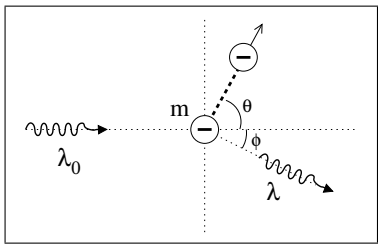
Physics 215:
Introduction to Quantum Physics
(And special relativity, too!)
Lafayette College
Fall 2013



Instructor

Prof. David Nice
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Course Website

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

Course Locations and Times

Class: Hugel Science Center 017
Monday, Wednesday, Friday; 10:00-10:50

Lab: Hugel Science Center 042
Time to be determined. See "Labs" section below.

Office hours

My schedule of office hours will be posted on moodle, on my homepage, and on my office door. The weekly times will vary a bit at the start of the semester but will then settle into a regular pattern.

I am often available at other times. E-mail me if you wish to meet outside my usual hours, or just stop by my office and try your luck.

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 978-0-07-239714-7
- John S. Townsend. *Quantum Physics: A Fundamental Approach to Modern Physics.* 2010. University Science Books ISBN 978-1-891389-62-7

Prerequisites

Prerequisites for this course are Physics 132, 133, or 152. By the transitive property of course prerequisites, this implies that Physics 131 or 152, Math 161, and Math 162 are also prerequisites.

Homework

There will be weekly homework assignments, due Thursday at 5 p.m. in a bin in the hallway near my office door. (Exception: Homework #1 is due on Friday.) Late homework papers will be accepted for 50% credit through the following Monday at 5 p.m.. If you cannot complete a homework due to illness, family emergency, or similarly compelling reason, contact me. (Also see the section on "Dean's excuse policy" in the Student Handbook.)

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 absolutely essential in advanced physics classes.

I will have extensive office hours. You will find some homework problems very challenging or confusing. Please come and visit. I am here to help. This is how you learn.

Labs

You will perform and analyze seven experiments over the course of the semester. Each experiment will begin with an orientation session (scheduling to be determined). After that, you will free to work on the experiment either that afternoon or at a later time. You will be given a key to the lab room. You will work in pairs. There will only be one or two sets of apparatus for each experiment, so you will need to schedule a time to work to avoid running into other students. I will set up a wiki page on the course moodle site for scheduling.

For each lab, an instructional writeup will be supplied ahead of time. You will need a lab notebook. You should get a notebook which has sewn-in pages (this is standard for lab books) and is quadrille ruled (graph paper). Any notebook which satisfies these criteria is acceptable. Details of note-keeping, writeups, etc., will be given at the time of the first experiment.

You and your lab partner will work closely together, but you will maintain separate lab notebooks.

Week	Experiment
2	Speed of light I. Time of travel
4	Speed of light II. Interferometer
7	Photoelectric effect
9	Interference patterns
11	Frank-Hertz experiment
13	Spectrometer I. Sodium
15	Spectrometer II. Hydrogen

Exams

There will be three exams. The first two will be on Friday, October 4, and Friday, November 15 You will have one hour and fifty minutes for each of these exams, including 60 minutes before or after the regular class time on that day. (If you have schedule conflicts before and after class time, we will find an alternate time later that day.) The third exam will be three hours, during finals week, at a time and place designated by the registrar.

The first exam (October 4) will be on special relativity, which is material that will be covered in the first five weeks of the semester. This is the only exam in this course which will cover special relativity. The exam will be closed book with an equation sheet provided.

The second exam (November 15) will be on quantum mechanics material from the seventh week through the eleventh week of the semester. This exam will be closed book with an equation sheet provided.

The third exam (Finals week) will be on all quantum mechanics material covered throughout the course. It will be weighted more heavily on material from the last weeks of the semester, but it will include some material covered by the second in-class exam. It will be open book (course text only) with an integral table provided.

Exam questions will resemble homework problems.

Grades

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

Lab	10%
Homework	20%
Exam #1	25%
Exam #2	20%
Exam #3 (finals week)	25%

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

What to call me

Please, let's all use first names. Call me David.

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.

The revolution begins now

The subjects you will study this semester, special relativity and quantum mechanics, were a revolution in humankind's understanding of the physical world when they were developed. To this day, the rules of special relativity and quantum mechanics seem bizarre and un-intuitive, yet they are absolutely needed to explain experiments involving matter at microscopic scales (quantum mechanics) and at high energies and speeds (special relativity). They provide a foundation for advanced work in physics, and they form the basis of most modern physics research, underlying everything from nanotechnology to cosmology.

You will be introduced to special relativity and quantum mechanics; you will see why they are needed to explain outcomes of experiments (some of which you will perform yourself in lab); you will learn to make qualitative and quantitative analysis of situations in which special relativity or quantum mechanics must be invoked; you will use modern computing tools (Mathematica) to make quantum mechanical calculations; and you will hone your skills at performing analytical calculations to predict and analyze physical phenomena.

The list below shows the topics which we will cover this semester, along with the corresponding sections of the textbooks and a rough estimate of which week each topic will be covered. The schedule may evolve as the semester progresses. Specific topic and text coverage will be given on a weekly basis on the homework assignments.

Week	Topic	Text*
1	Galilean relativity, Spacetime diagrams, Types of time	M §R1, R2, R3
2	Metric equation, Time dilation, Lorentz transform	M §R4, R5, R6
3	Lorentz transform (cont'd), Lorentz contraction, Causality	M §R6, R7, R8
4	Velocity transform, Four-momentum	M §R9, R10
5	Four-momentum of photons, Compton effect, Doppler effect	M §R10, RB
6	Black holes and the Schwarzschild metric; *Exam #1*	Handout†
7	Quantum mechanics overview; Waves, Complex numbers	T §1
8	*Fall break*; Light, Waves, Complex numbers (cont'd)	T §1
9	De Broglie wavelength, Schrödinger equation, Wavefunctions	T §2
10	Momentum operator, Schrödinger eqn. (cont'd)., Particle in a box	T §2, 3
11	Orthonormal functions, Hamiltonian operator, Finite square well	T §3, 4
12	Wavefunction shapes, Scattering; *Exam #2*	T §4
13	Tunneling, Harmonic oscillator, Operators, uncertainty relations	T §4
14	Delta functions; *Thanksgiving break*	T §5, Handout†
15	Three-dimensional wavefunctions, Hydrogen atom	T §6
Finals	*Exam #3*	

*M=Moore, *Six Ideas, Unit R*; T=Townsend, *Quantum Physics*

†Reading handout week 6: Taylor & Wheeler, *Spacetime physics*, pp. 2-17–2.49.
Reading handout week 13: Liboff, *Introductory Quantum Mechanics*, §3.1–3.3.

Outcomes

After completing this course, you will be able to....

- Explain the need for the theory of special relativity
- Use Lorentz transformations and spacetime diagrams to reconcile observations made in different reference frames
- Use 4-vectors to perform energy-momentum calculations and analyze particle interactions
- Explain counter-intuitive aspects of relativity ("paradoxes")
- Understand the experimental need for quantum mechanics
- Qualitatively and quantitatively interpret quantum mechanical wavefunctions
- Understand properties of quantum mechanical operators
- Undertake detailed quantum mechanical calculations in situations such as square-well potentials and hydrogen atoms
- Use computer-based tools such as Mathematica for physical problem solving
- Use advanced lab equipment, including a high quality optical spectrometer

In addition to the outcomes listed above, this course (particularly the lab component) 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.

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. On labs, you should work closely with your lab partner. You may share data, but you must produce separate lab reports.

Exams must be done on your own, using only materials specifically allowed. This will be discussed in detail before each exam.

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.