Physics

Faculty and Fields of Interest

Physicists are involved in theoretical studies, in experimental research, and in the development of new devices to uncover the mysteries of nature; they probe the depths of space, design and program computers, solve environmental problems, teach science, and investigate the structure of nuclei. Research in physics has often paved the way for technological innovations such as lasers, fusion power, solar cells, diagnostic techniques in medicine, and solid-state electronics. Physicists lead some of the world's major technology companies. Physicists spearheaded the development of the vast Internet computer network.

The powerful array of technical skills acquired by physics majors—critical thinking and problem solving, computers, electronics, mathematical analysis, technical writing—are of practical importance in many areas of theoretical and applied science. Employers value the broad training, versatility, and laboratory experience of physics graduates.

In addition to experiencing the department's course offerings, students are encouraged to participate in research in physical oceanography, particle physics, theoretical physics, liquid crystals, (electro-)optics, traffic engineering, computational physics, physics education and astronomy. In addition, many possibilities exist for physics students to study and participate in research in closely allied areas such as computer science, acoustics, electro-optics with faculty in departments in engineering, science, and mathematics.

The physics department has equipment including computers, lasers, x-ray apparatus, and a fully-equipped observatory with a new state of the art 16 inch Meade computer-controlled telescope and electronic CCD imaging camera. A significant number of our faculty and students are involved in the Marine Science program offered through the newly established system-wide Intercampus Graduate School (IGS) of Marine Science and Technology.

Jim Bisagni satellite oceanography, physical oceanography, and physical-biological interactions

Renate Crawford liquid crystal displays, polymer-liquid crystal composites, physics education and outreach

Avijit Gangopadhyay physical oceanography, ocean modeling and prediction, ocean-atmosphere interaction, El Nino and climate system dynamics and modeling

Alan Hirshfeld astrophysics, observational astronomy

Elliott Horsch observational astronomy, astrophysics, astronomical imaging systems

Jong-Ping Hsu symmetry principles and gauge field theories

Sergei Krivoshlykov quantum and waveguide theory, fiber optics, lasers, photonics

George Yan-Chok Leung theoretical particle physics, astrophysics

Grant O'Rielly photonuclear physics at intermediate energies, few-body systems, pion photoproduction, fundamental nuclear energies

Amit Tandon fluid dynamics, physical oceanography, environmental, and computational physics

Jay (Jianyi) Wang theory and simulations of electronic, atomic and optical processes, ion-solids and ion-surface interactions, computational physics

Marguerite Zarrillo traffic engineering, queuing, computer simulation and modeling of surface transportation, active galactic nuclei, radio astronomy, and astrophysics

Mission

As the focus of its mission, the Physics Department works to provide its students with:

1. a comprehensive, high-quality education in the physical sciences;

2. a flexible curriculum allowing students to tailor their education according to their own interests;

3. supportive, one-on-one guidance to help formulate an effective individual educational plan;

4. the opportunity to experience the excitement of scientific discovery through direct participation in faculty research;

5. an increased awareness of the physical processes in the surrounding world;

6. the essential knowledge and analytical tools with which to pursue post-graduate education in a variety of physics-related fields; and

7. the foundation for eventual success in any of a broad array of careers.

Faculty in Related Fields

Several members of other departments teach courses with a large component of physics and carry out research in areas which may interest physics students. The following faculty members are included in this category. Students should always feel free to propose interdisciplinary projects, even if faculty involved are not on this list:

Electrical and Computer Engineering
David A. Brown acoustics and transduction

John R. Buck underwater acoustics and signal processing

Lee E. Estes electro-optics, underwater systems

Mathematics
Dana Fine applied math, gauge theory

Physics Major
BS degree

Career plans of the physics major may include graduate study in physics, materials science, biophysics, geophysics, oceanography, medical physics, or in various branches of applied science or engineering. Other physics majors establish careers in industrial or government laboratories or teach in secondary schools. A major in physics is sometimes selected by students wishing to enter the professions of law, business, or medicine with the competitive edge that a good physics background can provide.

The advanced courses selected during the third and fourth years should be consistent with the students' interests and goals. These interests may be in physics or in allied fields such as astronomy, computer science, environmental science, biophysics, meteorology and oceanography.

Students are encouraged to arrange supervised independent study as well as work on individual research projects. There are frequent opportunities for student participation in faculty research.

Students should consult frequently with their departmental advisors and familiarize themselves with department activities such as the meetings and special lectures of the Physics Club.

The department also offers a graduate program leading to the Master of Science degree in physics and, in conjunction with UMass Amherst, offers a cooperative PhD program.

General Education Departmental Requirement

Students majoring in Physics will meet their departmentally-controlled General Education requirements as follows:

Area E: Select a course from the approved list
Area I, Tier 2: CIS 115 or other CIS/ computer course approved by advisor
Area W, Tier 2: ENL 266 or PHY 115
Area O: PHY 115

Physics Major
Conventional Option

Requirements

Semester Credits

Of the 120 credits needed for a Bachelor of Science degree in physics, the department requires 45 credits in physics, 12 credits in specified courses in mathematics, and 6 credits in courses in a second science or mathematics or engineering. The recommended course sequence of required and recommended mathematics courses is given. Of the 120 credits, 30 must be in the upper-division. Each student is required to consult with his or her advisor before registering for courses.

First Year		**First**	**Second**
EGR 107, 108	Intro. Engineering through Applied Sci. I, II[1]	3	2
PHY 111 (or 113)	Physics for Science & Engineering I[2]	4	
PHY 112 (or 114)	Physics for Science & Engineering II[2]		4
MTH 113 (or 111)	Calculus for Applied Sci. and Engineering I	4	
MTH 114 (or 112)	Calculus for Applied Sci. and Engineering II		4
ENL 101, 102	Critical Writing and Reading I, II	3	3
	General Education		3
		14	**16**
Second Year	(Recommended Sequence)		
PHY 115	Introduction to Classical Physics	3	
PHY 213	Applied Modern Physics		3
PHY 225, 227	Introductory Experimental Physics I, II	2	1
PHY 234	Intermediate Mathematical Physics		3
MTH 213 (or 211)	Calculus for Applied Sci. and Engineering III	4	
MTH 212	Differential Equations I (recommended)		3
ENL 266	Technical Communications		3
CIS 115	Computer Programming with C[3]	3	
	Humanities/Social Sciences/Literature	3	3
		15	**16**
Third Year	(Recommended Sequence)		
PHY 341, 342	Modern Physics and Quantum Mechanics I, II	3	3
PHY 300	Undergraduate Seminar	3	
PHY 313	Mechanics	3	
MTH 321, 322	Topics in Applied Math I, II (recommended)[3]	3	3
	Physics Electives (minimum required)[4]		3
	General Education	3	6
		15	**15**
Fourth Year	(Recommended Sequence)		
	Advanced Laboratory Requirement[5]	3	3
	General Education	3	
	Physics Electives (minimum required)	3	1
	Additional Physics Electives or Free Electives	6	10
		15	**14**
	Total credits		**120**

1. Students who transfer from another school or who change their UMmass Dartmouth major to Physics should see their advisor for substitute courses.
2. A grade of 'C' or better is required for physics majors in the PHY 111/112 or PHY 113/ 114 sequence.
3. Other computer courses may be substituted for CIS 115, as approved by advisor.
4. MTH 321/322 are recommended OR students must take a total of six credits of science or mathematics or engineering courses offered by the following departments: biology, chemistry, computer and information science, mathematics, civil engineering, electrical computer engineering or mechanical engineering. 200- or 300-level physics courses in the area of astrophysics are also eligiblet. The courses must be acceptable for credit to students majoring in the respective science or engineering departments, and be approved by the advisor.
5. Upper-division Laboratory requirement: a minimum of 6 credits must be selected from the laboratory courses PHY 321, 322, 421, 422—included in total of minimum required physics electives (ECE 211, 251 may substitute for PHY 321).

Physics Electives are listed on the following page.

Physics Major
Materials Science Option

Requirements

Materials science is a rapidly developing field that includes theoretical and experimental studies relating to solid state microelectronics, liquid crystals, superconductors, optical fibers, metallic alloys, ceramic materials, gravity-free processing, and other advanced applications.

		Semester Credits	
First Year		**First**	**Second**
EGR 107, 108	Intro. Engineering through Applied Sci. I, II	3	2
PHY 111 (or 113)	Physics for Science & Engineering I	4	
PHY 112 (or 114)	Physics for Science & Engineering II		4
MTH 113 (or 111)	Calculus for Applied Sci. and Engineering I	4	
MTH 114 (or 112)	Calculus for Applied Sci. and Engineering II		4
CHM 151, 161	Princ. Modern Chem. I / Applied Chem. I	4	
CHM 152, 162	Princ. Modern Chem. II/ Applied Chem II		4
ENL 101	Critical Writing and Reading I		3
		15	**17**
Second Year			
PHY 115	Introduction to Classical Physics	3	
PHY 213	Applied Modern Physics		3
PHY 225, 227	Introductory Experimental Physics I, II	2	1
PHY 234	Intermediate Mathematical Physics		3
MNE 231	Materials Science[1]	3	
MTH 213 (or 211)	Calculus for Applied Sci. and Engineering III	4	
ENL 102	Critical Writing and Reading II	3	
ENL 266	Technical Communications		3
CIS 115	Computer Programming with C[2]		3
		15	**13**
Third Year			
PHY 313	Mechanics	3	
PHY 321, 322	Electronic Devices and Circuits I, II[3]	3	3
PHY 341, 342	Modern Physics & Quantum Mech I, II[1]	3	3
CHM 315, 316	Physical Chemistry I, II[1]	4	4
PHY 300	Undergraduate Seminar	3	
	General Education		6
		16	**16**
Fourth Year			
PHY 441	Statistical Thermodynamics[1]	3	
PHY 442	Elements of Solid State Physics[1]		3
	General Education	6	6
	Free Electives		3
	Physics Electives***	6	3
		15	**15**
	Total credits:		**122**

1. Required courses for materials science option (beyond those for Conventional Option).

2. Other computer course may be substituted for CIS 115, but must be approved by advisor.

3. Upper-division Laboratory requirement: a minimum of 6 credits must be selected from the laboratory courses PHY 321, 322,421, 422— included in total minimum required physics electives (ECE 211, 251 may substitute for PHY 321).

Electives: Conventional Physics Option

PHY 251, 252	Elem. Astrophysics I, II
PHY 301	Undergraduate Seminar
PHY 314	Wave Motion*
PHY 315	Fluid Mechanics Supplement (Corequisite MNE 332)
PHY 321, 322	Electronic Devices and Circuits*
PHY 351, 352	Physics of the Environment
PHY 363	Intermediate Astrophysics
PHY 411, 412	Electric and Magnetic Fields I, II*
PHY 421, 422	Advanced Physics Laboratory I, II*
PHY 441	Statistical Thermodynamics
PHY 442	Elements of Solid State Physics
PHY 495	Independent Study
PHY 480	Undergraduate Research
PHY 490	Senior Thesis
PHY 510	Special Topics in Physics
PHY 521	Computational Physics
PHY 531	Intermediate Quantum Mechanics I*
PHY 543	Statistical Thermodynamics
PHY 550	Fundamentals of Physical Oceanography

***** Students who intend to continue their studies in physics at the graduate level should consult with their advisors. A typical course selection for students planning on attending graduate school is indicated above by a star after the course number.

Recommended Electives: Materials Science Option

ECE 231	Electrical Material Science**
EGR 232	Engineering thermodynamics
PHY 313	Mechanics*
PHY 314	Wave Motion*
PHY 411, 412	Electric/magnetic Fields I, II*
MNE 471	Physical Metallurgy
PHY 531	Intermediate Quantum Mechanics I*
CHM 523	Thermodynamics

***** Recommended for graduate-school bound students

****** Requires a minimal knowledge of circuit theory — PHY 321 is sufficient

Physics Minors

In the course of their studies, many UMass Dartmouth students acquire a background in basic physics and mathematics which enables them to take upper division physics courses. A number of these students may elect to extend their study of physics into more advanced areas. A major goal of our two physics minors is to provide encouragement and formal recognition for these students.

The Physics Minor has the additional goal of establishing the physics background needed to enter interdisciplinary fields which have a significant physics content. This would be particularly useful for students majoring in fields such as Chemistry, Mathematics, Engineering, and Computer Science. Students considering a career in fields such as Biophysics or Medical Physics would benefit from a minor in physics.

The Environmental Physics Minor focuses specifically on the physics background needed to enter interdisciplinary environmental fields which have a significant physics content.

Students who wish to enter either program must obtain approval of the Physics Department chairperson, preferably before enrolling in upper-division courses. Students who adopt one of the Physics minors must meet the university requirements of cumulative grade point averages and total number of credits. In addition, the Physics Department requires that the cumulative grade point average in physics courses submitted for recognition of completion of a minor in physics be 2.0 or above.

Physics

Requirements

		credits
PHY 113	Classical Physics I	4
PHY 114	Classical Physics II	4
PHY 213	Applied Modern Physics **OR**	3
PHY 115	Intro. to Classical Physics	3

An additional nine credits selected from the following upper division courses:

PHY 300	Undergraduate Seminar	9
PHY 313	Mechanics	
PHY 314	Wave Motion	
PHY 341, 342	Modern Physics and Quantum Mechanics I, II	
PHY 351, 352	Environmental Physics I, II	
PHY 363	Intermediate Astrophysics	
PHY 411, 412	Electric & Magnetic Fields I, II	
PHY 441	Statistical Thermodynamics	
PHY 442	Elements of Solid State Physics	
PHY 531	Intermediate Quantum Mech. I	

Total 20

Notes: Physics Minor

Certain other graduate courses may be substituted for the listed upper division courses, with the approval of the Physics Department.

A student wishing to minor in Physics must also acquire a substantial background in calculus (MTH 111, 112, and 211 or equivalent are required).

Environmental Physics

Requirements

		credits
PHY 113	Classical Physics I **OR**	3 or 4
PHY 101	Introduction to Physics I	
PHY 114	Classical Physics II **OR**	3 or 4
PHY 102	Introduction to Physics II	
PHY 351	Physics of the Environment I	3
PHY 352	Physics of the Environment II	3
PHY	300/400/500 Physics elective with an environmental theme*	3
PHY	One other Physics environmental elective**	3

Total 18-20

Notes: Environmental Physics Minor

***** Fundamentals of Physical Oceanography is an example.

****** Environmentally related courses include PHY 162, 163, 171, 172, and 182.

Physics Courses

PHY 030 three administrative credits*
START Science I
A laboratory based course which develops scientific reasoning skills by the study of basic physical concepts. Students study properties of matter (mass, volume, density, etc.). This course is for students accepted to the university into the special START Program. (Formerly STR 030, fall semester.)

PHY 101 three credits **S**
Introduction to Physics I
Pre- or Corequisite: MTH 101 recommended
An introductory course in physics covering mechanics, heat, and thermodynamics. Emphasis is on fundamentals and their application to practical problems. Non-calculus presentation.

PHY 102 three credits **S**
Introduction to Physics II
Pre- or Corequisite: MTH 102 recommended
Continuation of PHY 101. The topics covered include heat and thermodynamics, vibrations, optics, electricity and magnetism. Non-calculus presentation.

PHY 103 one credit **S**
General Physics Laboratory I
2 hours laboratory
A laboratory course that accompanies PHY 101. An introduction to experimental techniques. Experiments in mechanics.

PHY 104 one credit **S**
General Physics Laboratory II
2 hours laboratory
A laboratory course that accompanies PHY 102 or PHY 108. Experiments in optics, electricity and modern physics using electrical measurement techniques.

PHY 111 four credits
Physics for Science and Engineering I
4 hours lecture
Corequisite: MTH 113, EGR 107
A calculus-based introduction to the concepts of classical mechanics. The course is taught in an active learning mode in a computerized physics studio. Topics include one and two dimensional motion, dynamics, conservation of energy and momentum, rotational motion and angular momentum. Covers the same topics as PHY 113 in an integrated instructional mode.

*****
Administrative credits do not count toward the total required for graduation.

Gen Ed note: Physics courses satisfy the Natural Science and Technology requirement. Those marked **S** below are appropriate for non-science/engineering majors. Some courses satisfy other requirements, as noted.

PHY 112 four credits
Physics for Science and Engineering II
4 hours lecture
Prerequisite: PHY 111 or PHY 113
Corequisite: MTH 114, EGR 108
A calculus-based introduction to the concepts of thermodynamics and electricity and magnetism. The course is taught in an active learning mode in a computerized physics studio. Topics include the first and second laws of thermodynamics, electric fields, flux, electric potential, elementary DC and AC circuits and magnetic fields. Covers the same topics as PHY 114 in an integrated instructional mode.

PHY 113 four credits **O if honors**
Classical Physics I
Includes 2-hour weekly laboratory
Prerequisite: MTH 113 or 111
A calculus based introduction to classical mechanics emphasizing problem solving. Topics include particle kinematics and dynamics, concepts of work, energy and momentum, rotational motion and oscillations.

PHY 114 four credits **O if honors**
Classical Physics II
Includes 2-hour weekly laboratory
Prerequisite: MTH 114 or 112
Continuation of PHY 113. Study of electric and magnetic fields, electric potential, capacitance and inductance, elementary circuits, electromagnetic oscillations, and optics.

PHY 115 three credits **S, W, O**
Introduction to Classical Physics
Prerequisite: PHY 111 or 113
This course treats topics in classical physics from the areas of waves, optics, and thermodynamics. Two oral presentations with technical write-ups are required.

PHY 130 three credits **S**
START Science II
Prerequisite: PHY 030 (STR 030)
A laboratory based course which develops scientific reasoning skills by the study of basic physical concepts, continuing from STR 030. Students study properties of motion (position, velocity, acceleration, etc.). This course is for students accepted to the university into the special START Program. (Formerly STR 130, spring semester.)

PHY 151 three credits **S**
Introductory Astronomy
An introduction to astronomy that surveys the content, structure, and scale of the cosmos as it is presently known. Properties of the solar system, the sun and stars, exotic objects such as pulsars and black holes, galaxies, quasars, and the universe as a whole are discussed. Each semester a different topic of current interest in astronomical research will also be covered. Evening observing sessions will be arranged.

PHY 161 three credits **S**
Science, Technology, and Society I
Interaction of science and technology with the individual and contemporary society. Topics include forensic physics, including how science and technology are used in today's judicial system.

PHY 162 three credits **E, S, G**
Science, Technology, and Society II: The Environment
This course studies current environmental issues and their relations to technological choices. For example, air and water quality are examined in relation to the use of various renewable and non-renewable energy resources. The course is non-mathematical and satisfies 3 credits of the Natural Science requirement.

PHY 163 three credits **S**
Energy and Energy Alternatives
A non-mathematical yet quantitative survey of contemporary energy questions. Energy sources such as coal, oil, natural gas, solar energy, and wind power are examined. Energy conservation techniques are examined in detail.

PHY 171 three credits **S**
Planet Earth and its Resources I
Origin and history of earth; composition and structure of its interior, crust, oceans, and atmosphere. Plate tectonics and sea floor spreading; seismology, vulcanism and earthquakes; magnetism of earth. Forces shaping earth's surface, faults and folds, erosion, sedimentation and weathering. Earth materials: soil, minerals and ores, igneous, sedimentary, and metamorphic materials. Earth resources: salts and fertilizers, chemical supplies, and building materials.

PHY 172 three credits **S**
Planet Earth and its Resources II
Earth resources: rare and abundant metals and their uses, history of life on earth, the fossil record. Energy and fossil fuels. Nuclear energy sources, uranium, plutonium, and deuterium. Water and its distribution, rate of use, and pollution. Atmospheric-oceanic circulation and heat balance. Weather and climate. Humanity as agent of change on planet Earth. Outlook on future.

PHY 180 three credits **S**
Scientific and Social Aspects of Solar Energy
The development of solar energy in the U.S. Individual sources both direct and indirect (biomass, wind, etc.) are examined as to current state of the art and future potential. Different development schemes such as centralized or distributed modes are considered. The goal of the inquiry will be to determine the optimum paths for future development.

PHY 182 three credits **S, G**
Introduction to the Weather
The fundamentals of atmospheric science. Basic physical principles which affect the general circulation of the atmosphere and their relation to the day-to-day sequence of weather events are discussed. As part of the course, students generate short-term forecasts using real time information available by computer from the internet.

PHY 183 three credits **S, G**
Global Climate Change
What we know about global climate change and how to understand it, and with what certainty we know it, aimed to meet the increasing need for citizens of the world to be scientifically literate about this issue. Using basic physical principles, this course concentrates on the science of climate change.

PHY 213 three credits
Applied Modern Physics
4 classroom hours weekly
Prerequisite: PHY 112 or 114
A first course in modern physics designed for engineering and physics students. It deals with basic atomic and nuclear physics and emphasizes the applied areas of modern physics that are likely to be of use in practical engineering applications.

PHY 225 two credits
Introductory Experimental Physics I
1 hour lecture, 3 hours laboratory
Introduction to techniques, equipment and data analysis in experimental physics. Develops skills in the use of instruments such as the oscilloscope and multimeter; error estimation and propagation; data analysis using computer spreadsheets; and laboratory notetaking and reporting. The lectures introduce the theory of error analysis, interpretation of experimental data and scientific ethics.

PHY 226 three credits
Introductory Experimental Physics II (long version)
2 hours lecture, 3 hours laboratory
Prerequisite: PHY 225 or permission of instructor
Continuation of PHY 225. The lecture portion introduces the computer as a tool in physics for acquiring, analyzing and displaying experimental data, and computers are used for solving differential equations and simulating dynamical problems.

PHY 227 one credit
Introductory Experimental Physics II (short version)
3 hours laboratory
Prerequisite: PHY 225 or permission of instructor
Continuation of PHY 225.

PHY 234 three credits
Intermediate Mathematical Physics
3 hours weekly
Prerequisites: PHY 112 or 114, MTH 213 or 211
The development of the mathematical and computational tools needed for solving more advanced physics problems. Topics are selected primarily from classical mechanics and electricity and magnetism.

PHY 251 three credits
Elementary Astrophysics I
Prerequisite: One year of science or mathematics or permission of instructor
Basic concepts and modern developments in astrophysics at an elementary level. It can be used to fulfill the science requirement. Subjects to be discussed range from the solar system and the structure and evolution of the stars to galaxies and the expanding universe. Observing techniques are also taught using the observatory telescope.

PHY 252 three credits
Elementary Astrophysics II
Prerequisite: PHY 251 or permission of instructor
A continuation of PHY 251, this course consists of a more detailed analysis of subjects introduced the preceding semester. Among the topics to be considered are cosmology and high-energy astrophysics including pulsars, quasars and black holes. More advanced observing techniques are introduced, including astrophotography and electronic imaging.

PHY 261 three credits **S**
Physics of Music: Waves, Wiggles, and Music
The science behind how musical instruments work, with hands-on activities and demonstration. No mathematics beyond simple algebra will be used. Topics include simple vibrators; waves on strings and in other structures; scales, temperaments, and harmony; acoustical environments: production and perception of musical tones. Previous musical experience is helpful.

PHY 271 three credits **S**
The Solar System: Exploring the Planets
3 hours lecture
Prerequisite: PHY 171
Introduction to the physical nature of the solar system. Characteristics of the planets and major satellites will be examined using lecture and WWW sites. Topics will include compositions, internal structures, atmospheres, possibilities for biological activity and the development of geologic surface features. The presentation is non-mathematical and will introduce the use of the observatory and basic astrophotography.

PHY 298 one to six credits
Experiential Learning
Prerequisites: At least sophomore standing; permission of the instructor, department chairperson, and college dean
Work experience at an elective level supervised for academic credit by a faculty member in an appropriate academic field. Conditions and hours to be arranged. Graded CR/NC. For specific procedures and regulations, see section of catalogue on Other Learning Experiences.

PHY 300, 301 three credits each
Undergraduate Seminar I, II
A seminar conducted at the sophomore-junior level on topics in contemporary physics, astrophysics and related topics.

PHY 313 three credits
Mechanics
Prerequisites: PHY 115, 234, MTH 211 or 213
Mechanics of particle systems including central force motion and two body scattering, accelerating coordinate systems, rigid body kinematics and dynamics, coupled oscillators, small vibrations and normal modes, introduction to Lagrangian methods.

PHY 314 three credits
Wave Motion
Prerequisites: PHY 234, MTH 211 or 213
Wave phenomena in mechanics, optics and acoustics. A study of the wave equation and its applications with emphasis on the general properties of waves. Interference, diffraction, reflection, refraction and polarization.

PHY 315 1 credit
Fluid Mechanics Supplement
1 hour lecture
Prerequisites: PHY 115, MTH 211 or 213
Corequisite: MNE 332
To enhance the background of physics students who take MNE 332. Specific topics include distributed force and moment analysis for applications to fluid statics, thermodynamic principals applied to fluid mechanics, Coriolis force in rigid bodies and in the ocean-atmospheric system, and basic force balance for the ocean and the atmospheric flows.

PHY 321 three credits
Electronic Devices and Circuits I
2 hours lecture, 3 hours laboratory
Prerequisites: PHY 114, MTH 211
A lecture and laboratory course in electronic circuit theory covering both active and passive devices and elementary networks.

PHY 322 three credits
Electronic Devices and Circuits II
2 hours lecture, 3 hours laboratory
Prerequisite: PHY 321
A continuation of PHY 321 with emphasis on applications using the elements and techniques of modern research, including integrated-circuit devices, digital circuits, and computer interfacing.

PHY 341 three credits
Modern Physics and Quantum Mechanics I
Prerequisite: PHY 213
Experimental evidence leading to the development of modern physics, Bohr-Sommerfeld theory of the hydrogen atom. Special relativity, introduction to the Schroedinger equation with solutions to simple problems leading to the study of one electron atoms. Electron spin, magnetic moment, and the fine structure in hydrogen spectra.

PHY 342 three credits
Modern Physics and Quantum Mechanics II
Prerequisite: PHY 341
Continuation of PHY 341. Further applications of the principles of quantum mechanics with applications to many particle systems. Quantum statistics, atomic spectra of many electron atoms, nuclear structure, nuclear models and scattering.

PHY 351 three credits
Physics of the Environment I
Prerequisites: A one year course in physics and MTH 101 or 131
A course applying scientific concepts and simple mathematical modeling (noncalculus) to environmental problems. Major topics addressed include the cycling of various substances (water, carbon, sulfur, etc.) in the natural environment and effects of anthrogenic perturbations on them.

PHY 352 three credits
Physics of the Environment II
Prerequisite: PHY 351
Continuation of PHY 351. Acid rain, climatology and the "greenhouse effect". Survival of populations. More elaborate mathematical modelling, some of which involves a little calculus, but a knowledge of calculus is not a prerequisite.

PHY 363 three credits
Intermediate Astrophysics
Prerequisites: PHY 251, 252; or permission of instructor.
This course explores in greater detail topics in stellar and galactic astronomy that were introduced in PHY 251-252. Variable stars, binary stars, star clusters, and galactic structure will be discussed with an emphasis on areas of current astronomical research. Astronomical imaging and image-processing techniques will be taught using equipment at the observatory.

PHY 411 three credits
Electric and Magnetic Fields I
Prerequisite: PHY 234
Study of the fields of static charges and constant currents, the properties of dielectric and magnetic materials, and magnetic induction leading to the formulation of Maxwell's equations.

PHY 412 three credits
Electric and Magnetic Fields II
Prerequisite: PHY 411
Continuation of PHY 411. Development of the wave equation. Electro-magnetic waves in space and in matter. Study of radiation from time varying charge and current distributions.

PHY 421 three credits
Advanced Physics Laboratory I
1 hour lecture, 4 hours laboratory
Prerequisites: PHY 213, 226
Laboratory course to acquaint students with current experimental techniques in physics and methods of data analysis.

PHY 422 three credits
Advanced Physics Laboratory II
1 hour lecture, 4 hours laboratory
Prerequisite: PHY 421
A continuation of PHY 421. Projects in experimental physics with emphasis on independent work by the student.

PHY 430 three credits
Methods and Strategies for Physics Teachers
Prerequisites: PHY 111 or 113, 112 or 114, 213, 234
This course is designed for Physics teachers. It emphasizes the use of varied teaching strategies and methods to cater to different learning styles of students. Attention is given to analytic and graphic as well as intuitive presentation of physics concepts and phenomena. Teaching techniques including audio-visual aids, demonstration and hand-on experiments are used to enhance the learning experience.

PHY 441 three credits
Statistical Thermodynamics
Prerequisite: PHY 213
The laws of thermodynamics and their interpretation based on the microscopic behavior of matter. Entropy and probability, equilibrium, reversibility, thermodynamic functions, phase changes, quantum statistics. Applications to problems in solid state physics.

PHY 442 three credits
Elements of Solid State Physics
Prerequisite: PHY 342
Basic concepts of condensed matter physics, crystal structure, crystal diffraction, lattice vibrations, theory of metals, semiconductors and insulators, magnetic properties of solids.

PHY 480 three credits
Undergraduate Research
Prerequisite: Permission of department
Individual work under the supervision of a faculty member on an experimental, theoretical, or literature review project in physics. This work may lead to a senior thesis project or may be concluded by a written report at the end of the term.

PHY 490 three credits
Senior Thesis
Intensive individual work on an experimental or theoretical problem in physics under the guidance of a faculty member. The special project is to be selected at the beginning of the senior year. Credit will be assigned in the second semester.

PHY 495 three credits
Independent Study
Prerequisites: Upper-division standing; permission of instructor, department chairperson, and college dean
Individual study of selected topics in physics under the guidance of a faculty advisor. This course is suitable for study of physics subfields of special interest to individual students and faculty members. Conditions and hours to be arranged.

PHY 196, 296, 396, 496 three credits
Directed Study
Prerequisites: Permission of the instructor, department chairperson, and college dean
Study under the supervision of a faculty member in an area covered in a regular course not currently being offered. Conditions and hours to be arranged.

Note: 500-level courses are for graduate students and advanced undergraduates. 600-level courses are for graduate students only. See the *Graduate Catalogue* for graduate general and program requirements.

Graduate Courses in Physics

PHY 501 three credits
Graduate Laboratory I
Principles of electronics and electronic instrumentation. Recommended for students with little or no prior experience in electronics.

PHY 502 three credits
Graduate Laboratory II
Continuation of PHY 501. Introduction to experimentation in physics. Recommended for students with little prior experience in conducting experiments, especially those who wish to enter into experimental research projects. Emphasis is on advanced topics and methods of data analysis.

PHY 510 three credits
Special Topics in Physics
Prerequisites: Variable, depending on topic
An advanced treatment of a special topic in physics with an emphasis on recent developments. The subject matter varies according tho the interests of the instructor and the students.

PHY 515 three credits
Physics of Ocean Boundary Layers
Prerequisites: PHY 315 and MNE 332 or equivalent; or exposure to PDEs or undergradaute fluid medchanics
Tools and the physical concepts needed to understand the physics of ocean boundary layers. This course considers tensor analysis, motion relative to a point, Bousinessq approximation, vorticity dynamics in geophysical fluid flows and the physical processes pertaining to oceanic boundary layers, surface gravity waves, and oceanic turbulence. Also discussed is surface energy exchange at the ocean-atmosphere interface.

PHY 521 three credits
Computational Physics
Prerequisites: CIS 115 and PHY 313 or equivalents
Application of computational techniques to computer simulations in physical science and engineering. The course covers physical concepts such as realistic projectile motion, planetary systems, nonlinear dynamics, chaos and fractals, and electromagnetic and quantum systems. The course exposes students to numerical algorithms and methods such as solutions to optimization, quadrature, fast Fourier transform, and boundry value problems, and gives hands-on experience in programming and computer simulations.

PHY 531 three credits
Intermediate Quantum Mechanics I
Fundamentals of quantum mechanics. Schrödinger equation, operator techniques, angular momentum, central force motion, spin, matrix representations, and elementary perturbation theory are studied.

PHY 543 three credits
Statistical Thermodynamics
The laws of thermodynamics and their interpretation based on the microscopic behavior. Entropy and probability, equilibrium, reversibility, thermodynamic functions, phase changes, quantum statistics are studies. Applications to problems in solid state physics are examined. (Formerly offered as offered as PHY 441.)

PHY 550 three credits
Fundamentals of Physical Oceanography
Prerequisite: Differential and integral calculus or permission of instructor
Fundamental physical oceanographical processes important to coastal and open ocean environments. Included in the course are lectures by current researchers in specialized topics such as satellite oceanography and numerical modeling.

PHY 611 three credits
Electromagnetic Theory I
Boundary value problems in electrostatics, Green's functions and eigenfunction expansions. Also examined are Maxwell's equations, momentum and energy of the electromagnetic field, radiation, multipole expansions, scattering, special relativity and Lagrangian formulation, radiation from moving charge, radiation reaction. (Formerly offered as PHY 522.)

PHY 612 three credits
Electromagnetic Theory II
Prerequisite: PHY 611 or equivalent
Study of simple radiating systems, scattering and diffraction of electromagnetic waves, radiation by moving charges, special theory of relativity, Lorentz transformation, covariant formulation of Maxwell's equations, relativistic particle dynamics, scattering of charged particles, radiation damping and self-fields of a charged particle.

PHY 615 three credits
Theoretical Mechanics and Relativity
The Lagrangian and Hamiltonian formulation of Newtonian mechanics. Also covered are variational principles, transformation theory, Poisson brackets, Hamilton-Jacobi theory, special relativity and the covariant formulation of particle mechanics. General relativity is introduced. (Formerly offered as PHY 521.)

PHY 616 three credits
Graduate Seminar
A seminar devoted to the discussion of topics in modern physics and related subjects. (Formerly offered as PHY 575.)

PHY 621 three credits
Advanced Mathematical Physics I
Mathematical methods in physics. Linear algebra, complex variable theory, eigenfunction expansions and orthogonal functions, the special functions of mathematical physics are studied. (Formerly PHY 511.)

PHY 622 three credits
Advanced Mathematical Physics II
Continuation of PHY 511. Partial differential equations, integral equations, Green's functions, generalized functions, calculus of variations, and group theory are studied. (Formerly PHY 512.)

PHY 631 three credits
Intermediate Quantum Mechanics II
Radiative processes and the theory of scattering. Other topics included are variational principles, symmetry and invariance principles, and second quantization. Relativistic quantum mechanics and field theory are introduced. (Formerly offered as PHY 532.)

PHY 632 three credits
Advanced Quantum Mechanics
Further training for students in theoretical physics on a graduate level. Explores in depth topics discussed in PHY 531 and PHY 631. (Formerly offered as PHY 533.)

PHY 635 three credits
Solid State Physics I
Basic concepts of solid state physics, including crystal structures, lattice vibrations and ionic crystals. Also examined are dielectric and optical properties of insulators, ferroelectrics, free electron theory of metals, energy bands, and semiconductors. (Formerly offered as PHY 541.)

PHY 636 three credits
Solid State Physics II
Theory of conductivity and related effects. Rectification and transistors, imperfection in crystals, plastic deformation color centers, optical properties of solids, and theory of magnetism are also studied. (Formerly offered as PHY 542.)

PHY 641 three credits
Statistical Mechanics
Prerequisite: PHY 213 or equivalent
Thermodynamics and its statistical interpretation. Canonical, micro-canonical, and grand canonical ensembles. Boltzmann, Fermi, and Bose distributions, and their applications to equilibrium and transport phenomena. Phase equilibrium is also studied.

PHY 645 three credits
Ocean Circulation and Modeling
Prerequisite: PHY 550 or permission of instructor
Theories of ocean circulation, including wind-driven and thermohaline components, and their numerical modeling. The concepts of geostrophy, Sverdrup-to-Strommel dynamics, stratification, rotation, and diffusion processes are discussed for the general circulation features in all three world oceans. Primitive equation-based numerical modeling experiments are discussed for the global-scale, basin-scale, regional-scale, and feature-based models.

PHY 651 three credits
Nuclear Physics
Structure and properties of nuclei. Also studied are nuclear forces and potentials, nuclear shell model and collective model, strong, electromagnetic, and weak interactions, nuclear reactions and decays. (Formerly offered as PHY 551.)

PHY 652 three credits
Elementary Particle Physics
Relativistic kinematics of particle motion, phenomenological and dynamical theories of particle interactions and classification of particles according to symmetry principles. (Formerly offered as PHY 552.)

PHY 655 three credits
Ocean Atmosphere Dynamics
Prerequisite: PHY 550 or permission of instructor
Ocean atmosphere dynamic interaction processes related to short-term and long-term climate variability. El Niño/southern oscillation, North Atlantic osscilation and moonsoon dynamics are discussed with the perspective of global climate change. During the semester the class will conduct a real-time monitoring experiment of the Pacific Ocean using the Internet. Also presented are advanced assimilation techniques of satellite (GEOSTAT, Topex/Poseidon, SeaWifs) and in-situ data from the World Ocean Circulation Experiment (WOCE) in numerical climate models.

PHY 660 three credits
Physical-Biological Interactions in the Ocean
Prerequisite: PHY 550 or permission of instructor
Fundamental physical-biological interactions, emphasizing the relationships between physical oceanographic processes and oceanic biology over a variety of spatial and temporal scales. This interdisciplinary course uses lectures, readings, and sample problems, and requires a mini-research project or term paper.

PHY 661 three credits
Physical Oceanography of Shallow Seas
Prerequisite: PHY 550 or permission of instructor
Physical oceanographic processes important to European and United States shallow seas, continental shelves, and banks, and their relationship to nutrients and biology (plankton and fish) in these regions. Included in the course are lectures by current researchers in appropriate topics.

PHY 662 three credits
Physical Oceanography of Enclosed Basins
Prerequisite: PHY 550 or permission of instructor
Physical oceanographic processes important to enclosed basins and their relationship to nutrients and biology (plankton and fish) in these regions. Regions of study include the Gulf of Maine, Gulf of Mexico, and Mediterranean Sea. Included in the course are lectures by current researchers in appropriate topics.