Subject: **Physical Sciences**

Physical Sciences 3

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

Louis Deslauriers, Roxanne Guenette

2021 Spring (4 Credits)

Schedule: TR 0900 AM - 1015 AM

Instructor Permissions: None

Enrollment Cap: n/a

This course is an introduction to electromagnetism, digital information, 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 laboratories.

Course Notes: **This course is part of an integrated introduction to the physical sciences intended for students who plan to pursue a concentration in the life sciences and/or satisfy pre-medical requirements in Physics. May not ordinarily be taken for credit in addition to Physics 1b, 11b, or 15b.**

Recommended Prep: **Physical Sciences 2 (or Physics 1a or 11a), Mathematics 1b, or equivalent.**

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Undergraduate Students

Physical Sciences 12A

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

Efthimios Kaxiras, Camille Gomez-Laberge, Anna Klales

2021 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 course sequence of introductory physical science and engineering. 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, waves, and a brief introduction to statistical physics. Examples are drawn from across the physical sciences and engineering.

Students will gain competence in both analytic (using pencil, paper, and single-variable calculus) and numerical methods (using the Python programming language) to model simple physical systems and to analyze experimental data. Students with no computing background are strongly encouraged to take Applied Mathematics 10 in the Fall Term prior to taking this course.

The course is aimed at first year students who have an interest in pursuing a concentration in the sciences or engineering. The course includes lecture, laboratory, and discussion components.

Course Notes: **Physical Sciences 12a may not be taken for credit by students who have passed Physics 15a or 16.**

Recommended Prep: **Applied Mathematics 10**

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Undergraduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration

Subject: **Physics**

Physics 15A

Introductory Mechanics and Relativity (111164)

Julia Mundy, Keith Zengel

2021 Spring (4 Credits) **Instructor**

Schedule: TR 1200 PM - 0115 PM

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.

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

Class Notes: **Students who are unable to attend the T/Th 12:00pm-1:15pm lecture time due to incompatible time zones will be able to watch the lecture videos at other scheduled times (to be determined). These viewings will take place in groups where students will periodically work together on short problems, as they would do in the main lecture. Please note we will only offer this accommodation due to an incompatible time zone, not for a conflict with another course. We anticipate offering three lab sections: one morning, one afternoon, and one evening time EST.**

Physics 15B

Introductory Electromagnetism and Statistical Physics (111896)

Carlos Arguelles Delgado, Amir Yacoby, Keith Zengel

2021 Spring (4 Credits) **Instructor**

Schedule: TR 1200 PM - 0115 PM

Permissions: NONE

Enrollment Cap: n/a

Electricity and magnetism. 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 Notes: **Principles of Scientific Inquiry (PSI) is the laboratory component of Physics 15b. Students use creative problem-solving in applying theoretical topics to explore physical phenomena and design real life applications. Topics include experimental design, model testing, error analysis, basic programming, introductory circuit analysis, and practical applications of electromagnetism. PSI will meet weekly throughout the semester.**

Physics 15C

Wave Phenomena (124154)

John Huth

Mara Prentiss

2021 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.

Course Notes: **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.**

Class Notes: **Lab times will be scheduled at times that work best for students enrolled in the course. 100% lab attendance is required.**

Physics 95

Topics in Current Research (111967)

Girma Hailu

2021 Spring (4 Credits) **Schedule:** MW 0430 PM - 0545 PM

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

Prior to taking this tutorial course, most juniors and seniors have learned physics by topics: Classical Mechanics, E&M, Quantum Mechanics, Particle Theory, Statistical Mechanics, etc. This tutorial is built around the Wednesday Night Seminar (WNS): every Wednesday two Harvard Faculty members give accessible presentations on their research to entering or interested graduate students (Gs), joined by the P95 students. Modern research uses all of the topics learned in physics courses, thus UGs are introduced to current research, including old and new developments and burning problems; they will learn from the Harvard experts as well as each other. The WNS is preceded by assigned reading and student presentations to the class on the basic underlying physics. Students develop critical skills in oral presentations, writing about research topics, and engaging in self and peer evaluation.

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

Physics 125

Widely Applied Physics (120167)

David Morin

2021 Spring (4 Credits) **Schedule:** WF 1200 PM - 0115 PM

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

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.

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

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	For Undergraduate and Graduate Students

Physics 129

Energy Science (125656)

Lene Hau

2021 Spring (4 Credits) **Schedule:** TR 0130 PM - 0245 PM

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

Non-fossil energy sources and energy storage are important for our future. We cover four main subjects to which students with a background in physics and physical chemistry could make paradigm changing contributions: photovoltaic cells, nuclear power, batteries, and photosynthesis. Fundamentals of electrodynamics, statistical/thermal physics, and quantum mechanics are taught as needed to give students an understanding of the topics covered.

Recommended Prep: **Physics 15a (or 16), 15b,c or 11a,b. Pre/co-requisite Physics 143a or Chemistry 160 or equivalent.**

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	For Undergraduate and Graduate Students

Physics 143A

Quantum Mechanics I (108465)

Masahiro Morii

2021 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)

Ashvin Vishwanath

2021 Spring (4 Credits) **Schedule:** TBA

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

IIntroduction 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)

Philip Kim

2021 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.

Class Notes: **Prof. Kim will hold lectures for Physics 153 on Mondays and Wednesdays, noon - 1:15pm. Students who are unable to attend the main lecture due to incompatible time zones will be able to watch the recorded lecture videos (times to be determined at the beginning of the semester), together with a Teaching Fellow who will be able to answer any questions.**

Physics 175

Laser Physics and Modern Optical Physics (121941)

Markus Greiner

2021 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)

Matthew Schwartz

2021 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.

Course Notes: **May not be taken for credit in addition to Engineering Sciences 181.**

Physics 201

Data Analysis for Physicists (161201)

Vinothan Manoharan

2021 Spring (4 Credits) **Schedule:** MWF 1030 AM - 1145 AM

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

This course covers methods for analyzing experimental data. Students will learn both frequentist and Bayesian frameworks for statistical inference, modern computational methods such as Markov-chain Monte Carlo techniques, and the application to problems in particle physics, biophysics, condensed matter, applied physics, astrophysics, and other fields. The course emphasizes an intuitive, principled approach to data analysis and will involve discussions of ethics and reproducible research.

Course Notes: **This course is suitable for students with limited or rusty programming skills. Students with more advanced programming skills may wish to take APMTH 207 or ENG-SCI 255.**

Physics 210

General Theory of Relativity (114266)

Jacob Barandes

2021 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.

Recommended Prep: **Physics 143a (quantum mechanics), 151 (mechanics) and 153 (electromagnetism), and Mathematics 21 (multivariable calculus) or equivalents.**

Physics 220

Fluid Dynamics (110144)

L Mahadevan

2021 Spring (4 Credits) **Schedule:** WF 0430 PM - 0545 PM

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

From statistical to continuum mechanics. Geometry of motion. Strain, strain rate, polarity and nematicity. Vorticity. Conservation laws. Stress - passive and active. Symmetry, invariance and constitutive equations. Dimensional analysis and scaling. Navier-Stokes, Toner-Tu and Nematodynamic equations. Experimental hydrodynamics. Solutions for simple flow states. Boundary layers (and engineering flows). Rotating flows (and geophysics). Thin film flows (and environmental physics). Active matter flows (and biophysics). Similarity and singularity. Linear and nonlinear waves in passive and active fluids- acoustics, shocks, water waves, bird flocks. Flow instabilities. Mixing and turbulence.

Physics 232

Advanced Electromagnetism (112263)

Girma Hailu

2021 Spring (4 Credits) **Schedule:** MWF 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 251B

Advanced Quantum Mechanics II (111876)

Matthew Reece

2021 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)

Xi Yin

2021 Spring (4 Credits) **Schedule:** WF 0130 PM - 0245 PM

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

A continuation of Physics 253a. Topics include: the renormalization group, implications of unitarity, Yang-Mills theories, spontaneous symmetry breaking, weak interactions, anomalies, and quantum chromodynamics. Additional advanced topics may be covered depending on time and interest.

Physics 285A

Modern Atomic and Optical Physics I (118734)

Susanne Yelin

2021 Spring (4 Credits) **Schedule:** TBD

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

Introduction to modern atomic physics. The fundamental concepts and modern experimental techniques will be introduced. Topics will include: Two-state systems, magnetic resonance, interaction of radiation with atoms, transition probabilities, spontaneous and stimulated emission, dressed atoms, trapping, laser cooling. Structure of simple atoms, coupling to fields, light scattering. Fundamental symmetries and introduction to molecules and artificial atoms. Selected experiments. The first of a two-term subject sequence that provides the foundations for contemporary research.

Physics 289R

Topics in Mathematical Physics (118733)

Arthur Jaffe

2021 Spring (4 Credits) **Schedule:** TR 0130 PM - 0245 PM

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

Over the past few years, the development of new mathematical picture languages led to insights in several fields, including quantum information, entanglement, entropy, error correction, uncertainty principles, Fourier analysis, and fusion algebras. This course will overview a number of these directions and develop several of these topics from scratch and in depth, relating them to statistical mechanics models and to quantum field theory.

Physics 295B

Quantum Theory of Solids (127979)

Subir Sachdev

2021 Spring (4 Credits) **Schedule:** MW 1200 PM - 0115 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 302B

Instructional Training for New Teaching Fellows (205610)

Jacob Barandes

2021 Spring (4 Credits) **Schedule:** TBD

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

Through this course, first-time teaching fellows in the Physics graduate program engage in supervised training through practice microteaching, video review, evaluation and feedback, development of instructional materials, and follow-up meetings with teaching consultants.