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# Physics

## Faculty and Fields of Interest

**Bisagni, James J** Associate Professor of Physics and Marine Science and Technology (1997), BS 1972 University of New York at Stony Brook, MS 1976, PhD 1991 University of Rhode Island Graduate School of Oceanography. *Specializations:* Physical oceanography, satellite oceanography.

**Crawford, Renate** (Chairperson, Department of Physics) Associate Professor of Physics (1996), BS 1990, MA 1991, PhD 1993 Kent State University. *Specializations:* Experimental liquid crystals, condensed matter, physics education and outreach.

**Gangopadhyay, Avijit** Associate Professor of Physics and Marine Science and Technology, BTech 1979 Indian Institute of Technology, Kharagpur, MTech 1982 Indian Institute of Technology, New Delhi, PhD 1990 University of Rhode Island. *Specializations:* Physical oceanography, numerical modeling, climate studies.

**Hirshfeld, Alan** Professor of Physics (1978), BA 1973 Princeton University, MS 1975, PhD 1978 Yale University. *Specializations:* Astrophysics, observational astronomy.

**Horch, Elliott** Assistant Professor of Physics (2002), BA 1987 University of Chicago, MS 1989 Yale University, PhD 1994 Stanford University. *Specializations:* Observational astronomy, astrophysics, astronomical imaging systems.

**Hsu, Jong-Ping** (Graduate Program Director) Chancellor Professor of Physics (1978), BS 1962 National Taiwan University, MS 1965 National Tsing-Hwa University, PhD 1969 University of Rochester. *Specializations:* Symmetry principles and gauge field theories.

**O'Reilly, Grant** Assistant Professor of Physics (2002), BS 1986 University of Melbourne, PhD 1997 University of Melbourne. *Specializations:* Photonuclear physics at intermediate energies, few-body systems, pion photo productions, fundamental nuclear symmetries.

**Tandon, Amit** Assistant Professor of Physics and Marine Science and technology (1999), BTech 1987 Indian Institute of Technology, PhD 1992 Cornell University. *Specializations:* Fluid dynamics, physical oceanography, environmental and computational physics.

**Wang, Jay (Jianyi)** Assistant Professor of Physics (1998), BSc 1983 Lanzhou University, China, PhD 1992 University of Tennessee, Knoxville. *Specializations:* Theory and simulations of electronic, atomic and optical

processes, ion-solids and ion-surface interactions, computational physics.

**Zarrillo, Marguerite** Assistant Professor of Physics (1998), BS 1978 Purdue University, MS 1981 University of Illinois, PhD 1998 University of Central Florida. *Specializations:* Traffic flow modeling, intelligent transportation systems, highway capacity.

## Graduate Physics at UMass Dartmouth

### Department of Physics, College of Engineering

The Physics Master of Science program is open to full-time as well as part-time students who are planning to pursue careers in physics research or teaching, or in applied areas of industrial research and development. The part-time option is attractive for students who are already professionally active as physics teachers. In addition, the university offers an international exchange program for a year of study abroad at universities in Baden-Württemberg in Germany.

The program is designed to advance students' understanding of the concepts of modern and classical physics as well as their mastery of applying these concepts to solve practical problems. Under the guidance of a graduate advisor, all students follow a course of study that is in harmony with their background and individual goals. The size of the program fosters close and informal contact between students and faculty active in research. These personal contacts enable graduate students to keep abreast of current problems in physics and offers them the opportunity to participate in original research.

The Physics Department offers a range of graduate courses in classical mechanics, electrodynamics, quantum mechanics, physical oceanography, condensed matter physics, and advanced mathematical physics. The department also offers courses emphasizing research including thesis research as well as independent study courses on special topics. There is also advanced laboratory instruction in experimental techniques, including electronic instrumentation, computer interfacing and data analysis. Graduate students are encouraged to participate in ongoing faculty research programs in theoretical physics, physical oceanography, optics, liquid crystals, and astronomy. In addition, research projects in physics education are available for students pursuing a teaching career. Students interested in applied areas of physics or in closely related fields such as computer science or electrical and computer engineering can take graduate courses and obtain research projects in those areas as well.

The physics background and expertise acquired by students at UMass Dartmouth has enabled many of them to continue their studies at premier research universities in the US and abroad. Others have embarked on careers in teaching or in applied areas like nuclear power, materials science, communications, computer or electrical engineering, and computer software.

Careers of our graduates as professional physicists are remarkably broad in scope. The

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majority of physics students who obtained their MS degree at UMass Dartmouth in recent years have continued their studies at the Ph.D. level at other universities including Brandeis, City University of New York at Brooklyn, Illinois, Johns Hopkins, Kentucky, Maryland, MIT., Notre Dame, Ohio State, Penn State, Purdue, Rensselaer, Rice, Rutgers, State University of New York at Stony Brook and Wesleyan. Our graduates are employed at computer software companies, high schools, industrial concerns, national laboratories, nuclear power plants and universities. They work in fields as varied as astrophysics, biophysics, computer programming, electrical engineering, experimental high energy physics, liquid crystals, materials science, mathematical statistics, nuclear engineering, nuclear theory and satellite communications.

### Faculty and Student Research

Experimental research is being conducted by the Physics Department in the areas of condensed matter, oceanography, and physics.

Current theoretical research in oceanography involves remote sensing, ocean-atmosphere interaction, biophysical coupling, coastal oceanography, upper ocean mixed layer studies, and dynamics of ocean fronts. Also under investigation are image and signal processing, El Nino and its impact on society, ocean circulation, and multidisciplinary integrated systems for ocean-biological fish management.

Current theoretical research on condensed matter physics is on problems in solids, molecules and atoms. Theory of ion-solids, ion-surface, and light-matter interactions; computational physics and computer simulations; scattering of Rydberg atoms with large angular momenta by protons and positrons.

Research in the area of liquid crystals is carried out by one faculty member at facilities both on and off campus. On-campus facilities include a modified nuclear magnetic resonance spectrometer and a polarizing microscope with temperature stage and video and regular cameras. Much of the research is done in collaboration with scientists at Kent State University in Ohio and the University of Leeds, England. Several students have gone on to work in the display industry or into research involving magnetic resonance and/or liquid crystals. Recent research topics include molecular dynamics and ordering in various phases, the nature of unknown phases, and

practical details regarding phase separation, used to make new kinds of materials with switchable optical properties.

Theoretical research is pursued in a number of areas. The first is the investigation of the physical properties of very dense matter by means of theoretical models. This study is applicable to the properties of neutron stars in astrophysics as no such high-density matter exists terrestrially even in the most advanced laboratory. Our understanding of the properties of matter from atomic physics, nuclear physics as well as high energy physics is applied to extract useful information and extrapolate the properties of very dense matter.

A second study in elementary-particle theory investigates quark confinement based on a perturbative framework with a new concept of fields and quantization. A third study deals with the geometrization of classical electrodynamics and other gauge theories based on a modified Finsler geometry with gauge-symmetry structure. A fourth project deals with the transition between classical and quantum mechanics and possible new physical laws for mesoscopic objects; and a fifth study topic is concerned with four-dimensional symmetry in its broadest form.

The program in observational astronomy is just getting underway. A recent grant from the National Science Foundation is permitting one of our faculty members to undertake astronomical research on variable stars, using the department's computer-controlled telescope, photoelectric photometer, and new charge-coupled device (CCD) camera. Computers and software have been purchased to set up an image analysis laboratory.

### Admission Requirements

Applicants must submit the required application materials to the Graduate Office. The following aspects are related specifically to the graduate physics program.

Admission to the graduate physics program may be either for the fall or the spring semester. Admission is competitive and requires the completion of an undergraduate degree in physics or a closely related field with a grade point average that attests to the student's ability for graduate level study. The General Record Examination (GRE) is not required for admission, but the selection of candidates for financial support includes consideration of GRE scores as well as Test of English as a Foreign Language (TOEFL) scores

for international students whose native language is not English.

### Financial Assistance

A limited number of teaching and research assistantships are available. They are awarded on a competitive basis. The selection of candidates is based on academic transcripts from the student's home institution, three letters of recommendation from professors or other senior scientists well acquainted with the qualifications of the candidate, the GRE scores and, where applicable, the TOEFL scores. Assistantships are awarded either on a full-time or a partial basis. The number of applicants for financial support has traditionally far exceeded the number of assistantships available.

Other assistance, such as loans or work study, may be available to you. Please consult the chapter on "Expenses and Financial Assistance."

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## Physics Courses

### Degree Requirements (MS degree)

Candidates for the MS degree in physics must complete a minimum of thirty semester hours of coursework. Graduate coursework comprises 500- and 600-level courses, although up to six credits of the total may be taken in advanced undergraduate (400 level) courses.

Up to 15 credits of appropriate courses in engineering or in other sciences, including computer science, may be accepted toward the degree, with prior approval of the Physics Graduate Program Director. Students can thus design programs to meet a variety of professional or personal goals.

The Department offers three MS plans. It is recommended that the entering student consult with a faculty advisor as soon as possible to choose a plan and to project a course sequence.

#### *Plan A: Master of Science with Thesis*

The thesis topic may range from research in one of the traditional fields of physics and applied physics to research in physics education such as innovative curricula and laboratories. The latter is of particular interest for physics teachers whose main goal is the improvement of physics instruction and pedagogical techniques in secondary schools. There is no limit on the number of thesis credit hours a student may take; however, no more than 6 thesis credit hours may be used toward the graduation requirement. A written thesis, successful completion of a formal departmental thesis defense, and approval by the student's thesis committee are all required. The comprehensive examination is waived. The thesis may be written while the student is no longer present on campus, although the student must remain registered in Program Continuation status and will not receive the degree until the thesis is finished. The thesis plan is noted in the student's record. This plan is strongly recommended to the student.

#### *Plan B: Master of Science with Research Project*

The student may choose a research project in consultation with a faculty advisor in an area of common interest to determine a research topic. Assigned readings and periodic progress reports will be required. A written project report and a formal department presentation are required before graduation. There is no limit on the number of research credit hours a student may take; however, a maximum of only 6 research credit hours may be used toward the graduation requirement. The comprehensive examination is waived.

Conversion to the thesis plan may be possible if sufficient grounds for conversion exist, at least one semester prior to graduation. This plan is recommended to students interested in research but not yet committed to the thesis.

#### *Plan C: Master of Science*

In order to fulfill the requirements for the award of an MS degree in this plan, the student must pass a written comprehensive examination. The student choosing this plan should successfully complete the comprehensive examination after the first year of study. The comprehensive examination is offered once every year. The examination emphasizes the mastery of topics in undergraduate as well as graduate physics.

#### Language Requirement

There is no foreign language requirement for US students. International students have to demonstrate their knowledge of English and their ability to follow advanced courses by taking the TOEFL examination prior to applying for admission. The minimum score for admission to the physics graduate program is specified as 500; for admission with a teaching assistantship, the minimum score is 550.

#### Cooperative PhD Program with UMass Amherst

The Department participates cooperatively in a doctoral program with the University of Massachusetts Amherst. The Department nominates one or two outstanding students who are completing our master's degree for this program and are accepted to the UMass Amherst PhD program in Physics. Cooperative Dartmouth/Amherst Physics PhD students are supported by a research assistantship from UMass Dartmouth and pursue their principal research with UMass Dartmouth faculty while they are matriculated degree students of UMass Amherst.

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### Contact

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### Undergraduate Courses

eligible for use toward the graduate degree

#### PHY 411 three credits Electric and Magnetic Fields I

Study of the fields of static charges and constant currents, the properties of dielectric and magnetic materials; and vector calculus.

#### PHY 412 three credits Electric and Magnetic Fields II

Continuation of PHY 411. Study of magnetic induction and the formulation of Maxwell's equations. Development of the wave equation and of electromagnetic waves in space and in matter. Study of radiation from time varying charge and current distributions.

#### PHY 421 three credits Advanced Physics Laboratory I

One hour lecture and four hours laboratory. Acquaints students with current experimental techniques in physics and methods of data analysis.

#### PHY 422 three credits Advanced Physics Laboratory II

One hour lecture and four hours laboratory. 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

Teaching strategies and methods for different learning styles of students. Attention is given to analytic and graphic as well as intuitive presentation of physics concepts and phenomena. Uses techniques including audio-visual aids, demonstration and hands-on experiments.

#### PHY 441 three credits Statistical Thermodynamics

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 are studied, with applications to problems in solid state physics.

#### PHY 442 three credits Elements of Solid State Physics

Basic concepts of condensed matter physics, crystal structure, crystal diffraction, lattice vibrations, theory of metals, semiconductors and insulators, magnetic properties of solids.

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## Graduate Courses

### 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 to 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 undergraduate fluid mechanics

Tools and the physical concepts needed to understand the physics of ocean boundary layers. This course considers tensor analysis, motion relative to a point, Boussinesq 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 boundary 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 studied. Applications to problems in solid state physics are examined. (Formerly 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 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 PHY 521.)

### PHY 616 three credits Graduate Seminar

A seminar devoted to the discussion of topics

in modern physics and related subjects. (Formerly 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 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 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 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 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.

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**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-Stommel 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 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 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 oscillation and monsoon 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.

**PHY 680** three credits

**Graduate Project**

Prerequisite: Departmental permission  
Directed research on a project in experimental, theoretical, or applied physics under the supervision of a faculty sponsor. The research may lead to a graduate thesis project or may be concluded by a written report at the end of one or two terms. Graded A-F. (Formerly PHY 580.)

**PHY 685** three credits

**Graduate Research**

Prerequisite: Permission of instructor  
Supervised research on an experimental or theoretical topic in physics under a faculty advisor. This course is offered only to students indicating strong intention and ability to do thesis work in subsequent semesters. The credits are considered equivalent to Thesis (PHY 690) if thesis work on the same topic is taken up later. Otherwise, a written report is required at the end of the research. Graded A-F, or IP if the work is approved to be continued as PHY 690 Thesis, in which case the grade earned when the thesis is completed will replace the IP.

**PHY 690** not to exceed 6 credits

**Graduate Thesis**

Thesis research on an experimental or theoretical project in physics under a thesis advisor. The specific project will usually be selected at the beginning of the second year of graduate study. Submission of a formal thesis required at conclusion. Graded A-F. (Formerly PHY 590.)

**PHY 695** three credits

**Independent Study**

Prerequisite: Permission of the instructor, graduate program director, and college dean  
Individual study under the supervision of a faculty member in an area of physics that is not otherwise part of the graduate course offerings. (Formerly PHY 595.)

**PHY 696** three credits

**Directed Study**

Prerequisite: Permission of the instructor, graduate program director, and college dean  
Individual study under the supervision of a faculty member in an area of physics that is part of the graduate course offerings but not being taught during a particular year.