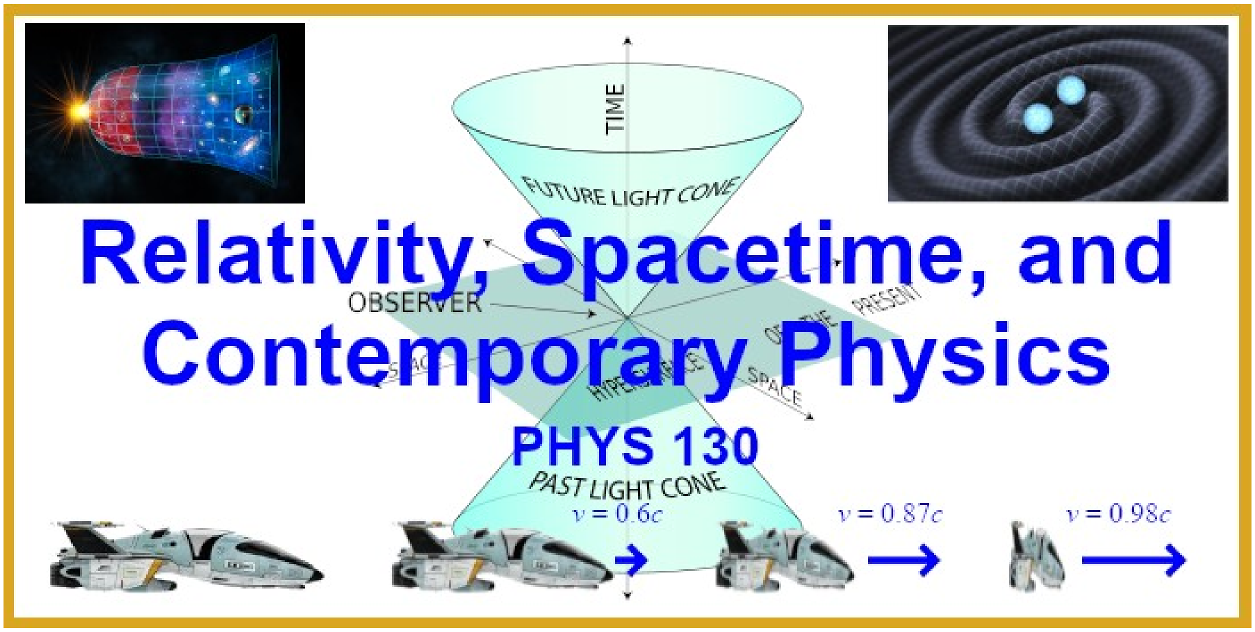

Relativity, Spacetime, and Contemporary Physics (PHYS 130)

Fall Semester, 2025

Instructors:

Lecture: Brooks Thomas
Email: thomasbd@lafayette.edu
Office: Hugel 020
Phone: (610) 330-5207

Lab: Scott Shelley
Email: shelleys@lafayette.edu
Office: Hugel 015
Phone: (610) 330-5223

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 physics discoveries hat have taken place during the 21st Century (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 able to reconcile observations made by different observers by **performing Lorentz transformations** and **constructing spacetime diagrams**.
- 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 course include an understanding of basic algebra, geometry, and trigonometry. You should be aware 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. Calculus is not a prerequisite for this course. However, MATH 161, which provides a basic introduction to the subject, is a co-requisite, and some knowledge of the subject will certainly enrich your experience in this course.

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 10:35 – 11:25 AM 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 on problem-solving activities with your peers. 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**. A portion of your grade in this course is based on class participation, and that portion of your grade will of course be reduced whenever you miss class or arrive significantly late to class without a valid reason (an illness, a family emergency, a religious holiday, participation in a College-sanctioned athletic event, etc.). In situations in which an Absence Verification is available, it is also your responsibility to provide me with that document. You are responsible for knowing anything covered in class, even if you have to miss class for *any* reason – even a valid one.

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*, 4th Ed. (McGraw-Hill Education, 2023).

This text is available from the Lafayette College Store. Alternatively, the 3rd Edition of this same textbook, which is almost identical to the 4th Edition and available in paperback and is therefore an acceptable substitute, may be acquired from any number of sources, including online retailers. 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.

<u>Homework Assignments</u>:

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 valid 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.

<u>Mid-Term Exams and Final Exam</u>**:**

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 1:15 – 3:00 PM on Thursday, Sept. 25th and one from 1:15 – 3:00 PM on Thursday, Oct. 30th**. 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.

<u>Laboratory:</u>

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 **from 1:15 – 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.

<u>Grading</u>

<u>Course Grade:</u>

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%

In calculating your homework grade, I will drop the individual homework assignment on which your receive the lowest percentage of possible points.

Instructor Drop-In Hours (a.k.a. "Office Hours"):

Drop-in hours are blocks of **time that I set aside specifically for you** and for other students in classes that I am currently teaching – they are times during which, for example, you can ask me to go over concepts that we've been studying in class again, get homework help, or ask me questions about any other aspect of the course. Sometimes these blocks of time are referred to as "office hours," but in this case, this is a misnomer because they will be held not in my office, but rather in Hugel 125. My drop-in hours this semester will be held on **Wednesdays from 12:00 noon – 1:00 PM**, on **Thursdays from 11:00 AM – 12:00 noon**, and on **Fridays from 9:00 – 10:00 AM** unless otherwise noted on the course web page. If you and other students in the course have the same question, you are welcome – and in fact encouraged – to meet with me during my drop-in hours as a group.

The default assumption is that my drop-in hours will take place in person. However, if the need arises for you to attend drop-in hours virtually at any point during the semester (e.g., because of a winter-weather emergency or an illness), please email me in advance to schedule a virtual drop-in-hours meeting. Such meetings will take place over my drop-in-hours Zoom link, which is

- https://lafayette.zoom.us/j/89137906511

The password is provided on the course Moodle.

If you are unable to make it to these official drop-in hours either virtually or in person, you may also email me to make an appointment to meet at some other time. However, I recommend that you do this as far in advance as possible in order to ensure that we can find a time to meet.

Intellectual Honesty:

All exams in this class are closed-book. Calculators are permitted, including graphing calculators (e.g., calculators similar to the Texas Instruments TI-84), but the use of cell phones and cell-phone-based calculator-emulator apps is not permitted on exams. 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.

One of the goals of this class is to help you develop your own intuition about how to apply your physics knowledge in practice. For this reason, the use of tools based on generative artificial intelligence (AI) when working on homework problems and taking exams is prohibited in this class (with exceptions made for rudimentary tools associated with basic text-autocorrect or search-engine functionality). However, if you believe that other applications of tools based on generative AI will help further your learning in this course, you should feel free to make use of them in those capacities.

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

- https://conduct.lafayette.edu/student-handbook/

Other Useful Information

Student Academic Resources Site:

This is a centralized website for Lafayette students which contains resources related to college-transition support, accessibility services, tutoring, health and well-being, advising and registration, technology help, library services, student funds, and more. A link to the site is provided below

https://spaces.lafayette.edu/enrol/index.php?id=1276

You are encouraged to self-enroll in this site and to bookmark it for future reference.

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 Accessibility Services Office (administered by the Academic Resource Hub) for disability verification and for the determination of reasonable academic accommodations. Accessibility Services will then provide me with a document which outlines what those accommodations are. I cannot provide accommodations until I receive 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:

As the semester progresses, 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, throughout the semester, you'll have the opportunity to fill out a short surveys and informal evaluations so I can get your feedback.

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

- https://workbench.lafayette.edu/~thomasbd/Phys130-RelativityContempPhys-Fall-2025/Phys130-RelativityContempPhys-Fall-2025.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=30620

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:

For students in the Class of 2016 through the Class of 2028, this course will promote the following outcomes in connection with the Natural Sciences (NS) attribute within the Lafayette Common Course of Study:

- NS1: Employ the fundamental elements of the scientific method in the physical and natural world by identifying and evaluating a testable scientific hypothesis.
- NS2: Create and evaluate descriptions and representations of scientific data via equations, graphs, tables, and/or models.

Likewise, for students in the Class of 2029, this course will promote these outcomes NW1 and NW2 in connection with the Study of the Natural World (NW) attribute within the revised Common Course of Study, the descriptions of which are identical to the descriptions of the outcomes NS1 and NS2 quoted above.

Health Protocols:

At the moment, masking is not required during class meetings or during my office hours under normal circumstances, though I encourage you to wear a mask if it makes you feel more comfortable. However, this policy may change at any point during the semester is circumstances change. In any event, if you are experiencing symptoms (cough, chills, fever, sore throat, etc.) typically associated with communicable respiratory illnesses, you are required to wear a mask while your symptoms persist, even if those symptoms are mild. If you do not feel well enough to attend class meeting, inform me of the situation by email and do not come to class. You are of course also required to abide by all campus-wide health protocols established by Lafayette College while they remain in effect. Health protocols for the lab portion of this class will be established separately by Scott Shelley.

Contingency Procedures for Virtual Class Meetings:

The default expectation is that all class meetings this semester will be held in person in Hugel 017. However, under certain circumstances (e.g., the campus closes due to a winter-weather emergency) we may temporarily be compelled to move those meetings online. If this should occur, the Zoom link that we will use for these class meetings is

- https://lafayette.zoom.us/j/99942989789

The password is provided on the course Moodle. I will notify all members of the class by email as far in advance as possible if we need to switch to a virtual classroom environment at any point during the semester. The assumption is that if this should even happen, we will return to an in-person learning environment as soon as circumstances permit.

If we are ever temporarily forced to move to a virtual format, I would like us to be able to simulate the atmosphere of a physical classroom to whatever extent we can. For this reason, I would like to ask that you have your camera on during any virtual class meetings we end up having and to use the "gallery view" option on Zoom so that we can all see each other and respond to each other's visual cues. I will do the same. That said, if there are extenuating circumstances which would make having your camera on an issue for you, please reach out to me and we will work out an equitable solution. Please mute yourself when you are not speaking in order to reduce background noise. Please raise your actual hand in order to take part in the discussion. If I do not see your actual hand, please raise your "digital hand."

Privacy Statement Concerning Course Materials and Classroom Recordings:

At Lafayette College, all course materials are proprietary and for class purposes only. This includes posted recordings of lectures, worksheets, discussion prompts, and other course items. Reposting such materials or distributing them through any means is prohibited. Such materials should not be reposted or distributed through any means. You must request my permission prior to creating your own recordings of class materials, and any recordings are not to be shared or posted online even when permission is granted to record. Permission will be granted only when sanctioned as an academic accommodation in an official letter from the Accessibility Services Office. If you have any questions about proper usage of course materials please ask me. Please also be in contact with me if you have any concerns with being recorded during the course.

Online discussions in Moodle occurring during synchronous class sessions should also remain private and not be shared outside of the course. Courses using Moodle will make student information visible to other students in this class. Student information in courses is protected by the Family Educational Right to Privacy Act (FERPA). Disclosure of student information to unauthorized parties violates federal privacy laws and it 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

- https://registrar.lafayette.edu/wp-content/uploads/sites/193/2022/07/Federal-Credit-Hour-Policy-Web-Statement.pdf

Winter-Weather Emergencies:

You should assume that class meetings will occur as usual, despite any weather-related issues (including power outages), even if campus offices open late or close early. In the rare event that class must be canceled, I will notify the class by email, and by leaving a voicemail message on my office phone, the number for which is (610) 330-5207.

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 to having both a better understanding of *why* things in the natural world behave the way they do and a practical grasp of *how* to apply fundamental physics principles toward solving the kinds of problems that scientists and engineers grapple with every day of their lives.

Course Schedule

The full, up-to-date schedule for the course, including due date for all assignments is available on the course web page.

Week	Topics and Readings	Due Dates
Week 1 8/25 – 8/29	**Velocity and Coordinate Transformations** Moore C: 1.1 – 1.9, 2.1 – 2.8, 3.1 – 3.6	HW 1 (Due 8/29)
Week 2 9/1 – 9/5	**Momentum and Energy** Moore C: 4.1 – 4.6, 5.1 – 5.6, 6.1 – 6.6	HW 2 (Due 9/5)
Week 3 9/8 – 9/12	**Spacetime Diagrams** Moore R: 1.1 – 1.6, 2.1 – 2.7	HW 3 (Due 9/12)
Week 4 9/13 – 9/19	**The Geometry of Spacetime** Moore R: 3.1 – 3.7	HW 4 (Due 9/19)
Week 5 9/22 – 9/26	**Time Dilation** Moore R: 4.1 – 4.6, 5.1 – 5.6	Midterm I (9/25)
Week 6 9/29 – 10/3	**Length Contraction** Moore R: 6.1 – 6.6	HW 5 (Due 10/3)
Week 7 10/6 – 10/10	**Velocity Transformations** Moore R: 7.1 – 7.4, 8.1 – 8.3	HW 6 (Due 10/10)
Week 8 10/13 – 10/17	**Four-Momentum** Moore R: 8.4 – 8.6, 9.4	HW 7 (Due 10/17)
Week 9 10/20 – 10/24	**General Relativity** Moore R: 9.1 – 9.3, 9.5 – 9.6; Taylor: 8; Handouts	HW 8 (Due 10/24)
Week 10 10/27 – 10/31	**Atoms and Atomic Nuclei** Taylor: 9; Krane: 12.1 – 12.4, 12.6 – 12.9	Midterm II (10/30)
Week 11 11/3 – 11/7	**The Fundamental Building Blocks of Nature** Griffiths: 1.1 – 1.4, 1.6 – 1.9, 2.1	HW 9 (Due 11/7)
Week 12 11/10 – 11/14	**Interactions Between Particles** Griffiths: 1.10, 2.2 – 2.4	HW 10 (Due 11/14)
Week 13 11/17 – 11/21	**Neutrinos and the Higgs Boson** Griffiths 1.5, Handouts	HW 11 (Due 11/21)
Week 14 11/24 – 11/28	**Colliders and Detectors** Handouts	
Week 15 12/1 – 12/5	**Cosmology and Dark Matter** Griffiths: 5.1, 5.4; Handouts	HW 12 (Due 12/5)
Final Exam Week		Final (TBA)