Subject: Physical Sciences

Physical Sciences 3

Electromagnetism, Circuits, Waves, Optics, and Imaging (122576)

Timothy Milbourne, Stephen Adams

2024 Spring (4 Credits)

Schedule: TR 0900 AM - 1015 AM

Instructor Permissions: None

Enrollment Cap: n/a

This course is an introduction to electromagnetism, waves, optics and sound. Topics covered include: electric and magnetic fields, electrical potential, circuits, simple digital circuits, wave propagation in various media, microscopy, sound and hearing. The course will draw upon a variety of applications to the biological sciences and will use real-world examples to illustrate many of the physical principles described. There are six required laboratory sessions, and a weekly asynchronous discussion section.

Physical Sciences 12A

Mechanics and Statistical Physics from an Analytic, Numerical and Experimental Perspective (109274)

Kathryn Ledbetter, Gregorio Ponti

2024 Spring (4 Credits)

Schedule: MWF 0900 AM - 1015 AM

Instructor Permissions: None

Enrollment Cap: n/a

This is the first term of a two-semester introductory course in physics. The focus is on quantitative scientific reasoning, with the first term exploring Newtonian mechanics. Topics include kinematics, linear and rotational motion, forces, energy, momentum, collisions, gravitation, oscillations, and waves, with a brief introduction to statistical physics. Examples are drawn from across the physical sciences and engineering.

Physical Sciences 70

Introduction to Digital Fabrication (215717)

Nathan Melenbrink

2024 Spring (4 Credits)

Schedule: TR 0300 PM - 0415 PM

Instructor Permissions: Instructor

Enrollment Cap: 25

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/tasr7b6

Related 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.

Subject: Physics

Physics 15A

Introductory Mechanics and Relativity (111164)

Julia Mundy

Stephen Adams

Anna Wang-Holtzen

2024 Spring (4 Credits) **Schedule:** TR 1200 PM - 0115 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Newtonian mechanics and special relativity. 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.

Physics 15B

Introductory Electromagnetism (111896)

Carlos Arguelles Delgado, Gregorio Ponti

2024 Spring (4 Credits) **Schedule:** TR 1200 PM - 0115 PM

Instructor Permissions: None **Enrollment Cap:** n/a

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.

Physics 15C

Wave Phenomena (124154)

Matteo Mitrano, Philip Kim, Anna Wang-Holtzen

2024 Spring (4 Credits) **Schedule:** MW 1030 AM - 1145 AM

Instructor Permissions: None **Enrollment Cap:** n/a

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.

Physics 90R

Supervised Research (111672)

David Morin

2024 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: None **Enrollment Cap:** n/a

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.

Physics 91R

Supervised Reading Course for Undergraduates (110569)

David Morin

2024 Spring (4 Credits) **Schedule:** TBD

Instructor Permissions: None **Enrollment Cap:** n/a

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

Physics 95

Topics in Current Research (111967)

Isaac Silvera

2024 Spring (4 Credits) **Schedule:** W 0730 PM - 0845 PM
M 0300 PM - 0415 PM

Instructor Permissions: Instructor **Enrollment Cap:** n/a

This tutorial is based on the Wednesday Night Seminars. Each Wednesday 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.

Physics 113

Electronics for Physicists (216641)

Masahiro Morii, Kathryn Ledbetter

2024 Spring (4 Credits) **Schedule:** TR 0130 PM - 0415 PM

Instructor Permissions: Instructor **Enrollment Cap:** 24

Introduction to electronics for the physical sciences, focusing on skills applicable to laboratory work. Topics include instruments (multimeter, oscilloscope, function generator, power supply), analog circuits (amplifiers, filters, integrators), digital logic, analog/digital interfaces, noise reduction, PID control, and microcontrollers. Emphasis on circuit understanding and use of laboratory instrumentation. The class meets twice weekly, with an hour of lecture/discussion, followed by lab.

Physics 129

Energy Science (125656)

Lene Hau

2024 Spring (4 Credits) **Schedule:** TR 1200 PM - 0115 PM

Instructor Permissions: None **Enrollment Cap:** n/a

With global warming and the climate crisis rapidly worsening, decarbonizing our society is more important than ever. In lectures, we will discuss the science behind possible solutions. The class will give students with an interest in physics, engineering, and/or physical chemistry a deep background in the field to optimally prepare them for making paradigm changing contributions in the future. We will cover photovoltaic cells, nuclear power, photosynthesis, and electrochemistry and batteries. Further subjects are covered in student projects. Fundamentals of electrodynamics, statistical/thermal physics, and quantum mechanics are taught as needed.

Physics 143A

Quantum Mechanics I (108465)

Louis Deslauriers

2024 Spring (4 Credits) **Schedule:** TR 1030 AM - 1145 AM

Instructor Permissions: None **Enrollment Cap:** n/a

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 143B

Quantum Mechanics II (111731)

Girma Hailu

2024 Spring (4 Credits) **Schedule:** TR 1030 AM - 1145 AM

Instructor Permissions: None **Enrollment Cap:** n/a

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 153

Electrodynamics (111822)

Girma Hailu

2024 Spring (4 Credits) **Schedule:** MW 1200 PM - 0115 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Aimed at advanced undergraduates. Emphasis on the properties and sources of the electromagnetic fields and on the wave aspects of the fields. Course starts with electrostatics and subsequently develops the Maxwell equations. Topics: electrostatics, dielectrics, magnetostatics, electrodynamics, radiation, wave propagation in various media, wave optics, diffraction and interference. A number of applications of electrodynamics and optics in modern physics are discussed.

Physics 175

Laser Physics and Modern Optical Physics (121941)

Markus Greiner

2024 Spring (4 Credits) **Schedule:** WF 0130 PM - 0245 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Introduction to laser physics and modern optical physics aimed at advanced undergraduates. Review of electromagnetic theory and relevant aspects of quantum mechanics. Wave nature of light. Physics of basic optical elements. Propagation of focused beams, optical resonators, dielectric waveguides. Interaction of light with matter, introduction to quantum optics. Lasers. Physics of specific laser systems. Introduction to nonlinear optics. Modern applications.

Physics 181

Statistical Mechanics and Thermodynamics (143450)

Susanne Yelin

2024 Spring (4 Credits) **Schedule:** TR 1200 PM - 0115 PM

Instructor Permissions: None **Enrollment Cap:** n/a

This course provides an introduction to statistical mechanics and thermal physics. It surveys the fundamental elements of classical and quantum statistical mechanics (ensembles and partition functions) and thermodynamics (temperature, heat, work, free energy) and their application to a variety of physical systems. Topics covered may include heat engines, solid-state physics, blackbody radiation, phase transitions, physical chemistry, stellar physics, quantum information, Bose-Einstein condensation, and transport phenomena.

Physics 191

Advanced Laboratory (121993) *Jenny*

Hoffman, Jason Hoffman

2024 Spring (4 Credits) **Schedule:** TR 0130 PM - 0530 PM

Instructor Permissions: Instructor **Enrollment Cap:** n/a

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.

Physics 210

General Theory of Relativity (114266)

Jacob Barandes

2024 Spring (4 Credits) **Schedule:** MWF 0300 PM - 0415 PM

Instructor Permissions: None **Enrollment Cap:** n/a

An introduction to general relativity: the principle of equivalence, Riemannian geometry, Einstein's field equation, the Schwarzschild solution, the Newtonian limit, experimental tests, black holes.

Physics 212

Cosmology (203431)

Cora Dvorkin

2024 Spring (4 Credits) **Schedule:** TR 1030 AM - 1145 AM

Instructor Permissions: None **Enrollment Cap:** n/a

Graduate course on Physical Cosmology. Topics will include: the physics of Inflation, Cosmic Microwave Background anisotropies, evidence for Dark Matter, discovery of the accelerated expansion of the Universe, primordial gravitational waves, gravitational lensing, likelihood analysis, structure formation.

Physics 231

Computational Neuroscience (217838)

Haim Sompolinsky

2024 Spring (4 Credits) **Schedule:** MW 0300 PM - 0415 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Follows trends in modern brain theory, focusing on local neuronal circuits as basic computational modules. Explores the relation between network architecture, dynamics, and function. Introduces tools from information theory, statistical inference, and the learning theory for the study of experience-dependent neural codes. Specific topics: computational principles of early sensory systems; adaptation and gain control in vision, dynamics of recurrent networks; feature selectivity in cortical circuits; memory; learning and synaptic plasticity; noise and chaos in neuronal systems.

Physics 232

Advanced Electromagnetism (112263)

Sonia Paban

2024 Spring (4 Credits) **Schedule:** MW 0300 PM - 0415 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Maxwell's equations in macroscopic media, conservation laws, Green's functions, time-dependent solutions and radiation, scattering and diffraction, and gauge invariance. Time permitting: geometrical optics and caustics, negative refractive index materials and radiation from rapidly accelerating charges.

Physics 247

Laboratory Course in Contemporary Physics (145024)

Jenny Hoffman

Jason Hoffman

2024 Spring (4 Credits) **Schedule:** TR 0130 PM - 0530 PM

Instructor Permissions: Instructor **Enrollment Cap:** n/a

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.

Physics 251B

Advanced Quantum Mechanics II (111876)

Ashvin Vishwanath

2024 Spring (4 Credits) **Schedule:** TR 0130 PM - 0245 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Path integrals; relativistic quantum mechanics and quantum fields; identical particles; scattering theory; quantum information theory.

Physics 253B

Quantum Field Theory II (115442)

Matthew Schwartz

2024 Spring (4 Credits) **Schedule:** WF 0130 PM - 0245 PM

Instructor Permissions: None **Enrollment Cap:** n/a

A continuation of physics 253a. Topics include non-renormalizable theories, infrared divergences, the renormalization group, non-Abelian gauge theories, spinor helicity methods, spontaneous symmetry breaking, weak interactions, anomalies and quantum chromodynamics. Additional or alternative topics may be covered depending on time and interest.

Physics 254

The Standard Model (109328)

Matthew Reece

2024 Spring (4 Credits) **Schedule:** MW 1030 AM - 1145 AM

Instructor Permissions: None **Enrollment Cap:** n/a

The Standard Model of particle physics: theory and experimental implications. Topics include nonabelian gauge theory, spontaneous symmetry breaking, anomalies, the chiral Lagrangian, QCD and jets, collider physics and simulation, the Higgs at the LHC

Physics 260B

Introduction to quantum information II (224016)

Mikhail Lukin

2024 Spring (4 Credits) **Schedule:** MW 1030 AM - 1145 AM

Instructor Permissions: None **Enrollment Cap:** n/a

Introduction to quantum information science and quantum computation. Emphasis on fundamental concepts including qubits and quantum operations, the nature of entanglement and its manipulation, quantum error correction, and various implementation models. Topics include: basics of quantum information, different models of quantum computing, fundamental quantum algorithms, quantum error correction, and fault tolerance; as well as experimental implementations. Recent developments in the field will be discussed.

Physics 295B

Quantum Theory of Solids (127979)

Subir Sachdev

2024 Spring (4 Credits) **Schedule:** T 0300 PM - 0545 PM

Instructor Permissions: None **Enrollment Cap:** n/a

A course on the application of the principles of many-particle quantum mechanics to the properties of solids. The objective is to make students familiar with the tools of second quantization and diagrammatic perturbation theory, while describing the theory of the electron liquid, the BCS theory of superconductivity, and theory of magnetism in metals and insulators. Modern topics on correlated electron systems will occupy the latter part of the course.

Physics 297

Professional Writing for Scientists and Engineers (217830)

Suzanne Smith

2024 Spring (4 Credits) **Schedule:** R 0300 PM - 0500 PM

Instructor Permissions: Instructor **Enrollment Cap:** 6

This class leads students to develop their skills in the critical reading and writing of science and engineering. Genres will include research articles, grant proposals, school/fellowship/job applications, or lay abstracts & press releases for the non-scientific public. Crucially, students will be empowered not only to achieve their own writing goals, but also to break down these learned skills and impart them to others, as effective collaborators and mentors of younger students.