Physics S-10: Introduction to Theoretical Physics

Summer 2016

Syllabus — Tuesday, June 21, 2016

Description

This course is an accelerated introduction to the conceptual and mathematical foundations of modern theoretical physics, with a particular emphasis on analytical mechanics, relativity, and quantum theory.

Purpose

Physics is a vast, highly developed subject, and it's easy for newcomers to feel overwhelmed. The purpose of this course is to provide an authentic presentation of the conceptual and mathematical foundations of modern theoretical physics in a highly collaborative, cooperative setting, especially (but not only) for students who have a strong interest in pursuing advanced study of the subject in an undergraduate program and beyond.

Goals

The course is intended to go beyond popular-level accounts and present a clear, quantitative picture of what theoretical physics really looks like. Primary goals include elucidating the elegance and unity of physics, along with helping students develop a framework for integrating future learning. We will cover material in the course in as self-contained a manner as possible—with occasional exceptions for special cutting-edge examples—and we will introduce any necessary mathematics along the way. The course will provide a welcoming environment and be highly participatory, so students should bring plenty of curiosity, a high degree of self-motivation, an interest in active learning, the courage to ask questions and make mistakes, an ability to share and collaborate with others, and a high comfort level with abstract ideas and mathematical thinking.

Topics

Topics include the general structure of physical systems, classical mechanics and field theory, orbital motion, the principle of least action, symmetries and conservation laws, special relativity, probability and information theory, and an extensive introduction to quantum theory. Examples are drawn from many areas of physics, including statistical mechanics, Newtonian mechanics, electromagnetism, general relativity, quantum information, quantum field theory, and string theory.

Prerequisites

The course is mathematically intensive and assumes a strong knowledge of high-school algebra, geometry, and trigonometry, as well as a high comfort level with abstract concepts. The course covers relevant topics from high-school physics, differential/integral calculus, and linear algebra as needed, so a familiarity with these subjects, while very helpful, is not strictly required.

Teaching Staff

Dr. Jacob Barandes, Course Head Associate Director of Graduate Studies and Lecturer on Physics
Jefferson 349, 617-384-8138, barandes@physics.harvard.edu
Office Hours: Mondays, Noon–2:00pm, Lyman 330

Teaching Follows

Delilah Gates, Teaching Fellow dgates@g.harvard.edu
Office Hours: Tuesdays, Thursdays, 10:30am–11:30am, Lyman 330
Sections: Wednesdays, 10:00am–1:00pm, Jefferson 356

Mobolaji Williams, Teaching Fellow mwilliams@physics.harvard.edu
Office Hours: Tuesdays, Thursdays, 9:30am–10:30am, Lyman 330
Sections: Wednesdays, 2:00pm–5:00pm, Jefferson 356

Course Website

`https://canvas.harvard.edu/courses/11768`

Meeting Times and Location

Tuesdays, Thursdays, Noon–3:00pm, in Science Center 302. (Map: `https://map.harvard.edu/`.)

Sections

Recitation sections led by the course teaching fellows are required and provide an opportunity to ask more questions, feature relevant examples and exercises, and also sometimes cover advanced side topics. Students should plan to attend one section time per week.

Section Times There are two available section times, and students should plan to attend one or the other: Wednesdays, 10:00am–1:00pm and 2:00pm–5:00pm, both in Jefferson 356. (Map: `https://map.harvard.edu/`.)

Homework

Homework (70%) consisting of questions involving both concepts and calculations is assigned weekly on Tuesdays and is officially due at the beginning of class on the following Tuesday, but students have a two-day grace period and can hand in their homework at the beginning of class on the next Thursday instead. (Students may freely take advantage of this two-day grace period as many times as needed, no questions asked.) Collaboration is encouraged and students who have difficulty finding a study group should contact the course head or teaching fellows. However, students must write or type up their own homework sets with their own answers and hand them in individually, as well as list all their collaborators on every homework assignment. Full simplification of results is necessary for full credit. Use of the Internet for general reference purposes is permitted provided that students cite all external resources they use, but students are not permitted to look up specific exercises or solutions on the Internet or elsewhere. In fairness to other students, late homework will not be accepted beyond the two-day grace period. For a detailed description of the Summer School's policies on academic integrity, please visit http://www.summer.harvard.edu/policies/student-responsibilities.

Final Projects

The course will conclude with final projects (30%), which students can either choose from a list of topics or select with the advance permission of the instructor. The last Wednesday section of the course will consist of student presentations on their projects, and full write-ups are due by 5:00pm on Friday, August 5.

Accommodations for Students with Disabilities

Students with accessibility issues should get in touch with the Accessibility Services office at accessibility@dcemail.harvard.edu or 617-998-9640.

Agenda (Tentative)

- Session 1 (Tue 6/21): General discussion of physics and physical systems. Classical kinematics.
- Special Session (Wed 6/22): Basic differential and integral calculus.
- Session 2 (Thu 6/23): Vectors, complex numbers, and integration.
- Session 3 (Tue 6/28): Vector calculus, Taylor series, and perturbation theory.
- Session 4 (Thu 6/30): Classical dynamics, ergodicity and thermodynamics, statistical physics, and entropy. First look at quantum systems. Schrödinger's cat. Entanglement. Newtonian mechanics.
- Session 5 (Tue 7/5): Newtonian gravitation, work and energy, rotational motion, and orbital motion.
- Session 6 (Thu 7/7): Reference frames. Classical fields. The calculus of variations.
- Session 7 (Tue 7/12): The Lagrangian formulation of classical physics, systems with constraints, Lagrange multipliers, and path integrals in quantum theory.
- Session 8 (Thu 7/14): Symmetries and conservation laws. Introduction to the Standard Model of particle physics and to Einstein's theory of general relativity. Breaking of dynamical symmetries. The Hamiltonian formulation of classical physics.
- Session 9 (Tue 7/19): Introduction to special relativity.
- Session 10 (Thu 7/21): Elementary special relativity.
- Session 11 (Tue 7/26): Further implications of special relativity. The equivalence principle and elementary general relativity.
- Session 12 (Thu 7/28): Probability theory and information theory.
- Session 13 (Tue 8/2): Introduction to quantum theory.
- Special Session (Wed 8/3): Final presentations.
- Session 14 (Thu 8/4): Further topics in quantum theory. Write-ups due online by Fri 8/5