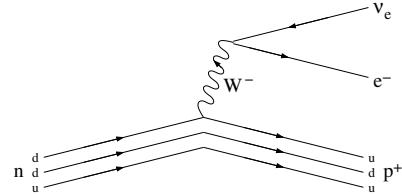
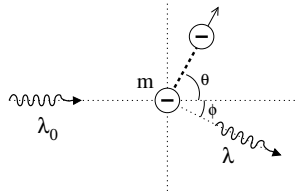
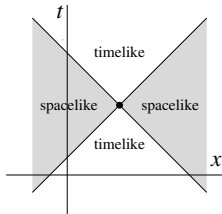


# Physics 130: Relativity, Spacetime, and Contemporary Physics

## Lafayette College

### Fall 2022



### *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 seven 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 one week to explore some aspects of general relativity, in particular the curvature of space around objects like stars and black holes and the expansion of space over cosmological time scales.

The final five weeks of the course will cover 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.

Week	Dates	Topics	Exams
1	Aug. 29-Sep. 2	Units Velocity Vectors	
2	Sep. 5-9	Momentum Energy	
3	Sep. 12-16	Galilean relativity Spacetime diagrams	
4	Sep. 19-23	Three kinds of time Metric equation	Exam #1 Sep. 22
5	Sep. 26-30	Time dilation Two-observer diagrams	
6	Oct. 3-7	Lorentz transform Length contraction	
7	Oct. 10-14	<i>Fall Break</i> Causality Velocity transform	
8	Oct. 17-21	Momentum-energy four-vector Photons	
9	Oct. 24-28	Momentum-energy four-vector (cont'd) Metric in general relativity	
10	Oct. 31-Nov. 4	Metric in general relativity Schwarzschild metric Friedmann-Robertson-Walker metric	
11	Nov. 7-11	Nuclei Nuclear decay	Exam #2 Nov. 10
12	Nov. 14-18	Leptons Neutrinos Quarks	
13	Nov. 21-25	Forces and interactions Feynman diagrams Strangeness	
14	Nov. 28-Dec. 2	Quarks (continued) Electroweak force <i>Thanksgiving break</i>	
15	Dec. 5-9	Electroweak force (continued) Neutrino mixing	
Finals	Dec. 13-20		Exam #3

## ***Course operations***

### ***Instructors***

Prof. David Nice (class)  
Hugel Science Center 030  
niced@lafayette.edu

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

<http://sites.lafayette.edu/niced>

### ***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://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 (no print edition; available free online, 2018).

### ***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. It can also be taken as a stand-alone course.

## ***Homework***

Weekly homework assignments will be distributed in class and on moodle.

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, as listed below. There is a small chance that exam dates will change, in which case the change will be announced at least one week in advance. Two of the exams are scheduled for lab periods. The longer lab periods (compared to class periods) are intended to reduce time pressure on exams.

The list below gives approximate topic coverage for each exam. A more detailed description of topic coverage will be announced around a week before each exam.

- *Exam #1* will be during the lab period on Thursday, September 22. 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 10. This exam will cover all 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 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 well in advance of each exam.

## ***Grades***

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

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

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.