

THE PHYSICS MAJOR AT DARTMOUTH: A SHORT GUIDE

Introduction

Physics has been defined as the study of that part of nature which can be understood in mathematical terms. Physicists use mathematics to help them comprehend the enormous complexity of the world: to them, as to Galileo, "mathematics is the language of nature." As our knowledge of the physical world becomes deeper, more of it becomes amenable to mathematical formulation, and hence part of physics: for example, atoms used to be regarded as the domain of the chemist alone, while now atomic physics is at the core of the physics curriculum. Mathematics also advances, and becomes able to tackle problems previously thought to be beyond its scope. The great physicist Richard Feynman said in 1963 that he could not conceive of a mathematical description of a cloud, but at that very moment Benoit Mandelbrot was developing the mathematics of "fractals," which turned out to provide just that description. As a result, new branches of physics, such as condensed matter physics and non-linear dynamics, are continually coming into being, as are hybrids with other sciences, for example, chemical physics, geophysics, biophysics and psychophysics.

It has been truly said that without chemistry there would be no life: but without physics there would not be anything at all. The first half of this century saw a revolution in physics, in which "classical" physics, which reigned supreme at the turn of the century, was replaced in the domain of the very large by relativity and in that of the very small by quantum theory. This revolution was comparable in its philosophical implications to the great scientific revolution of the 17th Century (also, primarily, the work of physicists and astronomers). However, just as the latter did not significantly affect the consciousness of the general educated public until the following century, so the profound changes in our view of the world that this century's revolution requires, though the subject of much popular writing, have yet to be fully assimilated. Physics is not just a branch of technology but is one of the humanities, in the sense that its study is one road towards an understanding of our place in the Universe. This may be one reason why so many leaders in the struggle for freedom of thought in recent history have been physicists: Albert Einstein, Andrei Sakharov, Edward Condon, Yuri Orlov, Irina Ratushinskaya and Fang Lizhi, for example.

The physics major and your career

What do students of physics do when they have obtained the bachelor's degree? About 40% of our graduating majors go on to graduate study in physics or a related discipline, aiming at a career in academia or research. Others go to medical school, to engineering school, or become research technicians or high school science teachers. However, by no means do all our majors pursue technical careers: there are many other possibilities. Many go into business, to law school, to social work and to a host of other careers. Because physics is "the most fundamental and all-inclusive of the sciences" (Feynman), a physics or modified physics degree is a good basis for any career in which scientific and technological considerations play an important role: in the modern world, this includes almost the entire spectrum of human activity. The study of physics provides training in problem solving by quantitative and logical thinking and by model building, and develops the habit of concentrating on essentials and eliminating irrelevant detail. These are valuable skills in every walk of life. It is significant that many of the analytical techniques (e.g. operational research and game theory) used in business and economics were originally developed by physicists.

The physics major: prerequisites, required and recommended courses

By its very nature, physics requires a strong mathematical background, and the physics major has a minimum mathematical prerequisite of the four-course Introductory Calculus sequence ending with Differential Equations (Math 3, 8, 13, 23, or equivalent). Many students come to Dartmouth with

advanced placement in mathematics and place out of one or more of these courses. While some of these courses can be taken in parallel with the introductory physics courses (numbered 13, 14, 19 and 24 or the honors sequence 15, 16, and 24), the minimum mathematical prerequisite must be satisfied before the core (40's level) physics courses are taken. More mathematics than this minimum is desirable, particularly for those interested in pursuing theoretical research in graduate school. Linear Algebra (Math 22 or 24), Mathematics in the Physical Sciences (Math 33), and Functions of a Complex Variable (Math 43) are particularly recommended, as is an introductory computer sci. course such as CompSci 5, 6 or 14 (CompSci 14 is cross-listed with Engineering 20).

First year students who achieve the levels of advanced placement in physics described in the *First Year*, available from the First Year Office, receive credit for Physics 3 and/or Physics 4. If they wish, they can place into the honors sequence beginning with Physics 15, so long as their mathematics preparation is adequate, and they are prepared to do the extra work involved in an honors course. First year students can also place into Physics 15 (and in exceptional cases Physics 24) on the basis of an examination administered during First Year Orientation Week.

The minimum physics major (including the physics prerequisites) consists of the following courses: Physics 13 and 14 (or 15 and 16), plus eight further courses. These must include Physics 19, 24, 41, 42, 43, 44. Students taking Physics 15 and 16 may substitute a third elective for Physics 19. Beyond this core there are either two or three electives required, depending on whether Physics 19 was taken. One of the electives must fulfill the culminating experience requirement (see below). The major requires one upper-level laboratory course; Physics 47, Physics 48, Physics 49, Physics 76 or Astronomy 61. Elective courses are Physics 47, Physics 48, Physics 49, Astronomy 15 or 25, and all physics and astronomy courses numbered in the sixties, seventies and nineties. Brief descriptions of all undergraduate physics courses mentioned here are given on p.10 of this guide. Courses in other departments (principally engineering or chemistry) can be substituted for some of these, by permission of the Chair. The core sequence (41-44) can be taken in any order. Students are required to complete a culminating activity in the major. For the physics major this requirement may be satisfied by receiving credit for one of the following courses: Physics 68, Physics 72, Physics 73, Physics 74, Physics 76, Physics 82, Physics 87 Astronomy 74, Astronomy 75, or Astronomy 81. Students who intend to proceed to graduate work in physics are strongly recommended to take more than the minimum number of electives. They should take Physics 66, 76, 91 and a selection of courses in the various subfields of physics (Physics 47, 68, 72 or 73), or in engineering, chemistry or another science department, depending upon their interests. There is also a wide range of graduate courses which are open to qualified undergraduates.

While it is desirable to begin the physics sequence in the first year, it is possible to begin in the sophomore year and still complete the minimum major within four years. Consult the Chair or a major adviser at once if you are thinking of doing this.

Students with a wide range of interests, or who are particularly interested in cross-disciplinary fields such as biophysics, are encouraged to take a modified major, a double major, or a physics major with a minor in another subject. A modified major requires at least ten courses, of which at least six (excluding the two prerequisites) should be in physics. It is discussed in more detail in the next section. Another option is the Engineering Physics Major, which is described on p. 5.

Students majoring in another subject may modify it with physics, or take a physics minor (see below) All courses numbered Physics 19 and above, or Astronomy 15 and above, are in principle suitable for the modified major, so long as the prerequisites are satisfied. It is often possible to substitute a course from another department for a prerequisite: for example Chemistry 81 can substitute for Physics 42, and EngSci 23 for Physics 41. Other substitutions can be made with the permission of the instructor of the course for which the prerequisite is required.

Some possible modified physics majors

A modified major must be approved by the Registrar and must satisfy the requirements given in the ORC. The most important requirement is that the major be "planned as a unified, coherent whole." To ensure this, the student is required to provide a written rationale of the intellectual coherence of the proposed program, which must be approved by the major advisor (or other representative) of both departments involved. Some possible modified majors, selected from a vast range of options, are listed below.

Physics modified with

Biochemistry: Chemistry 51, 52, Biology 77, 78.

Chemistry: Chemistry 71, 72, 81 and an elective.

Earth Sciences: Earth Sciences 34, 62, 64 and an elective.

Engineering Sciences: Four courses from Engineering Sciences numbered 50 or above.

Environmental Engineering: Engineering Sciences 37, 41, 42, 43.

History and Philosophy of Science: History 57, 96; Philosophy 27; Religion 35.

Mathematics: Mathematics 33, 43, 53, 56.

Music: Music 20 and three other major music courses.

Biology: Any four courses which all form part of a single biology major, eg BBMB (for which the permissible courses would be Biology 23, 60-79).

Computer Science: CompSci 15 plus any three above CS 20.

It may also be of interest that Computer Science offers a Computational Minor suitable for interested Physics majors.

Undergraduate research

Opportunities for undergraduate involvement in experimental or theoretical research abound in the physics department. Many faculty hire undergraduates to work on their research projects, and such research experience often leads to an independent student project and to a senior thesis. It is a good idea to get started on this type of work as early as possible, possibly in the sophomore year or the summer following, so that experience can be gained and a greater degree of independence can develop. There is a list of senior theses submitted for honors in the past few years on pages 8 and 9 of this guide.

The Physics Minor

The Physics Minor has the following course requirements:

Prerequisites: Mathematics 3, 8, 13, 23 or equivalents; Physics 13 and 14 (or 3 and 4, or 15 and 16,).

Four courses are required in addition to the prerequisites. One of these must be Physics 19, except students taking Physics 15 and 16 may substitute a third elective for Physics 19. The other three must be chosen from physics courses numbered 24 and above, and/or astronomy courses numbered 15 and above, at least one of which must be numbered above 40.

The Astronomy Major and Minor

A guide to the Astronomy major and minor is available from the Physics and Astronomy departmental office.

Suggested Enrollment Patterns for Physics Majors

The following are suggested course enrollment patterns for the sophomore through senior years. The first pattern is for students taking Physics 13 and 14 in their first year, while the second is for students who complete Physics 15, 16 and 24 in their first year. A good senior year sampling of graduate school preparatory and research related offerings is provided by P76 (advanced lab), P68 (Introductory Plasma Physics), P72 (Elementary Particle Physics), and P73 (Introductory Condensed Matter). Students choosing to do an honors thesis for their culminating experience may wish to take relevant research area courses in their junior year, eg. P68, P73, and appropriate Astronomy courses. Students who go quickly through 60's - 70's - 90's course offerings may choose to take graduate level courses in their senior year.

P13, 14, 19, 24 pattern: EXAMPLE

	<u>F</u>	<u>W</u>	<u>S</u>	<u>X</u>
Year 2	19	24	44	42
Year 3	43, 47	41	66	
Year 4	73	68, 91	72, 74, 75, 76	

P15, 16, 24 pattern: EXAMPLE

	<u>F</u>	<u>W</u>	<u>S</u>	<u>X</u>
Year 2	43	41	44	42
Year 3	47	48, 68	66	
Year 4	73	68, 91	72, 74, 75, 76	

ENGINEERING PHYSICS MAJOR

The Department of Engineering Sciences and the Department of Physics and Astronomy offer an exciting “Engineering Physics” major. A key feature of the major is a 5/5 split in courses, unlike a modified major which requires six courses from one field and four from the other.

•The prerequisites for this program are:

Math 3, 8, 13, 23; Phys 13, 14; Chem 5; and CoSc 5 or Eng 20

•The required or core courses for this program are:

Eng 22 (Systems), 23 (Distributed Systems and Fields), 24 (Science of Materials) **and** Phys 19 (Introductory Physics III), 24 (Introductory Physics IV), 43 (Statistical Physics). [Students taking Physics 15 and 16 may substitute a third elective for Physics 19.]

•In addition, there are four electives--two from each department. You must select two electives from the following list:

Eng 25	Thermodynamics
Eng 33	Solid Mechanics
Eng 34	Fluid Mechanics
Phys 42	Atomic Physics
Phys 68	Plasma Physics
Phys 91	Advanced Quantum Mechanics
Phys 73	Solid State Physics <i>or</i>
	Eng 131 Science of Solid State Materials
Phys 66	Electromagnetic Waves <i>or</i>
	Eng 120 Electromagnetic Fields and Waves
Phys 44	Mechanics <i>or</i>
	Eng 140 Applied Mechanics: Dynamics

and any two electives from the Engineering Sciences Department: Eng 21 and higher, excluding Eng 80 and 87, or from the Physics and Astronomy Department which fulfill the straight Physics major.

•You must also complete a culminating experience course which can be one of the following:

Phys 68	Plasma Physics
Phys 72	Particle Physics I
Phys 73	Solid State Physics
Phys 74	Space Plasma Physics
Phys 76	Methods of Experimental Physics
Phys 82	Special Topics Seminar
Phys 87	Undergraduate Research (honors thesis)
Eng 86	Independent Project
Eng 88	Honors thesis
Eng 190	Engineering Design Methodology and Project Initiation [which must be taken as part of the two-course design sequence 190/290]

Advanced Engineering Sciences courses (63, 76, 91, 92 or any Engineering Sciences graduate course available for AB credit. Effective with the Class of 2010, the course option consists of an advanced engineering sciences course with a significant design or research project, normally taken in the senior year, chosen from an approved list. Consult the Engineering Sciences Department for the most recent list)

The culminating experience is included in, not in addition to, the courses required for the major.

All major programs require an average GPA of 2.0 in all courses counted toward the major, including prerequisites

Remember - you must have a 5/5 split total.

For further information, please contact either

Professor Jay Lawrence or Mary Hudson
Physics and Astronomy

or Professor William Lotko or Christopher Levey
Engineering Sciences

Faculty and Research Staff of the Department of Physics and Astronomy, Dartmouth College

Faculty

Miles Blencowe (Ph.D., Imperial, London 1989)

Condensed matter theory: nano to mesoscale electromechanical systems, quantum measurement, non-equilibrium statistical mechanics.

Robert Caldwell (Ph.D., University of Wisconsin, Milwaukee, 1992)

Theoretical cosmology, gravitation, and relativistic astrophysics.

Brian Chaboyer (Ph.D., Yale University 1993)

Theoretical stellar astrophysics, formation of the Milky Way, globular cluster ages

Robert A. Fesen (Ph.D. University of Michigan, 1981)

Optical, UV, and infrared studies of supernovae and supernova remnants, and the interstellar medium.

Marcelo Gleiser (Ph.D., University of London 1986)

Nonlinear and statistical field theory, cosmology, and astrobiology.

Mary K. Hudson (Ph.D., University of California, Los Angeles, 1974)

Space plasma theory, plasma simulation; sun-earth connections, space weather, auroral particle acceleration and heating, ring current-plasmapause interaction, radiation belts, solar energetic particle trapping and effects of geomagnetic storms.

James W. LaBelle (Ph.D., Cornell University, 1985)

Ionospheric and magnetospheric physics; plasma measurements in space; remote sensing of ionospheric plasma processes.

Walter E. Lawrence (Ph.D., Cornell University, 1970)

Condensed matter theory: quantum information, entanglement, decoherence, electron correlations and electron-phonon interactions in condensed matter.

Kristina Lynch (Ph.D., University of New Hampshire, 1992)

Ionospheric and mesospheric physics; auroral plasma physics sounding rocket experiments.

Robyn Millan (Ph.D. University of California, Berkeley, 2002)

Experimental space physics, radiation belt electron losses; Hard X-ray/gamma ray observations and instrumentation.

Roberto Onofrio (Ph.D., University of Rome, Italy, 1991)

Atomic and condensed matter physics, quantum vacuum phenomena, mesoscopic quantum mechanical systems.

Alexander Rimberg (Ph.D., Harvard University, 1992)

Condensed matter experiment: electrical transport measurements of nanostructures such as quantum dots and single-electron transistors; quantum information science and quantum measurements; controlled physical realizations of open quantum systems; quantum noise and non-equilibrium effects.

Barrett Rogers (Ph.D., Massachusetts Institute of Technology, 1991)

Theoretical and computational plasma physics.

Yeong-Ah Soh (Ph.D., Cornell University, 1995)

Experimental condensed matter physics: magnetism, mesoscopic physics, quantum many-body problem, nanoscience, scanning probe microscopy, x-rays.

John R. Thorstensen (Ph.D., University of California, Berkeley, 1980)

Optical studies of close binary stars.

Lorenza Viola (Ph.D., Padova, Italy, 1996)

Theoretical quantum information science: open quantum systems and quantum noise control, physical implementations of quantum information, theory and applications of entanglement.

Gary A. Wegner (Ph.D., University of Washington, 1971)

Cosmology, large-scale structure of the universe, end states of stellar evolution.

Adjunct Faculty

Alain Brizard (Ph.D., Princeton University, 1990)

Low-frequency nonlinear gyrokinetic theory, relativistic quasilinear transport driven by arbitrary-frequency electromagnetic fluctuations, variational formulations of exact and reduced, kinetic and fluid plasma equations, applications of Lie-transform methods in plasma physics.

Maurice F. Kimmitt (Ph.D., University of Essex, 1973)

Far infrared optics and detectors, semiconductors, free electron lasers.

Christopher G. Levey (Ph.D., University of Wisconsin, Madison, 1984)

Micro optical and electro mechanical systems; micro and nanofabrication technology; solid state physics.

Robert A. Naumann (Ph.D. Princeton University, 1953)

Nuclear structure and spectroscopy.

Theodore Fulton (Ph.D., Cornell University, 1966)

Condensed Matter Physics, particularly single-electron devices and Josephson effects.

William Lotko (Ph.D., University of California, Los Angeles, 1981)

Geospace environment; space plasma physics, modeling, simulation; electromagnetic fields and waves.

Research Faculty

Philippe Crane (Ph.D., Yale University, 1969)

Dynamics of galaxies, radio galaxies, interstellar medium. Searches for extra-solar planets.

Meifang Chu (Ph.D., University of Florida, 1990)

Nano - electromechanical systems, molecular dynamics simulation, quantum field theory, theoretical high energy physics, financial engineering and mathematical biology.

Richard E. Denton (Ph.D., University of Maryland, 1986)

Computational plasma physics involving linear theory and particle and fluid simulations. Recent subject of study; ULF wave phenomena, reconnection, determination of plasmaspheric density and fluid models.

Brian Kress (Ph.D., Dartmouth, 2002)

Theoretical and computational fluid dynamics; numerical radiation belt modeling.

John Lyon (Ph.D., University of Maryland, 1972)

Space plasma physics and magnetospheric physics; numerical simulation and computational physics.

David C. Montgomery (Ph.D., Princeton University, 1959)

Nonlinear magnetohydrodynamics, MHD turbulence theory, disruptions in fusion devices, inertial confinement fusion and shocks, relaxation processes, statistical fluid mechanics, geophysical dynamo.

Hans Mueller (Ph.D. Dartmouth, 1997)

Theoretical space physics and astrophysics (physics of the outer heliosphere; interaction of solar and stellar winds with the interstellar medium); numerical simulations.

Timothy Smith (Ph.D., University of Massachusetts at Lowell, 1990)

Experimental intermediate energy physics; the distribution of quarks in neutrons and protons.

Postdoctoral Associates

Mustafa Bal (Ph.D., University of Massachusetts at Amherst, 2003)

Experimental condensed matter physics.

Kaveh Khodjasteh (Ph.D., University of Southern California, 2007)

Quantum information processing; quantum error correction; quantum control.

Bo Li (Ph.D., University of Texas at Austin, 2007)

Plasma physics; fluid dynamics; turbulence; fluctuation phenomena.

Feng Pan (Ph.D., University of Colorado at Boulder, 2004)

Experimental mesoscopic physics.

Lakshmana Sudheendra (Ph.D., JNCASR, India, 2003)

Experimental condensed matter; correlated electrons; order-disorder effects; quantum criticality; scanning probe microscopy.

Senior theses offered recently in Physics and Astronomy

<u>Name</u>	<u>Title of Thesis</u>
Nicholas C. Koshnick	A Study of Non-Exponential Decay in Metastable Quantum
Thomas S. Levi	Non-Topological Solitons
Andrew C. Crapser	Investigation of the Evolution of Free Radicals and the Oxidation of UHMWPE in Orthopedic Bearings
Nathaniel Ferraro	Turbulence in Low- β Reconnection Events
Alex Glocer	Asymptotic Spectral Measures in Finite Quantum Systems
Jessica Lamb	Electrical Transport Properties of Ligand-stabilized Nanoparticle Point Contact Devices
Gary E. Weissman	Testing General Relativity: A Parameterized Metric and Gravitational Lenses
Christopher C. Wipf	Quantum Cryptography in Space
Latchezar L. Benatov	Spectrum and Generalized Susceptibility of the Tunable Ginzburg-Landau Potential
Laura Trouille	TITAN: From an impervious cloud cover to an explorable world: Creation and Application of a 3_D Monte Carlo Radiative Transfer Code
Jeremy Althouse	The Energy Landscape of Q-Balls φ^6 Theory
Abigail Goodhue	A Search for Deytron Photodisintegration Events in BLAST
Andrew Hunter	Analysis and Modeling of X-ray Microbursts
Sarah Jones	Spaced-Antenna Measurements of AM Radio Stations to Measure the Earth's Ionosphere
Zosia Krusberg	BVI CCD Photometry of Old Open Clusters NGC 188, Berkeley 17, Berkeley 31 and the Formation of the Milky Way
Spencer Smith	Entanglement Dynamics in the Heisenberg Antiferromagnetic Spin Chain Model
Matthew A. Bartek	Me and MIE: An Investigation of Light Scattering in Breast Tissue
Nathan Monnig	A Proposal to Detect the Dynamical Casimir Effect Based Upon Absorption Spectroscopy of Lithium Atoms
Michael J. Holliday	Modeling Ionospheric Current Structures in Response to Sudden Impulse Events

Kelly Michaelson	Analysis of BLAST Events Involving Delta Formation, $H(e, e' \pi^+ n)$
Bart Butler	Environmental Effects on the Nonexponential Decay of Metastable Quantum States
Bryan Davis	Real-Time Detection of Electron Motion: Radio Frequency Single Electron Transistor and Resonant Impedance Matching
Paul Durkee	Micro-Cantilevers: A Novel Approach to Observing the Mechanical Properties of Materials Undergoing Phase Transitions
Jonathan Huang	The Physics of Sheared Flows in Fusion Plasmas
Ryan Michney	Anisotropy in the Cosmic Neutrino Background
Sarah Taylor Smith	Nonequilibrium Phenomena in Open Classical Systems
Karsten Chu	Real-Time Detection of Electron Motion: Radio-Frequency Single Electron Transistor and Resonant Impedance Matching
Bibek Dhital	The Search for Naturally Existing Delta Baryons in Deuterium
Lance Labun	Stochastic Resonance and Measurement Back-Action in Non-Linear Oscillators
Gwen Rudie	The Expansion Kinematics of the Remnants of Low-Mass, Core-Collapse Supernovae
Phillip J. Bracikowski	Study of Mesospheric Dust
Alexander B. Crew	Data Analysis of Magnetic Fields from ROPA Sounding Rocket
Parker Fagrelus	Understanding Quantum Mechanics: Entangling Our Reality
Brendan K. Huang	Investigation of Microscopic Photon and Phonon Quantum Non Demolition Schemes
Leon N. Maurer	Low Temperature Coulomb Blockade Thermometer
Bennet E. Meyers	Spectral Analysis of X-Rays Produced in Lightning Stroke Events
David A. Strauss	VLF Propagation Study at 24kHz
Karl B. Yando	A Monte Carlo Simulation of the MEPED Particle Detector Module
Jordan A. Zastrow	An Optical Study of the Circumstellar Medium in Cassiopeia A

Course descriptions (F = fall term, W = winter, S = spring, X = summer)

13. **Introductory Physics I (F, W)**
The fundamental laws of mechanics. Reference frames. Harmonic and gravitational motion. Thermodynamics and kinetic theory. Physics 13, 14, and 19 are designed as a three-term sequence for students majoring in a physical science. One laboratory period per week.
Prerequisite: Mathematics 3 and 8 (at least concurrently).
14. **Introductory Physics II (W, S)**
The fundamental laws of electricity and magnetism. Maxwell's equations. Waves. Electrical and magnetic properties of bulk matter. Circuit theory. Optics. One laboratory period per week.
Prerequisite: Physics 13 and Mathematics 8, or permission.
15. **Introductory Physics I, Honors Section (F)**
Physics 15, 16, and 24 are an alternative sequence to Physics 13, 14, 19, and 24 for students whose substantial background in physics and mathematics enables them to study the material in more depth than is possible in regular sections, and who are willing to devote correspondingly more work to the course. Admission criteria are described in the *First Year*, available from the First Year-Office. Classical dynamics of particles and rigid bodies. Special Relativity. Introduction to Quantum Mechanics including the wave-particle duality of radiation and matter, the Uncertainty Principle and the Schrodinger equation in one spatial dimension. One laboratory period per week. Supplemental course fee required.
Prerequisite: Mathematics 8 or 9 concurrently, and permission.
16. **Introductory Physics II, Honors Section (W)**
Electric and magnetic fields of charges and currents. Electromagnetic induction. Dielectric and magnetic materials. Circuit theory. Maxwell's equations, electromagnetic waves and optics. Special relativity. One laboratory period per week.
Prerequisite: Physics 15 and Mathematics 13 or 14 concurrently, or permission.
19. **Introductory Physics III (F)**
The general theme of this course is the wave-particle duality of radiation and matter, with an introduction to special relativity. Classical wave phenomena in mechanical and electromagnetic systems including beats, interference, diffraction, and polarization. Quantum aspects of electromagnetic radiation include the photoelectric effect, Compton scattering and pair production and annihilation. Quantum aspects of matter include DeBroglie waves, electron diffraction, and the spectrum of the hydrogen atom. The Schrodinger equation is introduced in one spatial dimension. Supplemental course fee required. Lectures and laboratory work.
Prerequisite: Physics 14 or 16, and Mathematics 13 or permission.
24. **Introductory Physics IV (W,S)**
The theme of this course is the application of the principles of physics to the structure of matter on various scales. The Schrodinger equation is discussed in three spatial dimensions, with emphasis on the description of hydrogenic wavefunctions. Spin and the Pauli exclusion principle. Applications may include many-electron atoms, molecules, solids, nuclei and elementary particles.
Prerequisite: Physics 19, or Physics 16 or permission.
41. **Electricity and Magnetism (W)**
The differential and integral laws of electric and magnetic fields in vector form. Potential theory and boundary value problems. Maxwell's equations, the wave equation and plane waves.
Prerequisite: Physics 24 and Mathematics 23, or permission.

42. **Introductory Quantum Mechanics (X)**
Detailed solutions of the Schrödinger equation for a variety of systems including bound states and scattering states in one and three dimensions. Matrix representations of spin and orbital angular momenta. Applications to atomic, molecular and nuclear problems are emphasized.
Prerequisite: Physics 24 and Mathematics 23, or permission.
43. **Statistical Physics (F)**
Kinetic theory of gases. Boltzmann's Principle. Boltzmann, Bose-Einstein and Fermi-Dirac statistics. The statistical approach to thermodynamics. Applications to radiation, atoms, molecules and condensed matter.
Prerequisite: Physics 24 or permission.
44. **Mechanics (S)**
The fundamental principles of mechanics. Lagrangian form of the equations of motion. Central force motion, collisions and scattering, dynamics of rigid bodies, vibrations, normal modes, and waves.
Prerequisite: Physics 24 and Mathematics 23, or permission.
47. **Optics (F)**
This course covers geometrical, physical, and modern optics topics including the propagation, reflection, dispersion, and refraction of radiant energy; polarization, interference, and diffraction in optical systems; the basics of coherence theory, lasers, quantum optics, and holography. Applications of optical and laser science will be discussed. Lectures and laboratory work.
Prerequisite: Physics 14 or 16, and Mathematics 13, or permission.
48. **Electronics: Introduction to Linear and Digital Circuits (W)**
(Identical to Engineering Sciences 32)
Principles of operation of semiconductor diodes, bipolar and field-effect transistors, and their application in rectifier, amplifier, waveshaping, and logic circuits. Basic active-circuit theory. DC biasing and small-signal models. Introduction to integrated circuits: the operational amplifier and comparator. Emphasis on breadth of coverage of low-frequency linear and digital networks. Laboratory exercises permit "hands-on" experience in the analysis and design of simple electronic circuits. The course is designed for two populations: a) those desiring a single course in basic electronics, and b) those desiring the fundamental necessary for further study of active circuits and systems.
Prerequisite: Physics 14 or 16 and Engineering Sciences 22, or equivalent background in basic circuit theory.
49. **Intermediate Physics Laboratory (S)**
An introduction to experimental physics designed to complement the theoretical framework covered in Physics 41-44. Students work independently on experiments drawn from classical mechanics, electromagnetism, statistical physics, and atomic physics. Weekly seminars cover such topics as experimental design, data and error analysis, signal recovery, and computer methods.
Prerequisite: Physics 24 or permission.
66. **Relativistic Electrodynamics (S)**
Classical electrodynamic radiation and relativistic electrodynamics. Topics include: electromagnetism and relativity; Maxwell stress-tensor; electromagnetic wave propagation in free space and media; radiation by charged particles; scattering; diffraction; basic elements of general relativity.
Prerequisite: Physics 41 or Engineering Sciences 23 and Physics 44.

68. **Introductory Plasma Physics (F)**
The physics of ionized gases with emphasis on the theory of waves and instabilities. Includes introduction to magnetohydrodynamics and kinetic theory of plasmas.
Prerequisite: Physics 41 or Engineering Sciences 23.
70. **Complex Variable and Transform Theory (F)**
(Identical to Engineering Sciences 92)
Survey of a number of mathematical methods of importance in Engineering and Physical Sciences. Topics include integration and differentiation of multivariable functions, complex variable theory, generalized functions, Fourier and Laplace transforms, directed toward applications in such areas as fluid mechanics, electromagnetics, wave and diffusion phenomena, linear systems, and signal theory.
Prerequisite: Mathematics 33 or Engineering Sciences 22, Engineering Sciences 23, or the equivalent.
72. **Introductory Particle Physics (S) (Alternate Years)**
Characterization of elementary particles and their interactions according to the standard model; leptons, quarks, gauge bosons, and the Higgs mechanism. Composite particles and their interactions. Methods of production and measurement of particles. Particle lifetime and cross sections.
Prerequisite: Physics 42.
73. **Introductory Condensed Matter Physics (F)**
The physics of condensed matter, primarily solids with periodic order. Theory and measurement of electronic, optical, magnetic, and thermal properties of solids. Lattice structures, symmetries, and bonding energies. The reciprocal lattice and the Brillouin Zone. Bloch's Theorem. Electron energy band structure and the Fermi surface, phonon mode dispersion, and other elementary excitations.
Prerequisite: Physics 42, Physics 43 recommended.
74. **Space Plasma Physics (S)**
Plasma processes in the solar system. The solar cycle, solar flares, solar wind outflow and interaction with distinct types of planetary magnetospheres. Plasma waves, particle acceleration and generation of escaping electromagnetic radiation. Magnetosphere-ionosphere coupling, and ionospheric interaction with the neutral atmosphere.
Prerequisite: Physics 66 and 68, or permission of the instructor.
75. **Quantum Computation and Information (S, alternate years)**
Overview of basic ideas in classical and quantum computation. Concepts and physical realizations of quantum bits (qubits). Topics in quantum computation may include the Deutsch-Jozsa, quantum Fourier transform, Shor factorization and Grover search algorithms. Topics in quantum communication include quantum key distribution schemes and quantum teleportation. Issues relating to the foundations and interpretations of quantum mechanics will be revisited throughout the course.
Prerequisite: Physics 19 or Mathematics 22 or 23.
76. **Methods of Experimental Physics (S)**
Experiments emphasizing modern techniques and topics in physical measurements. Experiments will cover areas including condensed matter, particle and plasma physics, and such practical laboratory techniques as noise suppression, digital data acquisition, and operation of standard laboratory equipment. Supplemental course fee required.
Prerequisite: Physics 24.
82. **Special Topics Seminar (Arrange)**
Advanced study in physics or astrophysics. Students will read and report orally on significant journal articles and write a paper summarizing their library research.

85. Reading Course (Arrange)
Advanced independent study of a particular field in physics or astrophysics, under the supervision of a member of the department, through a specially designed program of reading, problem sets, and reports.
87. Undergraduate Research (Arrange)
91. Intermediate Quantum Mechanics (W)
Formalism of quantum mechanics, operator methods and transformation theory. Measurement theory and uncertainty relations. Position and momentum representation. The harmonic oscillator and ladder operators. Introduction to path integrals. Perturbation methods: WKB, time-independent and time-dependent perturbation theory. Interaction of matter and radiation and selection rules. Symmetries and conservation laws.
Prerequisites: Physics 42. Dist: SCI.
92. Physics of the Early Universe (W, alternate years)
An introduction to the study of the early universe, focusing on the interaction of nuclear and particle physics and cosmology, the so-called inner-space outer-space connection. After an investigation of the Robertson-Walker metric and its application to the Big Bang model, the course will address the following topics; thermodynamics in an expanding universe; nucleosynthesis (synthesis of light nuclei) and baryogenesis (origin of excess matter over antimatter); inflationary models of cosmology; primordial phase transitions; introduction to quantum cosmology.
Prerequisite: Physics 41- 44, and Astronomy 25 (recommended).

For a complete listing with more detailed descriptions, including graduate courses and courses for non-majors, see the ORC.



If you are thinking of majoring in physics or engineering physics, and have any questions, please contact the department major adviser:

Professor John Thorstensen
239 Wilder Laboratory
Phone: 646-2869
Blitzmail: John.Thorstensen@dartmouth.edu