Physics

Faculty and Fields of Interest

Bisagni, James J 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 (1997), 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 (Graduate Program Director) 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 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.

Gaurav Khanna Assistant Professor of Physics (2003), BTech 1995 Indian Institute of Technology, PhD 2003 Penn State University. *Specializations:* Theoretical and computational astrophysics, black hole astrophysics, gravitational waves, quantum gravity, high performance computing, control and dynamical system theory.

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 Associate 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)** Associate 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 Associate 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 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, communications, materials science, computer or electrical engineering, and computer software.

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

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

Research activities in the Physics Department span a very diverse range within the field, but may be grouped into three main focus areas: Ocean Physics, Computational and Theoretical Physics, and Experimental Physics. Student participation is highly valued in all of these areas, and opportunities include research assistantships and summer internships along with tuition waivers. Current research efforts in the department are supported by grants from several federal agencies.

The world's oceans play a critical role in modulating both weather and climate. Current research projects in Ocean Physics cover physical scales from micrometers to thousands of kilometers using several different techniques. Satellite-derived data is used to study a variety of physical and physical-biological interactions concerning the relationship between ocean circulation and plankton. Numerical and analytical techniques are used to study many different aspects of both coastal and open ocean circulation, as well as upper ocean conditions and circulation. Specific projects include studies of feature oriented regional modeling systems and multivariate synthesis of biophysical data sets in different world oceans, biophysical modeling in the northern Humboldt Current, basin-scale simulations of the North Atlantic, upper-ocean mixing in the North Atlantic and Southern Ocean, interaction of mesoscale eddies with mixed layers, ageostrophic circulation near fronts in the upper ocean, and experimental fluid physics. Research is carried out at both the UMass Dartmouth main campus in North Dartmouth and the UMass Dartmouth Marine Campus located on Clark Cove in southern New Bedford, and conducted in collaboration with a variety of both national and international researchers located at other federal laboratories and major universities.

Theoretical and computational research is pursued in a number of areas. Atomic, molecular and optical (AMO) physics research focuses on electronic and optical properties of matter in interaction with charged particles, photons and laser pulses. Electron correlation effects and exotic properties of Rydberg atoms and molecules are areas of current interest. Research in gravitational physics is also represented in the theory area in several projects. One of the most significant of these involves studying the coalescence of binary black holes using perturbation theory and estimating properties of the gravitational waves produced in this process. This research is relevant to the various gravity wave observatories being constructed (e.g. LIGO, LISA) that will soon detect this radiation from astrophysical sources. Other areas of faculty interest in theoretical research include studies of the broad view of Lorentz and Poincare invariance and spacetime symmetry, spacetime transformations for non-inertial frames with limiting 4-dimensional symmetry and field theory in non-inertial frames, and translation gauge symmetry for gravity.

Research in experimental physics at UMass Dartmouth includes nuclear physics, condensed matter physics, traffic engineering, and observational astronomy. The nuclear physics research currently involves a series of measurements to investigate pion photoproduction near threshold from the proton and (eventually) the neutron. This project is a collaborative effort involving researchers from the U.S. and Sweden, and will be undertaken using the MAX-lab facility at Lund University in Lund, Sweden. Research into the physical phenomena of liquid crystals and polymers, a subdiscipline of condensed matter physics, currently includes working toward the development of electronically switchable diffraction gratings, which can steer and manage impinging light. An area that uses both modeling and experimental data is transportation engineering: specifically, transportation modeling, queuing, optimization and car following theory. This work involves the Florida Department of Transportation and the Center for Advanced Transportation Systems Simulation, CATSS, in Orlando, Florida. Observational astronomy research is focused on stellar and galactic studies of binary stars. *Hubble* Space Telescope data of extremely old binary stars are now being analyzed, and a ground-based effort using speckle imaging at the WIYN 3.5-m Telescope at Kitt Peak, Arizona is underway in collaboration with Yale University to develop comprehensive information of binaries in the solar neighborhood.

For further information on these and other research activities, please visit the department web page at www.umassd.edu/engineering/physics/

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."

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.

While the program is designed to meet a variety of professional needs, at least 15 credits of physics core courses are required. The remaining credits may be drawn from other engineering or science fields with prior approval of the Physics Graduate Program Director; or from PHY 616 Graduate Seminar, research-based courses (such as PHY 680, 685, and 690), or certain 400-level undergraduate Physics courses.

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 on the paper-based test (173 on the computer-based test); for admission with a teaching assistantship, the minimum score is 550 on the paper-based test (213 on the computer-based test).

Cooperative PhD 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.

Contact

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Physics Courses

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.

Graduate Courses

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 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, 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.

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 551 three credits
Introduction to Nuclear Physics
Prerequisite: PHY 341 or equivalent, or permission of instructor
Discussion of topics in nuclear physics, including nuclear forces, nuclear models, nuclear reactions, and nuclear decay.

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.

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.

PHY 616 three credits
Graduate Seminar
A seminar devoted to the discussion of topics in modern physics and related subjects.

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.

PHY 622 three credits
Advanced Mathematical Physics II
Continuation of PHY 621. Partial differential equations, integral equations, Green's functions, generalized functions, calculus of variations, and group theory are studied.

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.

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.

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.

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.

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 experi-

ments 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, electro-magnetic, and weak interactions, nuclear reactions and decays.

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.

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.

PHY 680 three credits
Graduate Project
Prerequisite: Permission of instructor
Directed research on a project in experimental, theoretical, or applied physics under the supervision of a faculty sponsor. The research may be concluded with a written report at the end of one or two terms. Graded A-F, or IP if the project is conducted across two terms.

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 up to twelve credits
Master's Graduate Thesis
Thesis research on an experimental or theoretical project in physics under a faculty advisor. The specific project is usually selected at the beginning of the second year of graduate study. A written thesis must be completed in accordance with the rules of the Graduate School and the College of Engineering. Graded A-F.