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THE DEPARTMENT OF PHYSICS AT NORTHEASTERN UNIVERSITY PROVIDES OPPORTUNITIES FOR GRADUATE STUDENTS TO ENGAGE IN RESEARCH AND SCHOLARSHIP UNDER THE DIRECTION OF INTERNATIONALLY RECOGNIZED FACULTY. STUDENTS HAVE A CHOICE OF PROGRAMS IN THEORETICAL OR EXPERIMENTAL RESEARCH IN CONDENSED MATTER PHYSICS, MOLECULAR BIOPHYSICS, MEDICAL PHYSICS, OR ELEMENTARY AND PARTICLE PHYSICS.

**the graduate programs**

The Department of Physics offers full-time Ph.D. programs and full- and part-time programs leading to an MS or MAT degree, with opportunities for individually designed programs. Thesis research can be undertaken in any one of the department's research specialties or in interdisciplinary areas such as materials physics, chemical physics, or applied engineering physics. A further option allows cooperative research to be done at high-technology industrial, government, national, or international laboratories, and at medical research institutions in the Boston area.

The graduate program in physics is committed to providing an effective education to students with a variety of backgrounds and preparations in physics and related subjects. All graduate students receive considerable faculty and peer support. Approximately fifty graduate students are enrolled in full-time programs leading to a Ph.D. degree in physics.
The reputation of the department brings a constant flow of well known visitors who enrich the department's colloquia and seminars. Faculty and students enjoy close contact with their distinguished counterparts located at other universities, government laboratories, and high-technology research centers in the greater Boston area. The department is a member of a consortium with the Massachusetts Institute of Technology, Boston College, Harvard, Boston University, Brandeis, and Tufts that organizes colloquia and seminars open to all faculty and students.

**Experimental Condensed Matter Physics**

Faculty and graduate students engaged in condensed matter and materials physics research have access to a wide spectrum of in-house and off-campus experimental techniques for basic research studies and diagnostic applications. Areas of current focus include: **High Temperature Superconductivity**, including microwave studies of gap symmetry and the dynamics of vortices, studies of fundamental mechanism, and novel fabrication techniques aimed at improving critical currents; **Correlated Electron Systems,** where high magnetic field and ultralow temperature optical spectroscopy and transport measurements are used to study the novel physics of electrons confined in 2D semiconductor quantum wells, including the quantum Hall effects, incompressible quantum fluid, composite fermions, skyrmions, and metal-insulator transitions; **Mesoscopic Physics**, where novel mesoscopic techniques, with an emphasis on noise measurements and analyses, are used to probe the properties of intermediate size systems with relatively small numbers of atoms, with implications for our understanding of complexity in disordered systems, critical phenomena, and nonlinear dynamics; **Quantum Chaos**, focusing on the role of chaos and disorder in quantum wave functions through electromagnetic experiments; **and Low Dimensional and Semiconductor Magnetism**, including high frequency electrodynamic measurements of a wide variety of novel magnetic materials, including high-Tc superconductors. The department has Molecular Beam Epitaxy (MBE) growth fabricating facilities for III-V (GaAs) semiconductors, and research is aimed at fabricating practical magnetic semiconductors such as GaAs:Mn. Work in theses overlapping areas is enhanced by close contact with a vigorous theoretical group.

Much of the experimental condensed matter research is done in collaboration with industrial and governmental laboratories. Opportunities exist for students to spend part of their thesis research at these facilities. The groups are also involved in a variety of off-campus activities. Ongoing experiments include X-ray reflectivity studies at the Brookhaven National Laboratory synchrotron light source; inelastic neutron scattering studies at the National Laboratories at Oak Ridge and Brookhaven, and at the Laue Langevin Institute in Grenoble, France; and high magnetic field studies at the Los Alamos and Tallahassee National High Magnetic Field Laboratories.

**Theoretical Condensed Matter Physics**

The condensed matter theory group has strong interactions with researchers in experimental condensed matter physics and molecular biophysics, and the group also enjoys a reputation for its independent activities in strictly fundamental areas. Research interests include the theoretical modeling of localization and percolation in order-disorder phase transitions; analysis of pattern formation, such as solidification, hydrodynamic instabilities, and chemical waves; theory of Josephson junctions; quantum optics; Fermi liquid theory; charge density waves; electronic structure, and optical properties of ordered and disordered systems; quantum chaos; nanotribology (atomic level friction); magnetism and magnetic resonance in ferrites; structural phase transitions in DNA; fermiology of high temperature superconductors; electronic structure of disordered materials; catalytic properties of alloys; positron annihilation and photoemission spectroscopy of materials; exact and rigorous results in statistical mechanics; magnetic properties of high temperature superconductors; transport theory in nanostructures; and biophysical problems in cell biology and neuroscience.

The group is the home for the **Center for Interdisciplinary Research in Complex Systems** (CIRCS), which was created to foster quantitative interdisciplinary research on many important problems in biology and materials science, including problems related to modern microfabrication and large-scale computer simulations.

**Biological and Medical Physics**

The **molecular biophysics** group is primarily engaged in a variety of experimental programs designed for a better understanding of the structure and function of macromolecules. Current research areas encompass heme-containing molecules, such as hemoglobin, myoglobin, cytochrome-c, and cytochrome P-450. Investigations of these systems have the potential of providing answers to fundamental questions involving electron transport in macromolecules, enzyme catalysis, and the role of protein dynamics in the binding and release of small molecules.
Techniques include femtosecond coherence spectroscopy, laser-based optical resonance such as inelastic (Raman) and elastic (Rayleigh) light scattering, infrared (FTIR) spectroscopy, and transient absorption spectroscopy. Opportunities also exist for students to perform research at the Advanced Photon Source or Argonne National Laboratory, using nuclear resonant absorption. These techniques provide information about inter- and intra-molecular motions ranging from the very slow (classical) to the very fast (quantum mechanical) time regime.

Theoretical research at the cellular and tissue level includes investigations of the electrical activity of the heart; force generation by molecular motors; and synchronization in the electrical firing of neuron networks in the hippocampus. The **Medical Physics** group is associated with other direct medical applications, which include theoretical and experimental studies of the anisotropy of electrical conduction in skeletal muscle showing how non-invasive measurements of rf impedance can be used to examine deep subsurface muscle structures. Another collaboration with local hospitals has successfully developed ultrasound techniques for measuring human body motion to evaluate the propensity to fall, particularly among the elderly.

**Theoretical Particle Physics and Cosmology**

The research interests of the **Theoretical Particle Physics** group focus on fundamental questions concerning the origins and properties of the elemental constituents of matter: their masses, the nature of the forces with which they interact, and the impact of these properties on the evolution of the universe and the structures within it. Supersymmetry, supergravity, and string theory play crucial roles in providing a unifying framework for contemporary models of nature at the microscopic level, and these topics have been extensively studied from many perspectives by members of the group. The group includes one of the original discoverers of the possible role of supergravity in setting the scale of all physics at lower energies (electroweak physics), and work continues on the development and impact of these theories at accelerators, in cosmology, and in large underground detectors searching for the decay of protons and neutrons. The group has made original contributions to the theories of dark matter and its super-symmetric origin and continues to study a range of other aspects of the interplay between elementary particle physics and cosmology. These studies include computational cosmology in which numerical simulations of structure formation are compared with astronomical observations in order to restrict particle physics models through their cosmological consequences.

Others in the group work at what is perhaps the forefront of the field, the superstring theory and its generalizations with investigations that include such fundamental questions as how the different string theories may be aspects of a single theory, and how the fundamental geometric properties of strings can dictate the low energy physics of our world. In addition, the group has made significant contributions to quantum field theory, to the interplay between classical and quantum field theory, and to quantum mechanics itself and the manner in which some of its most important properties are tested in the physics of K-mesons and neutrinos. These include significant works in the field of renormalization group analyses, which are crucial in connecting physics across large seemingly disconnected domains of energy, and progress in finding relations among the masses, spins, and Flavors of all the mesons of strongly interacting physics.

Faculty in the **Theoretical Particle Physics** group work closely with the high energy experimentalists on the interpretation and planning of experiments at the world's largest accelerators, such as Fermilab and CERN. They are also involved in collaborations with condensed matter theorists in studying sonoluminescence and in applying higher symmetry groups to the theory of high-Tc superconductors. The group routinely hosts international research conferences at Northeastern University, having founded the PASCOS (International Conference on Particles, Strings and Cosmology) conference series in 1990 (and hosting it again in 1991 and 1998), as well as the SUSY (International Conference on Supersymmetry) conference in 1993. These are presently two of the most important conferences in the field of elementary particle physics.

**Experimental High Energy Physics**

The high energy experimental physics group is supported by NSF and concentrates efforts on three major experiments: DØ at Fermilab , and L3 and CMS at CERN. The DØ detector in the Tevatron collider at Fermi National Accelerator Laboratory in Illinois measures the products of 2 TeV head-on collisions of protons and antiprotons. Fermilab is unique because nowhere else in the world will such high energies, essential for the study of such massive particles as the top quark, be available before the beginnings of the next century.

The L3 detector in the LEP collider at CERN (the European Organization for Nuclear Research) located near Geneva, Switzerland, measures the products of 92-100 GeV head-on collisions of electrons and positrons. LEP is the ultimate machine of this type: At 92 GeV it produces millions of Z's per year that decay to all particle-antiparticle pairs whose individual masses are below 46 GeV; when the energy is increased above twice the mass of the W, precise measurements of the WWZ vertex will be performed, as well as searches for new particles. The CMS detector, which is one of two large experiments for the LHC (the Large Hadron Collider, also at CERN) is under construction by a large international collaboration. Operating in the energy range well beyond beyond Fermilab, it will search for the elusive Higgs particle. On L3 we built a plastic scintillating fiber (PSF) tracker to calibrate the central tracker, in DØ we are participating in developing the new tracker based on PSF and silicon microstrips, and on CMS we are working on an APD-based calorimeter readout and gas microstrip tracking. We are also working on the physics analysis of the data accumulated at DØ and L3 and in a series of fixed target experiments: E706 at Fermilab and SMC at CERN.

A sub-group of HEP is also working in the area of cosmic-ray astrophysics. One project focuses on the study of events in the ultra-high energy regime at the Pierre Auger Observatory in Argentina. Another is with SCROD (School Cosmic-Ray Outreach Detector) where the goal is to put cosmic ray detectors in high schools worldwide.

More details about individual faculty and group research can be found on the Physics Department Web page at http://www.physics.neu.edu.

The department is housed in the **Dana Research Ce n t e r** with research laboratories, conference and seminar rooms, a large machine shop, and faculty and graduate student offices. New materials science, semiconductor, and molecular biophysics laboratories are housed in the recently constructed **Egan Engineering/Science Research Center**. The **Advanced Scientific Computation Center** (ASCC) was founded in 1999 with major external funding from the National Science Foundation and the Compaq Computer Corporation. The high performance server which has been upgraded in Jan 2001 consists of 16 state-of-the-art EV6 Alpha processors, 28 GB memory and 700 GB disk with a backup unit of 750 GB capacity. The ASCC network domain provides a 100 Mb switched computing and visualization environment. ASCC also supports a Research Cluster with 8 UNIX stations and peripherals, and an Educational Cluster with 15 workstations for holding UNIX or NT classes on a separate network of 8 UNIX workstations (NOW). The facilities of the ASCC are available to the university community including all physics faculty, research associates, and graduate students for appropriate research and training activities. In addition, the **High Energy** Group has its own facilities consisting of winNT and Linux work stations and symmetric multi-processing servers. The **Condensed Matter Theory** Group performs large-scale simulations with Cray and Connection Machine supercomputers as well as running locally on Alpha workstations. Department computers are connected by the campus-wide network (NUNET) to the main computers located in the University's **Computer Resource Center and** the Internet.

In-house experimental facilities in the **Egan Research Center** include a variety of spectroscopic instrumentation spanning many decades of the electromagnetic spectrum. A broad range of fundamental excitations in condensed matter and molecular biophysics can be studied using Fourier transform interferometers (FTIR); infrared, photoluminescence, laser excitation, and Raman spectrometers; and sub-millimeter, microwave, radio-frequency, and dielectric systems. In addition, ancillary equipment exists for many of these investigations to be made as a function of pressure, temperature, electric, and magnetic fields. A 14 tesla superconducting magnet has recently been installed in **the Semiconductor Physics** laboratory. The group also has a SQUID magnometer and an MBE for crystal growth. Surface physics tools include Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM), X-ray diffraction, a metallograph, and ultraviolet, visible, and infrared reflectance techniques. Laboratories devoted to multi-layer deposition systems, crystal growth, fabrication, sample preparation, and polishing facilities are also available to researchers.

In addition to the on-campus research facilities, faculty and graduate students also work at many large-scale research centers located in the United States and Europe. High energy physics experiments are under way at Fermilab, near Chicago, and at the European Laboratory for Particle Physics (CERN), in Geneva, Switzerland. High magnetic field experiments are in progress at the National High Magnetic Field Laboratory, Tallahassee, Florida, and at Los Alamos National Laboratory, New Mexico. Several groups use the synchrotron facilities at Brookhaven National Laboratories, Long Island, New York, and many faculty have flourishing collaborations with scientists in Europe, Asia, and South America.

The Department of Physics offers a Master of Science (MS) degree and a Doctor of Philosophy (PhD) degree as well as a Master of Arts in Teaching (MAT) degree. The requirements for the MS degree are such that it can be earned as a regular part of the process of attaining the PhD degree. Students with weak backgrounds in physics should first take appropriate senior undergraduate courses or introductory graduate courses as determined by the graduate coordinator. Special students who wish to become degree candidates and part-time MS students who wish to become PhD candidates may so indicate by a petition to the graduate coordinator of the department. For the PhD degree, the petition must include a timetable for completing the required courses and taking the qualifying examination.

Northeastern University has been awarded in September 2000 a prestigious GAANN (Graduate Assistantships in Areas of National Need) Grant by the Education Department. This grant provides a limited number of GAANN Fellowships for a Ph.D. in Biology, Chemistry, Math, or Physics, with special emphasis on Advanced Scientific Computation and Visualization Techniques in affiliation with the Advanced Scientific Computation Center (ASCC). The GAANN Fellowships provide the students with full support of a stipend and tuition for a full year. Awards are for one year, but in exceptional cases an additional award can be made. Applicants must be U.S. citizens or permanent residents. Special consideration will be given to members of underrepresented minorities and women.

**the doctor of philosophy degree**

The program for the PhD degree consists of the required coursework, a qualifying examination, the completion of a dissertation based upon original research performed by the student, and a final oral examination.

The required courses are grouped into two sets, Part 1 and Part 2,
having a total of sixty-six quarter hours. Part 1 courses are typically taken prior to the qualifying exam. Part 2 courses may be taken before or after passing the qualifying exam. In addition, it is strongly recommended that at least one advanced graduate course from the set in Part 3 be taken after the satisfactory completion of the Part 2 courses; at his/her option, a student may take the Part 3 courses on a pass/fail basis. Part 3 courses are usually offered in alternate years.
The three sets of courses are as follows:

**Part 1 (Required Courses)**

*Fall Winter Spring Total-33 qh*

PHY 3311 3312 3313 Intro. to Research, ABC 1 qh ea.
PHY 3607 3608 3609 Mathematical Methods and Classical Mechanics ABC 3 qh ea.
PHY 3611 3612 3613 Electromagnetic Theory ABC 3 qh ea.
PHY 3621 3622 3623 Quantum Theory ABC 4 qh ea.

**Part 2 (Required Courses)**

*Fall Winter Spring Total-35 qh*

PHY 3321 3322 3323 Intro. to Ad v. Research ABC 1 qh ea.
PHY 3606 Computational Physics 3 qh

PHY 3624 Adv. Quantum Theory 4 qh
PHY 3631 3632 3633 Statistical Physics ABC 3 qh ea.
3641 3642 Solid State Physics AB 4 qh ea.
3651 3652 Particle and Nuclear AB 4 qh ea.
**Part 3 (Advanced Elective Courses)**
*Fall Winter Spring*
PHY 3331 3332 3333 Ad v. Research Seminar ABC 2 qh ea.
PHY 3643 3644 3645 Adv. Solid State ABC 4 qh ea.
PHY 3653 3654 3655 Fields, Particles, and StringsABC 4 qh ea.

The grade requirements for the successful completion of Part 1, and hence entry into the qualifying exam, are at least a B (3.000) average in the Part 1 courses. The grade requirements for the successful completion of Part 2, and hence formal entry into the thesis research, are at least a B (3.000) average for the Part 2 courses. The Part 2 courses, including any make-up of grade average deficiencies (see following), must be completed within two calendar years of passing the qualifying exam. The department expects students to complete the bulk of these courses in the first year after the qualifying exam.The cumulative average will be calculated quarterly. No more than two courses or six quarter hours of credit, whichever is greater, may be repeated in order to satisfy the requirements for the PhD degree. A student who does not maintain a 3.000 cumulative average for two consecutive quarters, or is otherwise not making satisfactory progress toward the PhD degree requirements, may be recommended for termination at the discretion of the Graduate Committee.
Within the above limitations, a required course for which a grade of F is received must be repeated with a grade of C or better and may be repeated only once. The tuition for a repeated course is the responsibility of the student and may only be waived at the discretion of the Graduate Committee. In calculating the overall cumulative average, all graduate-level coursework completed at the time of clearance for graduation will be counted unless designated at the time of registration as not for graduate credit.

A student who fails to achieve the required B average for the Part 1 courses must petition the Graduate Committee in order to remain in the graduate program and be eligible to take the qualifying exam. A student who fails to achieve the required B average for the Part 2 courses must petition the Graduate Committee in order to remain in the graduate program. The final decision of the Graduate Committee will be determined by the result of a special exam in the course(s) determined to be the most serious contributor(s) to the grade average deficiency.

All students registered in the PhD program are required to pass a qualifying exam. The qualifying exam may include both written and oral parts. Any new, entering student with a master's degree may take the qualifying exam upon arriving at Northeastern University. Failure of the exam at this time will not be used to limit the two opportunities to take the examination in the future.

- The qualifying exam will consist of two parts.

Part I: Classical Physics (based on classical mechanics, and mathematical methods) and Electromagnetic Theory.
Part II: Quantum Physics (based on quantum mechanics and its applications).
The content of the qualifying exam will be based on the content of the first year courses. A syllabus is available and on request will be distributed by the graduate coordinator to any student prior to the exam.

- The qualifying exam will be given twice yearly: once in September before the start of classes, and again in early January within the first two weeks of the term. The September exam should be prepared by the end of the spring quarter. The January exam should be prepared by the end of the fall quarter. The exam will consist of one day each on Part I (Classical Physics, Math. Methods, and E&M) and Part II (Quantum Physics).

- A student must take the exam in September after completing the first-year graduate courses with the required grade point average, except that those students who enter with advanced standing (equivalent to completion of all the first-year courses) must take the exam at the first opportunity after entering the program. Students taking the exam for the first time must take both Parts I and II. A student who does not pass the exam on the first taking must pass the exam the next time it is given in order to continue in the PhD program. However, a student who passes one part on the first attempt is not required to repeat that part.
- A student who fails the written exam by less than 5 percent of the total possible score will be automatically given an oral exam. A student who fails the written exam by more than 10 percent is excluded from taking an oral exam. These provisions apply separately to Parts I and II of the exam.

Degree candidacy is established when the student has completed at least forty quarter hours of graduate credit (or has an earned master's degree) and has passed the qualifying examination. A student may be admitted into the PhD program with advanced standing based upon graduate courses taken elsewhere. Students must petition in writing through the Graduate Committee to the Director of the Graduate School of Arts and Sciences for all transfer credit. A copy of an official transcript must be attached to the Request for Transfer Credit Form. A maximum of twelve quarter hours of credit obtained at another institution may be accepted toward the PhD degree provided that the credits transferred consist of a grade of B or better in graduate-level courses, have been earned at an accredited institution, and have not been used toward any other degree. Grades are not transferred.

Course waivers may be accepted toward the PhD degree course requirements, though they will not change the number of credits required for the program. The student must have received a B grade or better in equivalent graduate-level core courses that have been earned at an accredited institution. Students must petition in writing to the Graduate Committee for all course waivers and provide documentation in the form of official transcripts to support their petition.
The residence requirement is satisfied by at least one year of full- time graduate work (i.e., enrollment in PHY 3895, PhD Dissertation, for three consecutive quarters).
Some teaching experience is required. This requirement may be satisfied by at least one year of service as a teaching assistant or by other teaching duties.

A PhD candidate may spend one year in a participating high-technology, industrial, or government laboratory immediately after passing the PhD qualifying examination. In this program, the student is expected to remain in touch with the University by taking one course per quarter at the University and by frequent contact with a faculty adviser. After the one-year paid internship, the student returns to the University to do the dissertation. Eligibility for this program is contingent on acceptance both by the department and by the external laboratory.

Graduate students are strongly encouraged to select a field of specialization and look for a faculty adviser at the earliest opportunity. In any case, students must arrange for a dissertation adviser no later than the fall quarter of the second year, immediately after the qualifying exam. They will be required to select their field of specialization prior to the summer term of the second year.
The student may choose a field of research from three options:

- In one of the current theoretical or experimental research programs in the department, under direct supervision of an adviser from the Physics department.
- In a recognized interdisciplinary field involving another research area of the University, under the direct supervision of a faculty member in that field. In this case, an interdisciplinary committee is formed under the approval of the Graduate Committee,

consisting of the direct supervisor, a departmental adviser, and one other member of the department.

- In an area of applied research in one of the industrial or high-technology laboratories associated with the department's industrial PhD program. The direct supervisor is associated with the institution where the research is performed. In this case, a dissertation advisory committee is established by the Graduate Committee, consisting of the direct supervisor, the departmental adviser, and one other member of the department. All graduate students engaged in research are required to submit an outline of their PhD dissertation and the names of the members of the dissertation committee for approval by the Graduate Committee. Graduate students must submit the written dissertation proposal no later than the third quarter in which they take PHY 3895 (PhD Dissertation). The dissertation committee must be constituted at the time of submitting the dissertation proposal. Both the proposal and the make-up of the committee membership will be circulated to the entire faculty upon their receipt by the graduate coordinator. If any objections are received by the graduate coordinator, they will be referred to the Graduate Committee for resolution.

The PhD dissertation committee will consist of at least three full-time faculty members from the department, including the adviser. This committee will certify the progress of the student toward the PhD to the Graduate Committee and will serve as the Preliminary Research Seminar and dissertation defense panel.

It should be noted that the Dissertation Proposal or the Dissertation Committee can be changed at any time. This is accomplished by following the rules outlined in the Dissertation Proposal and Selection of a PhD Dissertation Committee sections. To certify that the student is sufficiently prepared to perform dissertation research and ensure that the oversight committee is formed in a timely manner, a Preliminary Research Seminar will be given no later than two years after completion of the Qualifying Exam. The student must make the presentation before the dissertation committee, in a format open to the full department, on a subject that could become a final dissertation topic. The dissertation committee will meet in closed session to evaluate the seminar. In the event that the dissertation adviser is changed and a new committee is formed, then a new Preliminary Research Seminar must be given.

The dissertation defense will consist of a public presentation, followed by a closed questioning period with the dissertation committee. The date of the dissertation presentation must be publicized at least one week prior to the defense. The final oral examination is held in accordance with the Graduate School regulations. Students must be registered for dissertation or dissertation continuation during the quarter in which they take the final oral examination.

**the master of arts in teaching degree**

The Master of Arts in Teaching (MAT) degree program in physics is designed to develop and enhance the ability of urban middle and secondary school teachers to teach physics in a modern and creative manner. Students integrate traditional graduate course work in physics with courses designed to help them develop a hands-on experimental approach to teaching science.

Admissions Requirements: Undergraduate degree in physics or engineering, or a degree in a related science and at least four undergraduate physics courses beyond first-year physics and two mathematics courses beyond first-year calculus. Provisional Certification, which is also required for this program, can be obtained through an intensive summer program offered by the University.

Further information about the MAT in Physics program may be obtained from the graduate coordinator in the Department of Physics, 617.373.2902.

**the master of science degree**

There are several options for the MS degree: the standard MS, the MS degree with a thesis, the MS with a concentration in instrumentation, and the MS with a concentration in optics. All options require a minimum of forty-two quarter hours of graduate credit. Up to twelve quarter hours may be transfer credit approved by the Physics department's Graduate Committee and the Graduate School of Arts and Sciences. The MS degree options involve a common set of required graduate physics courses:

**Required Core Courses for All Master of Science Degree Options Credit (qh)**

PHY 3607/9 Mathematical Methods and Classical Mechanics ABC 3 qh ea.

PHY 3611/12 Electromagnetic Theory AB 3 qh ea.

PHY 3621/22 Quantum Theory AB 4 qh ea.

The four degree options have the following additional requirements:

**Standard Master of Science Degree**

*Required Courses Credit (qh)*

Core Courses 23 qh

PHY 3606 Computational Physics 3 qh

PHY 3623 Quantum Theory C 4qh

Elective Courses

The remaining twelve quarter hours may consist of elective courses carrying graduate credit in physics, math, engineering, chemistry, biology, or psychology. Not more than nine quarter hours of elective credit may be taken from the following introductory graduate-level physics courses:

*Introductory Physics Courses Credit (qh)*

PHY 3414 Introduction to Solid State Physics 3 qh

PHY 3415Ð6 Quantum Mechanics 1*-2* 3 qh ea.

PHY 3405 Thermodynamics and Kinetic Theory 3 qh

PHY 3551Ð2 Electronics for Scientists 1-2 4 qh ea.

*For many incoming MS students, it is recommended that PHY 3415 and PHY 3416 be taken prior to the common set of required courses in Quantum Theory.

**Master of Science Degree with Thesis**

*Required Courses Credit (qh)*

Core Courses 23 qh

PHY 3606 Computational Physics 3 qh

PHY 3623 Quantum Theory C 4 qh

Master's Thesis 1Ð3 (PHY 3890, 3891, 3892: 4 qh each) 12 qh

MS Thesis

Graduate students desiring the MS with thesis option should arrange a thesis with a faculty adviser. The student may choose a field of research from three possible areas as outlined under the PhD Dissertation section. The thesis must demonstrate the individual's capacity to execute independent work based on original material. The thesis must be approved by the Graduate Curriculum Committee. The thesis may be completed in one quarter (e.g., summer quarter) or in consecutive quarters. Students who have not completed their thesis after the required number of thesis credits (12 qh) must register for MS Thesis Continuation (PHY 3798; 0 qh) each subsequent quarter until the thesis is approved by the Graduate School and submitted to the University library.

**Master of Science with a Concentration in Instrumentation**

*Required Courses Credit (qh)*

Core Courses 23 qh

PHY 3606 Computational Physics 3 qh

PHY 3551Ð2 Electronics and Data Analysis 1-2 4 qh ea.

**Master of Science with a Concentration in Optics**

*Required Courses Credit (qh)*

Core Courses 23 qh
PHY 3623 Quantum Theory C 4 qh
Elective Courses
In addition, students must take twelve quarter hours of credit from any of the following courses:
*Credit (qh)*
ECE 3572-3 Fourier Optics A-1, 1-B 2 ea.
ECE 3576-7 Lasers 1-2 2 ea.
ECE 3579 Optoelectronics and Fiber Optics 2
ECE 3580-1 Electro-Optics 1-2 2 ea.
ECE 3582 Electro-Optics 4
ECE 3583-5 Optical Properties of Matter 1-3 2 ea.
ECE 3586 Principles of Optical Detection 4
ECE 3587-8 Principles of Optical Detection A-B 2 ea.
ECE 3589 Optical Storage and Display 2
ECE 3590 Optical Instrumentation Design 2
ECE 3591 Spectroscopic Instrumentation 2

The remaining three quarter hours may be chosen from any courses carrying graduate credit in physics or in optics-related courses. To qualify for the MS degree, a cumulative average of 3.000, equivalent to a grade of B, must be obtained. No more than two courses or six quarter hours of credit, whichever is greater, may be repeated in order to satisfy the requirements for the MS degree. A student who does not maintain a 3.000 cumulative average for two consecutive quarters, or is otherwise not making satisfactory progress toward the MS degree requirements, may be recommended for termination at the discretion of the Graduate Committee.

Within the above limitations, a required course for which a grade of F is received must be repeated with a grade of C or better and may be repeated only once. Elective courses in which an F has been received may be repeated once to obtain a C or better. Students must petition, in writing, through the Graduate Committee to the director of the Graduate School of Arts and Sciences for all transfer credit. A copy of an official transcript must be attached to the Request for Transfer Credit Form. A maximum of twelve quarter hours of credit obtained at another institution may be accepted toward the MS degree provided that the credits transferred consist of a grade of B or better in graduate-level courses, have been earned at an accredited U.S. institution, and have not been used toward any other degree. Grades are not transferred.

For more information contact
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