesis.
- NS2: Create, interpret, and evaluate descriptions and representations of scientific data including graphs, tables, and/or models.
- NS3: Understand how scientific uncertainty informs the evaluation of hypotheses.

Moodle Privacy Statement:

Please note that Moodle contains student information that is protected by the Family Educational Right to Privacy Act (FERPA). Disclosure to unauthorized parties violates federal privacy laws. Courses using Moodle will make student information visible to other students in this class. Please remember that this information is protected by these federal privacy laws and must not be shared with anyone outside the class. Questions can be referred to the Registrar's Office.

Mandatory Credit-Hour Statement:

The student work in this course is in full compliance with the federal definition of a four-credit-hour course. The full policy and practice statement can be found on the Registrar's Office website at

- http://registrar.lafayette.edu/additional-resources/cep-course-proposal/

In Closing

If you have any questions about this syllabus, or about any aspect of the course, please don't hesitate to contact me. By the end of this semester, you can look forward not only to having developed a deep understanding of the fundamental principles of special relativity and particle physics, but also to having a sense of what fundamental unanswered questions we still have about how nature works are, what the most exciting research efforts in physics are right now, and how you yourself could contribute to those efforts as a member of the physics community.