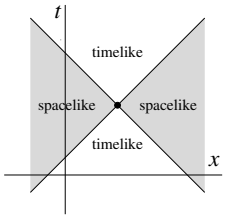
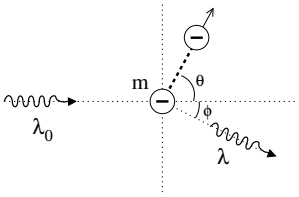
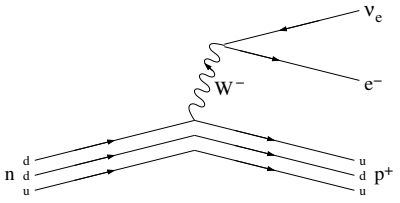
Physics 130: Relativity, Spacetime, and Contemporary Physics
Lafayette College
Fall 2023







About this course

Physics 130 is the first course in Lafayette's introductory Physics sequence. We created this course a few years ago with the goal of putting interesting, exciting, contemporary material into the forefront of the physics curriculum. While designed as the first course in our curriculum, Physics 130 can also be taken after taking other courses such as introductory mechanics.

The first two weeks of this course will introduce some classical physics concepts: units, vectors, velocity, energy, momentum, and conservation laws. This will serve as a foundation for the rest of the semester.

The next nine weeks will cover special relativity, Einstein's theory of space and time. We will see how such non-intuitive phenomena as length contraction and time dilation are inevitable consequences of the principle of relativity, and how seemingly paradoxical observations can be reconciled by careful analysis within the framework of relativity. We will emphasize both geometric understanding and mathematical calculations. We will study conservation of four-momentum, which encapsulates conservation of both relativistic momentum and relativistic energy.

We will then take two weeks to explore some aspects of general relativity, focusing the curvature of space around objects like stars and black holes.

The final two weeks of the course will give a brief view into elementary particle physics, the study of the most fundamental constituents of matter. We will describe phenomenological observations of atoms, nuclei, and elementary particles. We will cover the Standard Model of particle physics, which posits that matter is made up of quarks and leptons, and that forces between particles are mediated by gauge bosons. We will see how conservation laws are fundamental to understanding particle interactions.

Course topics and schedule

This is an approximate plan of topics. It will evolve as the semester progresses. Weekly topic lists will be given on each homework set.

Week	Dates	Topics	Exams
1	Aug. 28-Sep. 1	Course overview Velocity Vectors	
2	Sep. 4-8	Momentum Energy	
3	Sep. 11-15	Galilean relativity The need for special relativity Spacetime diagrams	
4	Sep. 18-22	SR units Coordinate time Proper time Spacetime interval	Exam #1 Sep. 21
5	Sep. 25-29	Metric equation Time dilation Lorentz factor Binomial approximation Two-observer diagrams	
6	Oct. 2-6	Lorentz transform Matrix multiplication Lorentz transform matrix	
7	Oct. 9-13	*Fall Break* Relativistic beaming Length contraction Dot product	
8	Oct. 16-20	Simultaneity & Non-simultaneity Causality	
9	Oct. 23-27	Velocity transformation Four-momentum	
10	Oct. 30-Nov. 3	Four-momentum conservation Mass of a system Photons	
11	Nov. 6-10	Photon momentum Relativistic Doppler shirt	Exam #2 Nov. 9
12	Nov. 13-17	General relativity overview GR units Schwarzschild metric Proper time Black holes	
13	Nov. 20-24	Gravitational redshift *Thanksgiving break*	
14	Nov. 27-Dec. 1	General Relativity experiments Gravitational waves Particle physics fundamentals *Thanksgiving break*	
15	Dec. 4-8	Electroweak force Particle physics examples	
Finals	Dec. 12-19		Exam #3

Course operations

Instructors

Prof. David Nice (class)
Hugel Science Center 030
niced@lafayette.edu
`http://sites.lafayette.edu/niced`

Scott Shelley (lab)
Hugel Science Center 034
shelleys@lafayette.edu

Course locations and times

Class: Monday, Wednesday, and Friday, 2:10-3:00
Hugel Science Center 017

Lab: Thursday, 1:10-4:00
Hugel Science Center 142

Office hours

I will have office hours for several hours a week. Details will be announced near the start of the semester and posted on Moodle. If you cannot make office hours, feel free to drop by and try your luck, or E-mail for an appointment.

Course website

We will use moodle, `http://my.lafayette.edu` or `http://moodle.lafayette.edu`.

Text and other readings

The following text is required and are available through the college bookstore:

Thomas Moore, *Six Ideas That Shaped Physics: Unit R: The Laws of Physics Are Frame–Independent.* Fourth edition. (McGraw Hill, 2023). ISBN 978-1-264-87761-4.

We will supplement this with other readings which will be distributed by Moodle. They will include excerpts from the following (and perhaps others):

- Thomas Moore. *Six Ideas That Shaped Physics: Unit C: Conservation Laws Constrain Interactions.* Third edition (McGraw-Hill, 2003).
- David Griffiths. *Introduction to Elementary Particles.* Second edition (Wiley, 2008).
- Edwin F. Taylor, John. A. Wheeler, and Edmund Bertschinger, *Exploring Black Holes: Introduction to General Relativity.* Second edition (2018), no print version, available free online at `https://www.eftaylor.com/exploringblackholes/`.

Prerequisites

Math 161 is a co-requisite of this course. It can be waived by permission of the instructor.

Physics 130 typically precedes Physics 131 or 151, but it can also be taken after Physics 131 or 151, or it can also be taken as a stand-alone course.

Homework

Weekly homework assignments will be distributed in class and on moodle. They will be due in class on Wednesdays, except for the first assignment which will be due on Friday. They should be submitted on paper.

You are strongly encouraged to work with other students on the homework. Try the problems yourself. When you get stuck, talk to someone else about them. Physics is hard. You won't get all the problems on your own. Working with others is an essential part of learning physics.

Labs

You will perform and analyze numerous experiments over the course of the semester on a variety of modern physics topics. Our goal is to introduce you to some interesting physics ideas as well as to develop your lab skills.

Contact the lab instructor, Scott Shelley, for any questions regarding lab.

Exams

There will be three exams. The list below gives dates and approximate topic coverage for each exam. More details of each exam (topic coverage, whether or not open-book, whether or not equation sheets are provided, etc.) will be given approximately one week before that exam. Two of the exams are scheduled for lab periods. Holding exams in lab periods is intended to reduce time pressure, since lab periods are longer than class periods.

- *Exam #1* will be during the lab period on Thursday, September 21. It will cover material from the early part of the course, including classical physics concepts (energy, momentum, vectors, etc.) and material from the first week of relativity (particularly Galilean relativity).
- *Exam #2* will be on Thursday, November 9. This exam will cover material on special relativity.
- *Exam #3* will be during final exam week at a time determined by the Registrar. This exam will cover material on general relativity and particle physics.

Exam questions will resemble problems worked on homework and discussed in class.

Exam procedures (e.g., whether or not open-book, whether or not equations sheets are provided) will be announced in advance of each exam.

Grades

There must be grades. Your grade will be based on:

Homework	30%	Exam #1	10%
Lab	20%	Exam #2	25%
		Exam #3	15%

I will post homework and exam grades on Moodle. The exam grades may be re-scaled depending on the difficulty of the exam. I will use the following numerical score when setting letter grades:

A	92.500 and higher	B−	79.500−82.499	D+	66.500−69.499
A−	89.500−92.499	C+	76.500−79.499	D	62.500−66.499
B+	86.500−89.499	C	72.500−76.499	D−	59.500−62.499
B	82.500−86.499	C−	69.500−72.499	F	59.499 and below

Whom we root for (besides Lafayette, of course)

We root for the Philadelphia Eagles. In emergency situations, when the Philadelphia Eagles are not available to be rooted for, we root for the Green Bay Packers.

Objectives and Outcomes

Objectives

In this course you will...

... see why conventional physical thought, including Newton's laws and Euclid's geometry, leads to contradictions with observations.

... learn about classical physics concepts such as energy and momentum.

... see how the principle of relativity leads to a new understanding of space and time.

... learn how to use Lorentz transformations and spacetime diagrams to reconcile observations.

... use 4-vectors to perform energy-momentum calculations and analyze particle interactions.

... see the experimental basis for our modern view of fundamental particles.

... learn about the Standard Model of particle physics, including the fundamental particles of which the universe is made and the forces that govern their interactions.

... understand conservation laws.

... explore a variety of physics phenomena in a lab setting.

... gain an understanding of topics of current physics research.

Learning Outcomes

After taking this course you will be able to...

... demonstrate an ability to work quantitative physics problems.

... explain and reconcile "paradoxical" phenomena in relativity.

... perform energy-momentum calculations and analyze particle interactions.

... identify the components (particles and interactions) of the Standard Model.

... use spacetime metrics for relativistic calculations.

Within the Lafayette Common Course of Study, this course (particularly the lab component) will promote the following outcomes for Natural Sciences:

- 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.

Course Policies

Intellectual Honesty

You are expected to abide by the principles of intellectual honesty outlined in the Lafayette Student Handbook available at `http://conduct.lafayette.edu`.

Learning is a collaborative process, I encourage you to discuss and collaborate with other students on homework. "Collaboration" does not mean "copying." You must understand and individually write out your answer to each problem.

Exams must be done on your own, using only materials specifically allowed.

Accommodation

My policy. It is important to me that you do well in this class. If you have any disabilities which you feel may interfere with your ability to succeed and prosper in this class, please contact me to discuss ways of accommodating them.

Mandatory statement for any Lafayette course with a disability policy. 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. Requests for academic accommodations need to be made during the first two weeks of the semester, except for unusual circumstances, so arrangements can be made. Students must register with the Office of the Dean of the College for disability verification and for determination of reasonable academic accommodations.

Mandatory Moodle Privacy Statement

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.