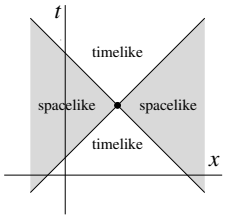
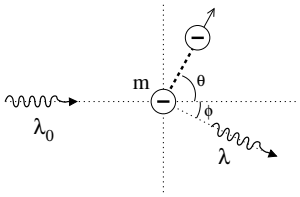
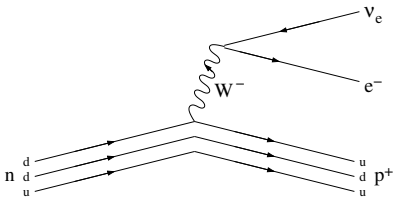
Physics 130: Relativity, Spacetime, and Contemporary Physics

Lafayette College Fall 2014







About this course

We are very excited to be offering Physics 130 for the first time in Fall 2014!

Physics 130 is the first course in Lafayette's newly-revised introductory Physics sequence. Our goal in creating this course was to put interesting, exciting, contemporary material into the forefront of the physics curriculum.

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.

The final six 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 discuss topics of contemporary experimental study such as neutrino mixing and the recently-discovered Higgs boson.

Instructors

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Course schedule

This is an approximate plan of topics, readings, and labs; it may change as the semester progresses.

Week	Dates	Instructor	Text*	Topic	Lab
1	Aug. 25-29	ZB		Units Velocity Energy	Measuring absolute zero
2	Sep. 1-5	ZB		Vectors Momentum	—
3	Sep. 8-12	ZB	R1-2	Galilean relativity Spacetime diagrams	—
4	Sep. 15-19	ZB	R3-4	Three kinds of time Metric equation *Exam #1*	Speed of light
5	Sep. 22-26	DN	R5-6	Time dilation Two-observer diagrams	—
6	Sep. 29-Oct. 3	DN	R6-7	Lorentz transform Length contraction	Polarization of light
7	Oct. 6-10	DN	R8-9	Causality Velocity transform Momentum four-vector	—
8	Oct. 13-17	DN	R9-10	*Fall break* Momentum four-vector (cont'd)	Hydrogen spectrum
9	Oct. 20-24	ZB	R10	Momentum four-vector (cont'd) Metric in general relativity *Exam #2*	(Exam #2 in lab time)
10	Oct. 27-31	ZB	CO1-3	Atoms Nuclei	Nuclear decay
11	Nov. 3-7	ZB	CO4-6	Forces Feynman diagrams Strangeness Quarks	—
12	Nov. 10-14	DN	CO6-8	Quarks (cont'd) Quantum Chromodynamics Electroweak force	Music & Fourier analysis
13	Nov. 17-21	DN	CO8-10	Electroweak force Top quark W and Z bosons	Digital electronics
14	Nov. 24-28	DN	CO11	CP violation *Thanksgiving break*	—
15	Dec. 1-5	DN	CO12-14	Neutrinos Higgs Boson Cosmology	—
Finals				*Exam #3*	

*R: Moore, *Six Ideas That Shaped Physics, Unit R*
CO: Close, *Cosmic Onion*

Course Website

We will use moodle, http://moodle.lafayette.edu.

Course Locations and Times

Class: Monday, Wednesday, and Friday, 10:00-10:50
Hugel Science Center 115

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

Lab will meet approximately every other week. The anticipated lab meeting dates (subject to change with two weeks advance notice) are: Aug. 28; Sep. 18; Oct. 2, 16, 10; Nov. 13; Nov. 20. (The Oct. 23 lab meeting time will be used for Exam #2.)

Office hours

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

Texts

The following texts are required and are available at the college bookstore:

- Thomas Moore. *Six Ideas That Shaped Physics: Unit R: The Laws of Physics Are Frame-Independent.* Second edition, 2003. McGraw Hill. ISBN 9780072397147.
- Frank Close. *The New Cosmic Onion* 2007. CRC Press. ISBN 9781584887980.

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 seven experiments over the course of the semester on a variety of modern physics topics, including measurements of the speed of light, experiments with digital electronics, and optical spectroscopy.

Exams

There will be three exams:

- *Exam #1* will be on Friday, September 19. This will cover material from the first three weeks of the course, including classical physics concepts (energy, momentum, vectors, etc.) and material from the first week of relativity (Galilean relativity, spacetime diagrams). It will be a 50 minute exam taken in class.
- *Exam #2* will be on Thursday, October 23. This exam will cover all material on special relativity. It will be one hour and 50 minutes, and will be given during the lab time.
- *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%
Homework	25%
Exam #1	10%
Exam #2	25%
Exam #3	25%

Participation, effort level, etc., may be factored into your final grade after your score is calculated as described above. This will be most important if you are on the borderline between two grades.

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.

... describe how our modern view of particle physics came to be.

... use your understanding of relativity for further exploration of physical laws.

In addition to the outcomes listed above, this course will promote the following outcomes from the Natural Sciences section of the Common Course of Study:

- NS1. Understand that the goal of science is to comprehend phenomena in the physical and natural world.
- NS2. Employ the fundamental elements of the scientific method:
  - NS2a. Demonstrate the ability to recognize and/or formulate a testable hypothesis based upon observations or existing scientific data;
  - NS2b. Generate, collect, and analyze evidence relevant to testing a hypothesis;
  - NS2c. Evaluate whether the evidence supports or refutes the hypothesis or leads to the development of a new line of inquiry and/or a revision of the original hypothesis.
- NS3. Create, interpret, and critically evaluate descriptions and representations of scientific data including graphs, tables, and models.
- NS4. Understand scientific uncertainty and how it is reduced with additional data acquisition and hypothesis testing.
- NS5. Distinguish the difference between scientifically testable ideas and opinion.

It will also promote the following outcomes from the Quantitative Reasoning section of the Common Course of Study:

- Q1. Interpret mathematical models such as formulas, graphs, tables, and schematics, and draw inferences from them.
- Q2. Represent quantitative information symbolically, visually, numerically, and verbally and draw conclusions from that information.
- Q3. Use arithmetical, algebraic, geometric, or statistical methods to solve problems that arise in different settings,.
- Q4. Analyze mathematical results to determine their reasonableness and validity.

Intellectual honesty

You are expected to abide by the principles of intellectual honesty outlined in the Lafayette Student Handbook (available from http://studentlife.lafayette.edu).

Learning is a collaborative process. Discussion and collaboration on homework in this course is very strongly encouraged. "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. This will be discussed in detail before each exam.

Accommodation

Our policy. It is important to us that nothing impedes your ability to do well in this course. If you have any disabilities which you feel may interfere with your ability to succeed and prosper in this class, please contact us 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, We are 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. Please see the Registrar's Office web site for the full policy and practice statement (http://registrar.lafayette.edu/additional-resources/cep-course-proposal/).