Fall 2024

Subject: Physical Sciences

PHYSCI 2 — Course ID: 122575
2024 Fall (4 Credits)

Mechanics, Elasticity, Fluids, and Diffusion

TR 0900 AM - 1015 AM

Gregory Kestin, Stephen Adams, Anna Wang-Holtzen

An introduction to classical mechanics, with special emphasis on the motion of biological systems, from proteins to people. Topics covered include: kinematics, Newton's laws of motion, oscillations, elasticity, random walks, diffusion, and fluids. Examples and problem set questions will often be drawn from the life sciences and medicine.

Physical Sciences 1 (or Chemistry 7), Mathematics 1b, or the equivalent.

FAS Divisional Distribution: Science & Engineering & Applied Science

PHYSCI 12B — Course ID: 109457
2024 Fall (4 Credits)

Electromagnetism from an Analytic, Numerical and Experimental Perspective

MWF 0900 AM - 1015 AM

Sonia Paban, Gregorio Ponti, Timothy Milbourne

This is the second term of a two-semester course sequence of introductory physical science and engineering. The focus is on quantitative scientific reasoning, with the second term exploring classical electricity and magnetism. Topics include electrostatics and magnetostatics, analog circuits, electromagnetic fields, and optics. Examples are drawn from across the physical sciences and engineering.The course assumes familiarity with mechanics, experimental physics, and computational techniques covered in Physical Sciences 12a offered during Spring Term (see course description). Students will further develop competence in both analytic (using pencil, paper, and multi-variable calculus) and numerical methods (using the Python programming language) to model simple physical systems and to analyze experimental data.The course is aimed at second year students who have an interest in pursuing a concentration in the sciences or engineering. The course includes lecture, laboratory, and discussion components.

Course Note: May not be taken for credit by students who have passed Physics 15b or Physics 15c.

Requires: Pre-Req: PS12A OR APMTH 10 OR Co-Req: APMATH 10

FAS Divisional Distribution: Science & Engineering & Applied Science

Quantitative Reasoning with Data: Yes

PHYSCI 70 Course ID: 215717

Introduction to Digital Fabrication 2024 Fall (4 Credits)

TR 0300 PM - 0415 PM *Instructor Permission Required*

Nathan Melenbrink

An immersive introduction to rapid prototyping, fusing physics, design, computer science, engineering, and art. Students will learn to safely use software and hardware to fabricate programmable projects. Tools and topics will include programmable microcontrollers, 3D CAD/CAM, electronic circuit design, and wireless networking (Internet of Things). Additionally, students will learn operational principles for techniques such as laser cutting, 3D printing, and computer-controlled milling. The course will culminate with an individual final project of the student's own conception, integrating as many of the weekly topics as possible. The course emphasizes self-directed learning, and supports students in accessing resources to help advance the development of their unique projects. Applications may include personal fabrication, product prototyping, fine arts, and the creation of scientific research tools. Students will document work on each weekly topic in a personal website, thereby finishing the course with an online portfolio that not only illustrates their new skill sets, but also contributes to a collective repository of knowledge that serves as a foundation for continued learning.Course website: https://tinyurl.com/tasr7b6Related Sections: In addition to class times, students enroll in a lab section where they will interact with course staff for hands-on assignment work. The shop will also remain open to enrolled students at additional times throughout the week.

Course Note: Attendance is mandatory since safety training will occur during class times. Class will meet twice each week. The first meeting will consist of a brief review of the previous week's assignment, followed by a short introduction to the current week's topic and assignment. The second meeting will primarily focus on a hands-on training session for the accompanying assignment. Meetings may also include appearances by guest presenters or experts on a particular topic.

There are no formal prerequisites for this course. Students are expected to provide their own laptop computer (tablets and Chromebooks are not sufficient for some of the software required for this course, but workarounds may be available -- please contact course staff with concerns). This course is accessible to those with no prior experience. For students already familiar with some of the topics, it will be an opportunity to explore further.

FAS Divisional Distribution: Science & Engineering & Applied Science

Subject: Physics

PHYSICS 15A

Introductory Mechanics and Relativity

Course ID: 111164
2024 Fall (4 Credits)

TR 1200 PM - 0115 PM

Anna Klales, Carlos Arguelles Delgado, Timothy Milbourne, Anna Wang-Holtzen,

Physics 15a is an introduction to the topics of Newtonian mechanics and special relativity, but it is also an introduction to what it means to be a physicist—formulating theoretical models to describe the natural world and testing those models for consistency with data. Topics include: vectors; kinematics in three dimensions; Newton's laws; force, work, power; conservative forces, potential energy; momentum, collisions; rotational motion, angular momentum, torque; static equilibrium, simple harmonic motion, damped and driven oscillations; gravitation; fictitious forces; fluids; special relativity; experimental methods and tools including: basic programming, experimental design and data acquisition, model testing and error analysis; scientific communication.

Course Note: Principles of Scientific Inquiry (PSI) is the laboratory component of Physics 15a. Topics include experimental design, model testing, error analysis, basic programming, and oral presentations. PSI will meet weekly throughout the semester.

Mathematics preparation at least at the level of Mathematics 1b concurrently is required. However, some elementary ideas from multivariable calculus may be used and students are encouraged to take Mathematics 21a concurrently.

Quantitative Reasoning with Data: Yes

FAS Divisional Distribution: Science & Engineering & Applied Science

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PHYSICS 15B

Introductory Electromagnetism

Course ID: 111896
2024 Fall (4 Credits)

TR 1200 PM - 0115 PM

Louis Deslauriers, Mara Prentiss, Stephen Adams

This course is an undergraduate-level course on electromagnetism. Topics include electrostatics, electric currents, magnetic field, electromagnetic induction, Maxwell's equations, electromagnetic radiation, magnetic fields in materials, and some basic notions in kinetic theory, entropy, temperature, and phase transition associated with electricity and magnetism.

Course Note: Principles of Scientific Inquiry (PSI) is the laboratory component of Physics 15b. The labs are designed to enhance your understanding of material presented in lectures. They also present applications of electricity and magnetism, as well as offering opportunities to build simple circuits and develop experience using measuring instruments, including oscilloscopes.

We recommend that you take Physics 15a, Physics 16, or Physics 19 (or you have written permission from the Head Tutor in Physics). Mathematics preparation at least at the level of Math 21a is a prerequisite. Students wishing to take Math 21a concurrently must obtain written permission from the instructor. Vector calculus (divergence, gradient, curl) is used extensively in this course.

Quantitative Reasoning with Data: Yes

FAS Divisional Distribution: Science & Engineering & Applied Science

PHYSICS 15C

Course ID: 124154
2024 Fall (4 Credits)

Wave Phenomena

MW 1030 AM - 1145 AM

Masahiro Morii, Markus Greiner, Gregorio Ponti

Forced oscillation and resonance; coupled oscillators and normal modes; Fourier series; Electromagnetic waves, radiation, longitudinal oscillations, sound; traveling waves; signals, wave packets and group velocity; two- and three-dimensional waves; polarization; geometrical and physical optics; interference and diffraction. Optional topics: Water waves, holography, x-ray crystallography, solitons, music, quantum mechanics, and waves in the early universe.

Course Note: Principles of Scientific Inquiry (PSI) is the laboratory component of Physics 15c. Topics include experimental design, model testing, error analysis, basic programming, oral presentations, and scientific writing. PSI will meet weekly throughout the semester.

Physics 15a and 15b or Physical Science 12a-b or equivalent. Mathematics at least at the level of Math 21b. Mathematical topics introduced during lectures will include matrix calculus, complex numbers, differential equations, and Fourier analysis.

FAS Divisional Distribution: Science & Engineering & Applied Science

Quantitative Reasoning with Data: Yes

PHYSICS 16

Course ID: 111197
2024 Fall (4 Credits)

Mechanics and Special Relativity

TR 1200 PM - 0115 PM

Howard Georgi, Anna Wang-Holtzen, Timothy Milbourne

Newtonian mechanics and special relativity for students with good preparation in physics and mathematics at the level of the advanced placement curriculum. Topics include oscillators damped and driven and resonance (how to rock your car out of a snow bank or use a swing), an introduction to Lagrangian mechanics and optimization, symmetries and Noether's theorem, special relativity, collisions and scattering, rotational motion, angular momentum, torque, the inertia tensor (dynamic balance), gravitation, planetary motion and a little glimpse of quantum mechanics.

Course Note: Principles of Scientific Inquiry (PSI) is the laboratory component of Physics 16. Topics include experimental design, model testing, error analysis, basic programming, oral presentations, and scientific writing. PSI will meet weekly throughout the semester. Emphasis is placed on collaborative teaching and learning. Many class materials are Mathematics notebooks.

Score of 5 on the mechanics section of the Physics C Advanced Placement exam, or equivalent. Mathematics preparation at least at the level of Mathematics 21a taken concurrently is required. Thorough knowledge of calculus of one variable and vectors plus some mathematical sophistication. The mathematical level will be significantly higher than that of Physics 15a. If in doubt, check the Canvas site ahead of time, or email the professor at hgeorgi@fas.harvard.edu, or just shop.

Quantitative Reasoning with Data: Yes

FAS Divisional Distribution: Science & Engineering & Applied Science

PHYSICS 19

Course ID: 207005
2024 Fall (4 Credits)

Introduction to Theoretical Physics

MWF 0300 PM - 0415 PM

Jacob Barandes

Physics 19 is a comprehensive introduction to the foundations of theoretical physics, with a first-principles approach to its five main areas: analytical mechanics, thermodynamics, fields, relativity, and quantum theory.The course is aimed primarily at students who are considering pursuing advanced study of physics in the concentration, as an option alongside Physics 15A and Physics 16. (Most physics concentrators start by taking either Physics 15A, 16, or 19.) The course is also open to undergraduate and graduate students in other fields of study—such as math, philosophy, astronomy, biology, chemistry, computer science, and engineering—who are interested in developing a better understanding of physics either to serve the needs of their own academic work or as a first step toward switching their area of study to physics.The purpose of the course is to present the foundations of modern theoretical physics in a welcoming setting for students from a variety of backgrounds. The course is intended to present a clear, faithful picture of what theoretical physics looks like. We will derive nearly everything from scratch in as self-contained a manner as possible—with occasional exceptions for special cutting-edge examples. We will also introduce all the necessary mathematics along the way.Specific topics will include Newtonian mechanics, chaos, perturbation theory, orbital mechanics, the Lagrangian and Hamiltonian formulations, the connection between symmetries and conservation laws, statistical physics and thermodynamics, electromagnetism, special relativity, relativistic gravitation, black holes, and an extensive introduction to quantum theory. In-class discussions will regularly address relevant issues in the history and philosophy of physics, as well as the conceptual implications of our modern physical theories for making sense of the world around us.Cooperation and diversity strengthen our academic community, so the course will prioritize collaboration and aim to provide a welcoming and inclusive environment for students with diverse identities and backgrounds. The instructor will help students form study groups as needed.

Course Note: For students intending on concentrating in physics, please note that the laboratory component of Physics 19, called Principles of Scientific Inquiry (PSI), is a departmental requirement. (For students in Physics 19 who are not planning on concentrating in physics, PSI is not required.) Sign-ups for PSI will be arranged at the beginning of the semester. PSI topics will include experimental design, model testing, measurements, data collection, data and error analysis, basic programming, oral presentations, and scientific writing. PSI will meet weekly throughout the semester, and will emphasize collaborative teaching and learning.
This course includes optional sections. Attendance is encouraged, but not required.

Physics 19 is mathematically intensive. The course will assume a working knowledge of single-variable differential and integral calculus at least at the level of Mathematics 1A, as well as a high comfort level with abstract concepts, but will not assume previous coursework in physics or multivariable calculus. Mathematics 1A is not a strict requirement, and students who are unsure whether they have adequate background should contact the instructor. The course will cover relevant topics from vector calculus, complex analysis, linear algebra, and other areas of mathematics as needed, so a prior familiarity with these subjects, while helpful, will not be required.

FAS Divisional Distribution: Science & Engineering & Applied Science

PHYSICS 20

Course ID: 220605
2024 Fall (4 Credits)

Introduction to Computational Physics

TR 1030 AM - 1145 AM

Efthimios Kaxiras, Logan McCarty

This course is a systematic introduction to computing with python and jupyter notebooks designed for concentrators in physics and related fields. The course consists of two parts: 1. Basics: essential elements of computing, including types of variables, lists, arrays, iteration and control flow (for, while loops, if statement), definition of functions, recursion, file handling and simple plots, plotting and visualization tools in higher dimensions. 2. Applications: development of computational skills for problem solving, including numerical and machine learning methods, and their use in deterministic and stochastic approaches; examples include numerical differentiation and integration, fitting of curves and error analysis, solution of simple differential equations, random numbers and stochastic sampling, and advanced methods like neural networks and simulated annealing for optimization in complex systems. Course work consists of attending lectures and labs, weekly homework assignments, a mid-term project and a final project; while work is developed collaboratively, coding assignments are submitted individually.

Course Note: Lectures meet concurrently with APMTH 10, although sections, homework and project assignments are different between the two courses.

Mutltivariable calculus (e.g. Mathematics 21a) is a prerequisite. Introductory courses in physics, such Physics 15a, 16 or higher are useful for better understanding of the applications. The course provides an introduction to programming using python, and starts from the level of a complete beginner.

FAS Divisional Distribution: Science & Engineering & Applied Science

PHYSICS 90R

Course ID: 111672
2024 Fall (4 Credits)

Supervised Research

No meeting time listed

Instructor Permission Required

Anna Klales

Primarily for selected concentrators in Physics, or in Chemistry and Physics, who have obtained honor grades in Physics 15 and a number of intermediate-level courses. The student must be accepted by some member of the faculty doing research in the student's field of interest. The form of the research depends on the student's interest and experience, the nature of the particular field of physics, and facilities and support available. Students wishing to write a senior thesis can do so by arranging for a sponsor and enrolling in this course.

Course Note: A list of possible faculty sponsors and their fields is available in Lyman 238 and on the Physics Department Web page. Course enrollment forms may be obtained from Lyman 238.

FAS Divisional Distribution: Science & Engineering & Applied Science

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PHYSICS 91R

Course ID: 110569
2025 Spring (4 Credits)

Supervised Reading Course for Undergraduates

No meeting time listed

Anna Klales

Open to selected concentrators in Physics, Chemistry and Physics, and other fields who wish to do supervised reading and studying of special topics in physics. Ordinarily such topics do not include those covered in a regular course of the Department. Honor grades in Physics 15 and a number of intermediate-level courses are ordinarily required. The student must be accepted by a member of the faculty.

Course Note: A list of possible faculty sponsors and their fields is available in Lyman 238 and on the Physics Department's website. Course enrollment forms may be obtained from Lyman 238.

FAS Divisional Distribution: Science & Engineering & Applied Science

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PHYSICS 95

Course ID: 111967
2024 Fall (4 Credits)

Topics in Current Research

T 0730 PM - 0845 PM

Aravinthan Samuel

This tutorial is based on the Tuesday Night Seminars. Each Tuesday night, one or two Harvard faculty members introduce their research to interested students, including undergraduates enrolled in the course, as well as graduate students who would like to learn about the topics investigated. The talks illustrate how research is done, and provide research examples of projects graduate students might study if they join the group. Before each seminar, the enrolled students read examples of previous work, and in the Monday class, they present and discuss the concepts. Students learn how to express scientific concepts verbally, and in writing for their final report. The course is aimed at juniors and seniors who are familiar with the basics in classical mechanics, electricity and magnetism, and quantum mechanics.

Course Note: Primarily for junior and senior concentrators, however interested sophomores are welcome.

FAS Divisional Distribution: Science & Engineering & Applied Science

PHYSICS 106 Course ID: 224281

Mathematical Methods for Physics 2025 Spring (4 Credits)

WF 1200 PM - 0115 PM

David Morin

This course is designed to give students the mathematical tools that will be helpful in their physics courses. Topics include: Fourier analysis, special functions, tensors, differential equations, contour integration, group theory, probability, statistics, variational principle, phase space, Green's functions, transforms.

Mathematics 21a and 21b; Physics 15a and 15b

FAS Divisional Distribution: Science & Engineering & Applied Science

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PHYSICS 123 Course ID: 124108

Laboratory Electronics 2024 Fall (4 Credits)

TR 0130 PM - 0530 PM *Instructor Permission Required*

Kathryn Ledbetter

An introduction to electronic circuit design intended to develop circuit intuition and debugging skills through daily design exercises, discussion and hands-on lab exercises. The approach is intensely practical, minimizing theory. Moves quickly from passive circuits to discrete transistors, then concentrates on operational amplifiers, used to make a variety of circuits including integrators, oscillators, regulators, and filters. The digital half of the course treats analog-digital interfacing, emphasizes the use of microcontrollers and programmable logic devices (PLDs).

Course Note: Physics 123 is the same course as Physics 223; if you are a graduate student, please enroll in 223. Limited to 20 students.

Some prior experience with computer programming, especially C or Arduino is helpful.

FAS Divisional Distribution: Science & Engineering & Applied Science

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PHYSICS 125 Course ID: 120167

Widely Applied Physics 2024 Fall (4 Credits)

TR 1200 PM - 0115 PM

David Morin

Uses physics to analyze important technologies and real-world systems. Stresses estimation and "back of the envelope" calculations, as are commonly used by research physicists. New physical concepts are introduced as necessary. Example topics: energy production and storage, nuclear physics, nuclear power and weapons, health effects of radiation, risk analysis, airplanes, spy satellites, rockets, fluids, water waves, mechanical design and failure, global warming, and cosmology. Emphasis is on developing physical intuition and the ability to do order-of-magnitude calculations.

Physics 15a, b, c, and mathematics at the level of Mathematics 21a. Physics 143a and 181 are very helpful, and may be taken concurrently.

FAS Divisional Distribution: Science & Engineering & Applied Science

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PHYSICS 143A Course ID: 108465

Quantum Mechanics I 2024 Fall (4 Credits)

TR 1030 AM - 1145 AM

Cora Dvorkin

Introduction to nonrelativistic quantum mechanics: uncertainty relations; Schrödinger equation; Dirac notation; matrix mechanics; one-dimensional problems including particle in box, tunneling, and harmonic oscillator; angular momentum, hydrogen atom, spin, Pauli principle; and if time allows: time-independent perturbation theory; and scattering.

Physics 143a will hold discussion sections, but attendance will not be not required.

Linear algebra including matrix diagonalization; Physics 15c or written permission of the Head Tutor.

FAS Divisional Distribution: Science & Engineering & Applied Science

PHYSICS 143B

Course ID: 111731
2024 Fall (4 Credits)

Quantum Mechanics II

MW 1200 PM - 0115 PM

Matteo Mitrano

Introduction to path integrals, identical particles, many-electron theory, WKB approximation, time-dependent perturbation theory, scattering theory, relativistic quantum mechanics, and basics of quantum information.

Physics 143a.

FAS Divisional Distribution: Science & Engineering & Applied Science

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PHYSICS 151

Course ID: 111231
2024 Fall (4 Credits)

Mechanics

TR 1200 PM - 0115 PM

Arthur Jaffe

One can consider this course as a general introduction and overview to theoretical physics, even though it centers on the theoretical aspects of classical mechanics. We will study problems in the mechanics of particle motion and also problems in continuum mechanics, including classical field theory. We will consider linear systems and non-linear ones. We stress the role of conserved quantities in studying the laws of physics, and emphasize the relation between conserved quantities and symmetry. We study Langrangian and Hamiltonian mechanics from the point of view of their relation to different fields of physics, including quantum theory. We discuss soliton solutions to some non-linear classical equations. Time permitting, we will discuss other non-linear phenomena that are important in physics.

Sections for this course are extremely useful but not mandatory, and will be decided at a later time.

Physics 15a, 15b or written permission of the Head Tutor; Mathematics 21a, b or equivalent.

FAS Divisional Distribution: Science & Engineering & Applied Science

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PHYSICS 187R

Course ID: 222725
2024 Fall (4 Credits)

Thinking Through Writing: Science Themes

W 0300 PM - 0545 PM

Claire Messud, Melissa Franklin

This is an open-enrollment writing course, cross-listed in both English and Physics, that requires writing 300 words a day, 4 days a week, all semester, responding to prompts. The writing portion of the class aims to enable students above all to explore writing freely, with the expectation that they will learn how to express themselves more lucidly and effectively as they grow in literary understanding. This year's theme is "The Time Things Take". In science, we ask questions like: what is the lifetime of a particle; how long does it take for raindrops to fall; how long does it take the universe to expand; how long does it take a rocket ship to reach infinity. And we ask ourselves how we might measure these times. This course will consider scientific concepts, the questions we can pose about them, and the thought experiments we might perform. The literary portion of the class involves close readings of these texts from a writerly perspective, also addressing questions of time and narrative, including pacing and form. We will examine precision in diction and syntax, the use of metaphor and other rhetorical strategies.The course has no prerequisites in either English or Physics. There will be no problem sets. The course will involve two lectures per week + a section. The final assessment will be a portfolio and a presentation.

Course Note: Physics 187r is also offered as English 187r. Students cannot take both courses for credit. The course satisfies humanities distribution or science distribution or a Physics course.
Please note that the lectures on Wednesdays will end at 5pm.

FAS Divisional Distribution: Arts and Humanities

PHYSICS 191

Course ID: 121993
2024 Fall (4 Credits)

Advanced Laboratory

TR 0130 PM - 0530 PM

Instructor Permission Required

Amir Yacoby, Isaac Silvera

Students will engage in the practice and discussion of experimental science by completing three projects, drawn from the fields of condensed matter, atomic, optical, nuclear, and/or particle physics. Laboratory techniques, theoretical understanding, data analysis methods, and scientific reading and writing skills are developed in collaboration with a lab partner, and with guidance from a team of experimental physics faculty and staff. Students will learn to write the results of each project in a format that is appropriate for a peer-reviewed journal. Available experiments range from classics of the twentieth century such as relativistic mass of the electron, lifetime of the muon, superfluid helium, and the quantum Hall effect, to topics of current interest such as slow light, nitrogen-vacancy centers in diamond, superconductivity and the Meissner effect, optical tweezers, and ultrafast optical spectroscopy.

Course Note: A substantial amount of outside reading is expected. Physics 191 is the same course as Physics 247; if you are a graduate student, please enroll in 247.

Physics 15a or 16, 15b, 15c. Physics 143a is highly recommended; 181 is also useful.

FAS Divisional Distribution: Science & Engineering & Applied Science

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PHYSICS 195A

Course ID: 112107
2024 Fall (4 Credits)

Introduction to Solid State Physics

MW 0300 PM - 0415 PM

Julia Mundy

The physics of crystalline solids and their electric, magnetic, optical, and thermal properties. Designed as a first course in solid-state physics. Topics: free electron model; Drude model; the physics of crystal binding; crystal structure and vibration (phonons); x-ray diffraction; electrons in solids (Bloch theorem) and electronic band structures; metals and insulators; semiconductors (and their applications in pn junctions and transistors); magnetism; superconductivity.

Course Note: Physics 195a is also offered as Applied Physics 195a. Students may not take both for credit.

Physics 15a, 15b and 15c or the equivalent. Physics 143a. Physics 181 and Physics 143b (taken concurrently) helpful but not required.

FAS Divisional Distribution: Science & Engineering & Applied Science

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PHYSICS 199

Course ID: 221972
2025 Spring (4 Credits)

Statistical Thermodynamics and Quantitative Biology

MW 1200 PM - 0115 PM

David R. Nelson

Course seeks to develop an understanding of thermodynamics and statistical mechanics, with applications to quantitative problems in biology such as configurations of biopolymers, equilibrium states of matter, chemical reactions and protein transport, using the concepts of entropy, free energy, adsorption, chemical kinetics and molecular diffusion.

Course Note: Also offered as MCB 199. Students may not take both for credit.

Two terms of college calculus, a calculus-based physics course, and some exposure to molecular and cellular biology. Experience with statistics and differential equations not essential, but helpful.

FAS Divisional Distribution: Science & Engineering & Applied Science

PHYSICS 217 Course ID: 224472

Foundations of Modern Optics 2024 Fall (4 Credits)

TR 1030 AM - 1145 AM

Lene Hau

Foundational concepts of E&M, optics, imaging, and interaction of electromagnetic fields with matter. Topics include electromagnetic wave propagation, optical properties of materials from a microscopic viewpoint, propagation of electromagnetic fields in inhomogeneous media: Ray optics and effective forces on optical rays and ray bending. Fourier Optics and advanced imaging based on full E-M wave theory. The lens as a Fourier transformer, Fourier synthesis and phase contrast imaging. Light matter interactions in the semiclassical limit and quantization of the electromagnetic radiation field. We will illustrate the material with applications in AMO physics and in biological as well as astrophysical imaging. The class has two weekly lectures and, in parallel, a series of workshops with a project-based approach that will illustrate and support the material covered in the lectures and motivate the homework problems.

Course Note: Physics 217 is also offered as AP 217. Students may not take both for credit.

Elements of electromagnetism, for example an undergraduate course in electromagnetism such as Physics 153 or similar.

FAS Divisional Distribution: Science & Engineering & Applied Science

PHYSICS 223 Course ID: 109346

Electronics for Scientists 2024 Fall (4 Credits)

TR 0130 PM - 0530 PM *Instructor Permission Required*

Kathryn Ledbetter

An introduction to electronic circuit design intended to develop circuit intuition and debugging skills through daily design exercises, discussion and hands-on lab exercises. The approach is intensely practical, minimizing theory. Moves quickly from passive circuits to discrete transistors, then concentrates on operational amplifiers, used to make a variety of circuits including integrators, oscillators, regulators, and filters. The digital half of the course treats analog-digital interfacing, emphasizes the use of microcontrollers and programmable logic devices (PLDs).

Course Note: Physics 223 is the same course as Physics 123; if you are an undergraduate student, please enroll in 123. Limited to 20 students.

Some prior experience with computer programming, especially C or Arduino is helpful.

FAS Divisional Distribution: Science & Engineering & Applied Science

PHYSICS 245 Course ID: 133281

Particle Physics 2024 Fall (4 Credits)

WF 0130 PM - 0245 PM

Girma Hailu

Foundations of particle physics with emphasis on fundamental concepts. Basic structures of quantum electrodynamics, quantum chromodynamics, and electroweak interactions will be covered.

Two terms of quantum mechanics, e.g., Physics 143a, b or equivalent.

FAS Divisional Distribution: Science & Engineering & Applied Science

PHYSICS 247 Course ID: 145024

Laboratory Course in Contemporary Physics 2024 Fall (4 Credits)

TR 0130 PM - 0530 PM *Instructor Permission Required*

Amir Yacoby, Isaac Silvera

Students will engage in the practice and discussion of experimental science by completing three projects, drawn from the fields of condensed matter, atomic, optical, nuclear, and/or particle physics. Laboratory techniques, theoretical understanding, data analysis methods, and scientific reading and writing skills are developed in collaboration with a lab partner, and with guidance from a team of experimental physics faculty and staff. Students will learn to write the results of each project in a format that is appropriate for a peer-reviewed journal. Available experiments range from classics of the twentieth century such as relativistic mass of the electron, lifetime of the muon, superfluid helium, and the quantum Hall effect, to topics of current interest such as slow light, nitrogen-vacancy centers in diamond, superconductivity and the Meissner effect, optical tweezers, and ultrafast optical spectroscopy.

Course Note: A substantial amount of outside reading is expected. Physics 247 is the same course as Physics 191; if you are an undergraduate, please enroll in 191.

FAS Divisional Distribution: Science & Engineering & Applied Science

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PHYSICS 251A Course ID: 111314

Advanced Quantum Mechanics I 2024 Fall (4 Credits)

WF 0130 PM - 0245 PM

Eslam Khalaf

Basic course in nonrelativistic quantum mechanics. Review of wave functions and the Schrödinger Equation; Hilbert space; the WKB approximation; central forces and angular momentum; spins and their addition, measurement theory; the density matrix; perturbation theory.

Physics 143a, b or equivalent, or permission of instructor.

FAS Divisional Distribution: Science & Engineering & Applied Science

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PHYSICS 253A Course ID: 122930

Quantum Field Theory I 2024 Fall (4 Credits)

TR 0130 PM - 0245 PM

Matthew Schwartz

Introduction to relativistic quantum field theory. This course covers quantum electrodynamics. Topics include canonical quantization, Feynman diagrams, spinors, gauge invariance, path integrals, ultraviolet and infrared divergences, renormalization and applications to the quantum theory of the weak and gravitational forces.

Physics 143a, b or equivalents.

FAS Divisional Distribution: Science & Engineering & Applied Science

PHYSICS 253CR

Course ID: 118459
2024 Fall (4 Credits)

Quantum Field Theory III

TR 0130 PM - 0245 PM

Matthew Reece

This course will use axions as a common theme to explore a variety of topics in quantum field theory and particle physics. This includes topics in formal QFT (e.g., instantons, Chern-Simons terms, anomaly inflow, recent developments in non-invertible symmetries); in particle phenomenology (e.g., the Strong CP problem, axion models, experimental searches for axions); and in particle astrophysics and cosmology (e.g., misalignment production of dark matter, isocurvature perturbations, constraints from stellar cooling and supernovas).

Familiarity with quantum field theory and the Standard Model (e.g., 253a, 253b and/or 254) is necessary. Familiarity with basics of cosmology and of algebraic topology would be ideal, but we will recommend reading material as we go along.

FAS Divisional Distribution: Science & Engineering & Applied Science

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PHYSICS 262

Course ID: 110526
2024 Fall (4 Credits)

Statistical Mechanics

MWF 1200 PM - 0115 PM

Vinothan Manoharan

Basic principles of statistical physics with applications including: the equilibrium properties of classical and quantum gases; phase diagrams, phase transitions and critical points, as illustrated by the gas-liquid transition and simple magnetic models; Bose-Einstein condensation.

Course Note: Also offered as Applied Physics 284. Either course can be used to satisfy the statistical mechanics requirement in the Physics PhD program or the Applied Physics model PhD program.

Physics 143a and Physics 181 or Engineering Sciences 181.

FAS Divisional Distribution: Science & Engineering & Applied Science

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PHYSICS 271

Course ID: 121970
2024 Fall (4 Credits)

Topics in the Physics of Quantum Information

MW 1030 AM - 1145 AM

Mikhail Lukin

Introduction to physics of quantum information, with emphasis on ideas and experiments ranging from quantum optics to condensed matter physics. Background and theoretical tools will be introduced. The format is a combination of lectures and class presentations.

Quantum mechanics at the level of introductory graduate courses.

FAS Divisional Distribution: Science & Engineering & Applied Science

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PHYSICS 283B

Course ID: 118724
2024 Fall (4 Credits)

Beyond the Standard Model

No meeting time listed

Lisa Randall

We will study beyond the Standard Model theories with an eye both to phenomenological consequences and to connections to high energy theory. We will study supersymmetry as well as extra-dimensional theories. If time permits we will also study light axion-like particles and ways of detecting them.

The material will be largely self-contained, but some familiarity with the basics of special relativity and quantum mechanics may be useful.

FAS Divisional Distribution: Science & Engineering & Applied Science

PHYSICS 285B
Course ID: 118509
2024 Fall (4 Credits)

Modern Atomic and Optical Physics II

MW 1030 AM - 1145 AM

Susanne Yelin

Introduction to quantum optics and modern atomic physics. The basic concepts and theoretical tools will be introduced. Topics will include coherence phenomena, non-classical states of light and matter, atom cooling and trapping and atom optics. The second of a two-term subject sequence that provides the foundations for contemporary research.

Course Note: Also offered as QSE 285B. Students may not take both for credit

A course in electromagnetic theory (Physics 232a or equivalent); one half-course in intermediate or advanced quantum mechanics.

FAS Divisional Distribution: Science & Engineering & Applied Science

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PHYSICS 287A
Course ID: 111191
2024 Fall (4 Credits)

Introduction to String Theory

TR 0300 PM - 0415 PM

Xi Yin

An introduction to the perturbative formulation of string theory, including lightcone and BRST quantization of bosonic and superstrings, the string S-matrix, supergravity, and D-branes.

Physics 253a, b or equivalent.

FAS Divisional Distribution: Science & Engineering & Applied Science

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PHYSICS 287BR
Course ID: 114008
2024 Fall (4 Credits)

Topics in String Theory

F 1000 AM - 0100 PM

C. Vafa

A selection of topics in string theory including dualities in superstring theories, compactifications, and the AdS/CFT correspondence.

This course will be taught in Jefferson 453.

Physics 287a.

FAS Divisional Distribution: Science & Engineering & Applied Science

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PHYSICS 295A
Course ID: 127980
2024 Fall (4 Credits)

Introduction to Quantum Theory of Solids

MWF 1200 PM - 0115 PM

Subir Sachdev

Lattices and symmetries. Electronic Structure of Crystals. Semiclassical Transport Theory. Semiconductors. Localization. Integer Quantum Hall effect. Topological Insulators. Phonons. Additional topics from the theory of interacting electrons, including introduction to magnetism and superconductivity.

Course Note: Also offered as Applied Physics 295a. Students cannot take both for credit.

One course on graduate quantum mechanics and one course on graduate statistical mechanics. Undergraduate course on solid state physics helpful, but not necessary.

FAS Divisional Distribution: Science & Engineering & Applied Science