Special Relativity

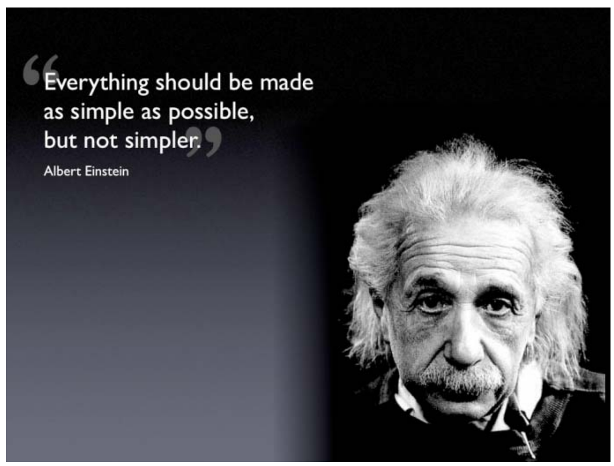
PHYS3019 — Special Relativity, Spring 2013

Lecturer: Jolyon Bloomfield, jkb84@cornell.edu
Lectures: Tuesday, Thursday 10:00-11:30 am 213 Rockefeller Hall
Office Hours: Monday, Wednesday 2:00-3:00 pm, PSB 430
Teaching Assistant: Karl Marx, km1@cornell.edu
Recitation Sections: Monday 12:10-1:00 pm 104 Rockefeller Hall
Grading: Letter grade only, 3 Credits
Website: Blackboard, http://physics.cornell.edu/~jbloomfield/phys3019/

Overview

Imagine you have a significant other who lives in Australia. Idly, you daydream of what they're doing at this moment. For some reason, your thoughts drift to what would change if they were on a planet orbiting Alpha Centauri. Is it even meaningful to think of what they're doing "at this moment"? Is there actually a difference between Australia and Alpha Centauri? While this course won't help you find a significant other who lives in Australia (or near Alpha Centauri), it will help you to understand the implications special relativity has for that question, and for physics in general.

Relativity has become the zeitgeist of modern physics, and it touches on almost all foundational aspects of physics. It is also a particularly beautiful theory, and one of my favourite subjects in physics. In this course, we'll start by exploring the ideas that led to its discovery and the experiments that validated it as a theory. We'll derive the important results from special relativity, and look at its application to mechanics, electromagnetism, field theory, and quantum mechanics.



This course is designed for junior to senior level students majoring in physics.

Course Goals

This course will teach you to:

- Appreciate the importance of relativity in modern physics
- Understand physical phenomena in the context of relativity
- Manipulate tools to investigate the physics of special relativity
- Develop key skills for professional scientific development, including presentation, problem solving, writing, and critical thinking skills

Course Outcomes

At the end of this course, you should be able to do the following:

- Explain the meaning and significance of the postulates of special relativity
- Describe the physics of simultaneity as it applies to theory, experiments, and your personal experiences
- Discuss significant experimental tests of special relativity
- Describe the significance and use of tensors in special relativity, including their transformation properties
- Analyze problems in special relativity, and apply appropriate tools to solve these problems
- Investigate the resolution of paradoxes in special relativity
- Describe relativistic phenomena, both qualitatively and quantitatively, and evaluate when relativistic effects become significant
- Research a topic in physics and present your findings both verbally and in written form

Prerequisites

Special relativity touches on many aspects of physics. As such, we will be drawing upon material from a number of different courses. At the very minimum, you must have completed a comprehensive course in Newtonian mechanics. Furthermore, courses containing the following content should have also been completed:

- Basic Quantum Mechanics, including the Schrödinger equation and perturbation theory
- Introductory Electromagnetism, up to and including Maxwell's equations
- Intermediate Classical Mechanics, in particular Lagrangian mechanics

At my discretion, it may be sufficient to be taking such courses concurrently with this one. No prior knowledge of special relativity will be required for this course.

Textbook

"Introduction to Special Relativity" by Wolfgang Rindler, Oxford University Press (1991)
I will set readings from this text, which will cover most but not all of the course content. It will often go into more detail than I have time to present in class, and so taking the time to read it will be important. The entire book is only 163 pages, so on average, there will be only around 15 pages of reading each week. It is the only detailed text on special relativity that I know of.

Assessment

Problem Sets: 40%

- 40% Weekly Problem Sets
- 5% Presentation of topic
- 10% Final paper
- 15% Preliminary Exam
- 30% Final Exam

The foundation of physics is the ability to describe nature with mathematical equations, and to make predictions based on our prior knowledge. To develop your skills at problem solving in physics, practising calculations is really important, and so the bulk of your grade will come from weekly problem sets. When doing problem sets, I want you to keep in mind that you are also practising presenting your work. Somebody who is familiar with the physics involved but not with the problem you are solving should be able to glean a thorough understanding of the solution from reading your homework. Given the confusing nature of special relativity, I expect about 20% of your problem sets to comprise of words and explanations, rather than just equations. To this end, 10% of your homework grade will be based on its presentation. There will be 10 problem sets.

Presentation (5%) and Final Paper (10%): 15%

In your final paper, you will be asked to choose a topic related to special relativity, research it, and present your findings in about four pages. The topic that you investigate should be described in mathematical language. I do not expect original work, but I do expect you to properly cite your references. You will be required to use LaTeX (or similar) to create this document.

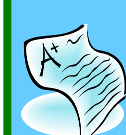
The first step will be to post your choice of topic (and breadth thereof) to the course discussion board. It is okay for multiple students to choose the same topic. Your choice of topic must be approved by me.

The first item of assessment pertaining to your final paper will be a presentation to me, in which you explain your topic with a blackboard. This is to be thought of as a draft presentation in which we develop your ideas and understanding, rather than a final polished presentation.

Next, you will draft your paper. You will be paired with another student in the class, and take the opportunity to read each other's drafts. You will be required to provide feedback on their draft, submitted to the course discussion board. Failure to do so will reduce your overall grade for the final paper from 15% to 13%. Your final papers will be graded with this feedback in mind.

Finally, the completed papers will be compiled into a collection for distribution to the entire class. The purpose of this final paper is to help develop your research skills, to let you explore something you find interesting, and to develop your writing and presentation skills.

Example topics



- Magnetic Monopoles
- Examining a paradox
- The Poincare group
- The Klein-Gordan/Dirac Equation

Preliminary Exam: 15%

Your first exam will be a preliminary exam on the first half of the course. It will be an open book exam, where you will be allowed to bring in your textbook and lecture notes. Rather than testing your ability to undertake mathematical calculations under duress, this exam will test your understanding of the concepts covered to date, with a particular focus on the course outcomes.

Final Exam: 30%

Your final exam will be a take-home exam over a period of three days, and will primarily test you on your problem solving ability in the framework of special relativity.

How to Approach this Course

My primary recommendation for this course is to do the problem sets. Performance on problem sets correlates incredibly well with overall grades. I encourage you to use my office hours and those of your TA to explore any ideas, concepts or problems you don't fully understand. Next, I recommend coming to the lectures. Special relativity can be a rather confusing subject, and we're going to introduce notation that you probably haven't seen before. It is really helpful to have somebody to guide you through this material! Finally, I strongly suggest that you read the set readings. It's probably a good idea to flip through the chapter to see what's coming up before the lectures, and then go back and read them in detail afterwards. We will not have time to cover everything in lectures, which you should think of as primarily an exposition to the material.

What to Expect from Lectures

Lecture will be loosely based around the following template:

- Overview of content
- Discussion of concept
- Mathematical description of concept
- Example of application
- Think-Pair-Share application of concept
- Finer details on concept (as applicable)

Be prepared for a dynamic class!

Every now and again, a convoluted mathematical derivation will dominate a lecture. When this is the case, I present the details because I think it will be instructive for you to see the derivation and see what is possible (and likely expected of you, should you continue your physics education). You won't be required to reproduce the derivation, but you should take the techniques to heart.

No electronics in class

Please do not use electronic devices during the lectures. While I understand that tablets can be used to take notes, in my experience, they're typically used to browse facebook/email/youtube, which is not only rude, but disruptive to your classmates. I will ask you to leave for anything more than putting a phone on silent mode. Please contact me if you require special accommodations.

In the recitation sections for this course, you will briefly review the concepts of the week's lectures, before working in groups on problems to reinforce the ideas of that week. Attendance in section is not mandatory, but you will be missing out if you do not participate.

My Expectations of You

I expect you to be prepared for class. This involves being prepared to interact with me as well as your peers. You should have appropriate writing implements, and be on time. I expect you to be respectful to your classmates.

I expect you to be in charge of your own learning, and seek help when you need it. I expect you to let me know when whatever I am doing isn't working for you, and suggest ways to improve the course if you have ideas.

Rationale for this Course

I have designed this course because I believe that Special Relativity is an important topic in physics that is often understated in undergraduate courses. Too often, students are uncomfortable with the subject, typically because they've never been shown a good way of thinking about it. Furthermore, it tends to be a "non-examinable subject", so students don't learn to use the tools associated with it properly.

The assessment for this course is based on a few ideas. The primary focus is on problem sets, because in physics at least, you learn through doing. Exams are included as a way to assess your achievements, but hopefully without quite so much stress as they often entail. I believe that exams are a relatively artificial construct at the best of times. I have also included an open-ended research assignment, which incorporates a number of aspects of self-directed learning. I hope to give you sufficient feedback such that you can guide yourself through a topic you find interesting.

I hope that this course will be a collaborative undertaking between myself and the class. I plan to assess student feedback around halfway through the course, to get an idea for how expectations are being met, and where the class would like to go as a whole. This will also allow us to decide which optional topics we'd like to explore at the end of the class.

Problem Sets

Problem Sets will be due in your teaching assistant's inbox by 5 pm on Mondays. With regards to late homeworks, I believe that you are here to learn, not to have your life's schedule mandated to you. Things happen, and I am happy for your teaching assistant to occasionally accept late work, so long as you have contacted them with at least 24 hours' notice, and do not make a habit of it. At their discretion, repeat offenders may be penalised by 10% per day. Solutions will be posted each Friday, after which no late homework will be accepted. The due date on the final paper is non-negotiable, and late papers will be penalised at a rate of 10% per day.

Late Homework Policy

Academic Integrity

The work you submit in this course should be your own. Plagiarism of any sort will not be tolerated. A first offence will receive a failing grade for that assignment, while a second offence will be reported to the University. Please make sure all referenced work is properly cited; the proper way to cite references will be discussed in section. Some examples of plagiarism are:

- Copy/pasting from a website, book, or scholarly paper
- Copying from another student
- Using somebody else's words or ideas without citing them

Academic Integrity is about being fair and honest

That is not to say that collaborative work is frowned upon. I am happy for you to solve homework problems in a group, and indeed, I want to encourage collaborative work. However, I expect that the work that is submitted to be your own, not word-for-word the same as your friends'.

Groupwork is Great!

Special Needs

If you have special needs, please let me know in the first two weeks of the semester. We should be able to accommodate whatever you require. I am happy to discuss appropriate academic accommodations with you if you have a disability.

Most of all, let's have fun exploring some beautiful physics!

Lecture Schedule (Tentative)

Date	Topics	Assessment	Readings
Week 1	Relativity in Newtonian Mechanics		
Week 2	Introduction to Special Relativity Experimental Tests of Special Relativity	Problem Set 1 Due	Chapter 1
Week 3	Basic Effects in Special Relativity	Problem Set 2 Due	Chapter 2
Week 4	Four-vectors, Lorentz Transformations, and Tensors	Problem Set 3 Due	Chapter 4 Appendix
Week 5	Energy, Momentum, Forces, Acceleration and Angular Momentum	Problem Set 4 Due	Chapter 5
Week 6	Virtual Effects	Problem Set 5 Due Preliminary Exam	Chapter 3
Week 7	Lagrangian Mechanics	-	
Week 8	Relativistic (Classical) Field Theory	Problem Set 6 Due	
SPRING BREAK			
Week 9	Electromagnetism	Problem Set 7 Due	Chapter 6
Week 10	Relativity in Quantum Mechanics	Problem Set 8 Due	
Week 11	Applications of Special Relativity, Astronomy and Particle Physics	Presentations for Final Paper Draft	
Week 12	Continuum Mechanics, Fluids, the Stress-Energy Tensor	Problem Set 9 Due	Chapter 7
Week 13	(Optional Topics)	Problem Set 10 Due	
Week 14	(Optional Topics)	(Optional Problem Set Due) Final Paper Due	

All readings listed are from Rindler's "Introduction to Special Relativity". The readings will supplement the lectures of the week in which they are set. You may do the readings either before the lectures or after, as your personal preference dictates. Some weeks will contain content that isn't included in the text. I will post a list of sources on the course website that you can read for further information on those weeks' topics.

Extra readings will be online

A choice of optional topics will be selected by the class for the final two weeks. In order to allow you sufficient time to complete your final paper, no problem set will be given on the optional topics. However, an optional problem set will be provided, along with solutions, in order to help you prepare for the final exam. Some possible optional topics include General Relativity (a *very* brief introduction), spinors, and further relativistic quantum mechanics. If you have any suggestions for topics you'd like to see covered, I'd be happy to offer the option to the class.