DEPARTMENT OF PHYSICS AND ASTRONOMY

The Master of Science (M.S.) in Physics and the Doctor of Philosophy (Ph.D.) in Physics programs offer opportunities for advanced study and research designed to prepare students for roles in industry, government, research institutions, or educational institutions.

Graduate students will be able to choose from several areas of specialization in experimental and theoretical physics, including condensed matter, advanced materials, nanomaterials, biophysics, laser spectroscopy, astrophysics, theoretical particle physics, cosmology, mathematical physics, and computational physics. The graduate program includes a partnership with the Space Science and Engineering Division of the Southwest Research Institute (SwRI) which, through the appointment of selected Adjoint Faculty, provides research opportunities in Space Physics, including space weather, ionospheric-thermospheric-mesospheric physics, plasmaspheric physics, magnetospheric physics, heliospheric physics, cometary and planetary science, space physics instrumentation, and computational space physics.

A limited number of teaching and/or research assistantships and fellowships are available to qualified students. Financial assistance is limited and is awarded on a competitive basis.

- M.S. in Physics
- Ph.D. in Physics

Master of Science Degree in Physics

The purpose of the Master of Science (M.S.) degree program in Physics is to offer students the opportunity to acquire a sound preparation of the fundamentals in several areas of physics, to introduce students to recent advances in physical theory and experimentation, and to encourage research in a specific area of study.

Faculty members offer the opportunity for personalized interaction and thesis development through coursework and research. Additional cooperative projects and programs are available within UTSA or with other research institutions.

Qualified students are encouraged to apply for teaching and/or research assistantships and fellowships. Requests should be sent to the Graduate Advisor of Record for physics when application is made for admission to UTSA.

Admission Requirements

Students must satisfy the University-wide graduate admission requirements. Applicants must have a Bachelor of Arts or a Bachelor of Science degree from an accredited university and a minimum grade point average of 3.0 (on a 4.0 scale) in upper division coursework, preferably in physics. Applicants with fewer than 12 credit hours of upper-division undergraduate physics coursework may be admitted as Special Graduate students under the condition that they complete 12 hours of upper-division undergraduate physics coursework before admission as Master's students.

Applicants must submit scores from the general Graduate Record Examination (GRE). A minimum of two letters of recommendation from persons familiar with the applicant’s undergraduate scholastic record must be sent to the Graduate School at the same time application is made for admission to UTSA. Background or remedial courses in physics may be required to remove deficiencies.

Applicants whose native language is not English must submit scores from the Test of English as a Foreign Language (TOEFL) or the International English Language Testing System (IELTS). The English Language Assessment Procedure is a mandatory assessment for incoming international students whose TOEFL scores are between 60 and 65 (paper version) or 79 and 100 (Internet version) or an IELTS score below 7. See Student Policies, Admission Policies, for details.

Thesis Option in Physics

Degree Requirements

The Master of Science program requires the successful completion of a minimum of 30 semester credit hours. Candidates must complete the following:

A. Required courses (a minimum of 24 semester credit hours):

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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credit Hours</th>
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<tbody>
<tr>
<td>PHY 5103</td>
<td>Classical Mechanics I</td>
<td>3</td>
</tr>
<tr>
<td>PHY 5203</td>
<td>Electrodynamics I</td>
<td>3</td>
</tr>
<tr>
<td>PHY 5303</td>
<td>Statistical Mechanics</td>
<td>3</td>
</tr>
<tr>
<td>PHY 5403</td>
<td>Quantum Mechanics I</td>
<td>3</td>
</tr>
<tr>
<td>PHY 6983</td>
<td>Master’s Thesis</td>
<td>6</td>
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</table>

Students must enroll in Master’s Thesis each semester that they receive advice and assistance in writing the thesis until final approval of the completed thesis has been given and the thesis has been filed with the Dean of the Graduate School. However, no more than 6 hours will count toward the M.S. degree.

B. 6 semester credit hours of advanced electives, including graduate courses offered by other departments, as approved by the Graduate Advisor of Record and by the comprehensive examination committee, or up to 6 hours of credit of undergraduate courses if the courses are appropriate for the student’s program of study, if they were not taken as an undergraduate, and if they are approved by the Graduate Advisor of Record. If approved to enroll in undergraduate coursework students must complete the Permission for Enrolling in Undergraduate Courses while a Graduate form and receive all approvals.

C. Students must successfully defend their thesis research results before their comprehensive examination committee prior to the submission of the thesis to the Dean of the Graduate School for approval.

| Total Credit Hours | 30 |

Non-Thesis Option in Physics

Degree Requirements

This program requires the successful completion of a minimum of 30 semester credit hours. Candidates for the degree must complete the following:

A. Required courses (21 semester credit hours):

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<td>Statistical Mechanics</td>
<td>3</td>
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<tr>
<td>PHY 5403</td>
<td>Quantum Mechanics I</td>
<td>3</td>
</tr>
<tr>
<td>PHY 5103</td>
<td>Classical Mechanics I</td>
<td>3</td>
</tr>
</tbody>
</table>

Qualified students are encouraged to apply for teaching and/or research assistantships and fellowships. Requests should be sent to the Graduate Advisor of Record for physics when application is made for admission to UTSA.
Department of Physics and Astronomy

Incoming international students whose TOEFL scores are between 60 and 65 (paper version) or 79 and 100 (internet version) or an IELTS score below 7. See Student Policies, Admission Policies, for details.

Degree Requirements

The doctoral degree requires a minimum of 81 semester credit hours beyond the baccalaureate degree. The coursework in the Program of Study includes a Core Curriculum (12 semester credit hours) and Advanced Electives (21 semester credit hours) including graduate courses offered by other departments with the approval of the student’s Graduate Advisor and the student’s Dissertation Committee. Research hours, including Research Seminar (3 semester credit hours), Directed and Doctoral Research (33 semester credit hours) and Doctoral Dissertation (12 semester credit hours), totaling at least 48 semester credit hours, complete the Program of Study.

Transfer of Credit

Transfer of credit from other institutions is possible under the following regulations:

1. Transfer of credit for core classes is granted only if the syllabi of the classes adhere to the standard of the syllabi used for the core classes in the current program and typically is allowed only from institutions that grant Ph.D. degrees in Physics.

2. A maximum of 30 semester credit hours is allowed to be transferred, excluding research and thesis hours, and must adhere to the Transfer of Credit policy under Doctoral Degree regulations, in the UTSA Graduate Catalog.

3. No research hours can be transferred to the program.

Program of Study

A. Core Curriculum:

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<td>PHY 5403</td>
<td>Quantum Mechanics I</td>
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B. Advanced Physics Electives (21 semester credit hours)

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<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit Hours</th>
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<tbody>
<tr>
<td>PHY 6103</td>
<td>Classical Mechanics II</td>
<td>3</td>
</tr>
<tr>
<td>PHY 6123</td>
<td>Plasma Physics and Magnetohydrodynamics (MHD)</td>
<td>3</td>
</tr>
<tr>
<td>PHY 6133</td>
<td>Introduction to Scientific Writing</td>
<td>3</td>
</tr>
<tr>
<td>PHY 6203</td>
<td>Electrodynamics II</td>
<td>3</td>
</tr>
<tr>
<td>PHY 6303</td>
<td>Quantum Mechanics II</td>
<td>3</td>
</tr>
<tr>
<td>PHY 6313</td>
<td>Solid State Physics</td>
<td>3</td>
</tr>
<tr>
<td>PHY 6323</td>
<td>Nonlinear Optics and Lasers</td>
<td>3</td>
</tr>
<tr>
<td>PHY 6403</td>
<td>Fundamentals of Space Physics</td>
<td>3</td>
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<tr>
<td>PHY 6413</td>
<td>Fundamentals of Astronomy</td>
<td>3</td>
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<tr>
<td>PHY 6503</td>
<td>Mathematical Physics I</td>
<td>3</td>
</tr>
<tr>
<td>PHY 6513</td>
<td>Mathematical Physics II</td>
<td>3</td>
</tr>
<tr>
<td>PHY 6523</td>
<td>Computational Physics</td>
<td>3</td>
</tr>
<tr>
<td>PHY 6613</td>
<td>Methods of Experimental Physics</td>
<td>3</td>
</tr>
<tr>
<td>PHY 6623</td>
<td>Space Physics Laboratory</td>
<td>3</td>
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</tbody>
</table>

Topics courses may be repeated for credit as the topics vary. The student should consult her/his Graduate Advisor if in doubt.

<table>
<thead>
<tr>
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</tr>
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<tr>
<td>PHY 7403</td>
<td>Topics in Biophysics and Biomedical Physics</td>
<td>3</td>
</tr>
</tbody>
</table>
Qualifying Examination

The qualifying examination is divided into written and oral portions. The details of the written portion of the examination can be found in the Department's Graduate Student Handbook. Additional details are described in the Department's Graduate Student Handbook.

Final Oral Examination

The final oral defense consists of a public presentation of the dissertation and a closed oral defense. It is administered and evaluated by the student's Dissertation Committee and covers the dissertation and the general field of the dissertation. The Dissertation Committee must approve the dissertation. Additional details are described in the Department's Graduate Student Handbook.

Composition of the Qualifying Examination and Dissertation Committees

It is highly recommended that both committees are composed of the same faculty members (internal and external). For students completing their Dissertations with SwRI joint faculty as their advisors, the committee must include at least one core faculty member from the Department of Physics and Astronomy at UTSA. It is also required that at least one member of the committee is external to the program. Additional details are described in the Department's Graduate Student Handbook.

Physics (PHY) Courses

PHY 5103. Classical Mechanics I. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Newtonian mechanics, Lagrangian and Hamiltonian dynamics, dynamics of rigid bodies, central force problem and orbital dynamics, symmetries and conservation laws, relativistic dynamics. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 5203. Electrodynamics I. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Electrostatics and magnetostatics; boundary value problems, Maxwell's equations; plane waves; wave guides diffraction; multipole radiation. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 5303. Statistical Mechanics. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Thermodynamics, equilibrium statistical mechanics, Boltzmann equation and the collision operator, moments of the Boltzmann equations, the Navier-Stokes equations, introduction to nonequilibrium concepts, ensembles, classical and quantum gases, statistical physics of solids. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 5403. Quantum Mechanics I. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Linear vector spaces and linear operators. Postulates. Hilbert space formulation, the Schrödinger equation and one-dimensional problems, the hydrogen atom, symmetries, rotational invariance and angular momentum, spin, system with N-degrees of freedom. (Formerly PHY 6003. Credit cannot be earned for both PHY 5403 and PHY 6003.) Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 5404. Quantum Mechanics II. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Canonical transformations. Hamilton-Jacobi theory, nonlinear dynamics and chaos, instabilities, pattern formation, the three-body problem, dust, planets, and planetary systems, continuous systems. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 6103. Classical Mechanics II. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing, PHY 5103, or consent of instructor. Canonical transformations. Hamilton-Jacobi theory, nonlinear dynamics and chaos, instabilities, pattern formation, the three-body problem, dust, planets, and planetary systems, continuous systems. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 6123. Plasma Physics and Magnetohydrodynamics (MHD). (3-0) 3 Credit Hours.
Prerequisite: Graduate standing, PHY 5103 and PHY 5203, or consent of instructor. Plasma equations, magnetohydrodynamics (MHD), waves and instabilities in two-fluid model, Vlasov and Fokker-Planck equations, Landau damping, turbulence in plasmas, radiation in plasmas, quasi-linear theory, wave-particle interaction, kinetic theory in space plasmas. Course Fees: GS01 $90; LRS1 $15; STSI $15.
PHY 6133. Introduction to Scientific Writing. (3-0) 3 Credit Hours.

PHY 6203. Electrodynamics II. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing, PHY 5203, or consent of instructor. Relativistic formulation of Maxwell equations, radiation from moving charges, collisions of charged particles, radiation damping, introduction to plasmas, and magnetohydrodynamics. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 6204. Advanced Electromagnetism. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing, PHY 5203, or consent of instructor. Advanced topics in electromagnetism, including advanced topics in classical electrodynamics, such as electrodynamics in non-inertial frames, quantum electrodynamics, and quantum field theory. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 6205. Quantum Mechanics I. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Conservation postulates, Heisenberg's uncertainty principle, quantum states, operators, eigenvalues and eigenstates, rigged Hilbert spaces and bra-ket notation. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 6206. Quantum Mechanics II. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Wave mechanics, Dirac formulation. Introduction to relativistic quantum mechanics and the Dirac equation. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 6233. Nonlinear Optics and Lasers. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Topics to be discussed in this course will include Gaussian beam optics, interaction of electromagnetic radiation with matter, semi-classical laser theory, experimental laser systems, nonlinear optical susceptibilities, harmonic generation, wave mixing, electro-optic and acousto-optic effects, coherent transient effects, optical breakdown, and laser plasma interactions. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 6253. Computational Physics. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Introduction to numerical techniques for solving physics problems, theory of computation and applications to various branches of physics, sample problems might include chaotic motion and nonlinear dynamics, plasmas, particle trajectories, Monte Carlo simulations, dynamical and statistical descriptions of many-body problems, hyperbolic, parabolic, and elliptic differential equations and solution techniques, stability analysis. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 6263. Fluid Mechanics. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. The fluid dynamics of incompressible and compressible fluids, including the Navier-Stokes equations, boundary layer theory, turbulence, and combustion. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 6303. Quantum Mechanics II. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing, PHY 5303 and PHY 5403, or consent of instructor. Variational and WKB methods. Time-independent and time-dependent perturbation theory. Scattering theory. Path integration formulation. Introduction to relativistic quantum mechanics and the Dirac equation. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 6313. Solid State Physics. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Lattice vibrations and thermal properties of solids; band theory of solids, transport properties of metals and semiconductors; optical properties; magnetic properties; magnetic relaxation; superconductivity, elementary excitations: phonons, electrons, spin waves; interactions: phonon-phonon, electron-electron, electron-phonon, theory of metals and semiconductors, transport theory; and optical properties. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 6353. Advanced Quantum Mechanics. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Advanced topics in quantum mechanics, such as quantum field theory, quantum information, and quantum computing. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 6403. Fundamentals of Space Physics. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. The Sun, solar models, solar and stellar winds, heliosphere and astrospheres, synthesis of elements in the Sun and stars, solar system composition and cosmoabundances, terrestrial magnetosphere, ionosphere and thermosphere, comparative planetary magnetospheres and atmospheres. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 6413. Fundamentals of Astronomy. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Photometry, stellar models, variable stars, white dwarfs, neutron stars, supernovae, cosmic rays, galaxies and galactic structure, and introduction to cosmology. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 6503. Mathematical Physics I. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Linear algebra, ordinary and partial differential equations, special functions, eigenvalue problems, complex analysis, group theory. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 6513. Mathematical Physics II. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing, PHY 6503, or consent of instructor. Advanced topics in mathematical physics, topology, functional analysis, differentiable manifolds, Lie groups and algebras, and cohomology theory. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 6523. Computational Physics. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing, PHY 5103 and PHY 5203, or consent of instructor. Introduction to numerical techniques for solving physics problems, theory of computation and applications to various branches of physics, sample problems might include chaotic motion and nonlinear dynamics, plasmas, particle trajectories, Monte Carlo simulations, dynamical and statistical descriptions of many-body problems, hyperbolic, parabolic, and elliptic differential equations and solution techniques, stability analysis. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 6613. Methods of Experimental Physics. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. This course is aimed at training graduate students in the basic aspects of experimental physics, such as instrumentation, data acquisition, and statistical treatment of data and error analysis, introduction to modern equipment control and data acquisition with LabVIEW, equipment design, detectors and interfaces. Course Fees: GS01 $90; LRS1 $15; STSI $15.
PHY 7002. Directed Research. (0-0) 2 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. The directed research course may involve either a laboratory or a theoretical problem. Normally a written report is required. This course may be repeated for credit, but not more than 6 hours will apply to the Master's degree, or 18 hours toward the Doctoral degree. Course Fees: GS01 $60; LRS1 $10; STSI $10.

PHY 7003. Directed Research. (0-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. The directed research course may involve either a laboratory or a theoretical problem. Normally a written report is required. This course may be repeated for credit, but not more than 6 hours will apply to the Master's degree, or 18 hours toward the Doctoral degree. Course Fees: GS01 $30; LRS1 $5; STSI $5.

PHY 7013. Research Seminar. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Formal presentations of research by outside authorities, as well as current research seminars presented by faculty, visiting lecturers, and Ph.D. candidates. The grade report for this course is either "CR" (satisfactory participation in the seminar) or "NC" (unsatisfactory participation in the seminar). This course may include a written component. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 7101. Doctoral Research. (0-0) 1 Credit Hour.
Prerequisites: Permission of the Graduate Advisor of Record and dissertation director. Doctoral research and preparation in the chosen area of concentration. May be repeated for credit, but not more than 21 hours will apply to the Doctoral degree. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 7102. Doctoral Research. (0-0) 2 Credit Hours.
Prerequisites: Permission of the Graduate Advisor of Record and dissertation director. Doctoral research and preparation in the chosen area of concentration. May be repeated for credit, but not more than 21 hours will apply to the Doctoral degree. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 7103. Doctoral Research. (0-0) 3 Credit Hours.
Prerequisites: Permission of the Graduate Advisor of Record and dissertation director. Doctoral research and preparation in the chosen area of concentration. May be repeated for credit, but not more than 21 hours will apply to the Doctoral degree. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 7111. Doctoral Dissertation. (0-0) 1 Credit Hour.
Prerequisites: Permission of the Graduate Advisor of Record and dissertation director. Preparation and writing of the Doctoral dissertation. May be repeated for credit, but not more than 12 hours will apply to the Doctoral degree. Course Fees: GS01 $30; LRS1 $5; STSI $5.

PHY 7112. Doctoral Dissertation. (0-0) 2 Credit Hours.
Prerequisites: Permission of the Graduate Advisor of Record and dissertation director. Preparation and writing of the Doctoral dissertation. May be repeated for credit, but not more than 12 hours will apply to the Doctoral degree. Course Fees: GS01 $60; LRS1 $10; STSI $10.

PHY 7113. Doctoral Dissertation. (0-0) 3 Credit Hours.
Prerequisites: Permission of the Graduate Advisor of Record and dissertation director. Preparation and writing of the Doctoral dissertation. May be repeated for credit, but not more than 12 hours will apply to the Doctoral degree. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 7403. Topics in Biophysics and Biomedical Physics. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. May be repeated for credit as topics vary. Topics may include the following: Topic 1: Biophysical Chemistry. Molecular structure of biological systems, energetics and entropy, relationship between structure and function of proteins and nucleic acids, structure prediction, role of hydration. Topic 2: Biomolecular Spectroscopy. Prerequisite: Completion of Topics class in Biophysical Chemistry. Introduction to traditional and modern optical spectroscopic techniques to the study of biological molecules. Physical basis of absorption, fluorescence, circular dichroism, and FTIR spectroscopy. Introduction to time resolved techniques (time-correlated single photon counting, transient absorption spectroscopy). Photoacoustic calorimetry, near-field scanning optical microscopy, atomic force microscopy, small angle X-ray and neutron scattering. Topic 3: Biophotonics. Optical methodologies for imaging, diagnosis, and therapy in biology and medicine. Review of basic elements of optics and optical sources, lasers and light-emitting solid state devices, in the context of biomedical applications. Dosimetry, tissue optics, and the principles of laser-tissue interaction. Current medical uses of lasers, along with their scientific and technical foundations. Topic 4: Biomedical Physics. Use of fundamental physical laws and experimental techniques to numerous biomedical fields such as applications of lasers to ophthalmology, lithotripsy, and dentistry will be covered. Topic 5: Chemical Physics of Biophysical Processes. Transition and reaction pathways, transition state theory approach, transition path sampling approach, atomistic models of biomolecules and their visualizations, modern techniques of molecular dynamics. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 7503. Topics in Experimental Physics. (3-0) 3 Credit Hours.
PHY 7603. Topics in Condensed Matter Physics. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. May be repeated for credit as topics vary. Topics may include the following:

PHY 7703. Topics in Space Physics. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. May be repeated for credit as topics vary. Topics may include the following: Topic 1: Heliospheric Physics. The connection between the Sun and solar wind. Formation of transient events such as Coronal Mass Ejections (CMEs), co-rotating interaction regions, solar energetic particles, plasma waves, pickup ions and mass loading, anomalous cosmic rays, heliospheric boundaries and interaction with the local interstellar medium, energetic neutral atoms (ENAs). Topic 2: Magnetospheric Physics. Earth's bow shock, magnetopause, magnetotail, plasma sheet, ring current and plasmasphere. Current systems, reconnection, magnetospheric storms and substorms, ionospheric interactions, aurora borealis. The geocorona and ENA emissions. Topic 3: Data Analysis Techniques in Space Physics. Space instrumentation and datasets, measurement processes, performance and instrument limitations, data interpretation, statistical data analysis, time series data analysis, Fourier wavelet analysis, correlation and regression, multi-spacecraft data analysis, minimum variance analysis, numerical modeling and simulations. Topic 4: Planetary Science. Planets, planetary atmospheres, and planetary magnetospheres. Planetary formation, composition, dynamics, and evolution of the solar system. Comparative planetology, interplanetary dust, comets, asteroids, and Kuiper belt objects. Extra-solar planets, astrobiology, exobiology, and the search for life beyond Earth. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 7803. Topics in Theoretical Physics. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. May be repeated for credit as topics vary. Topics may include the following: Topic 1: General Relativity. Special relativity, tensor analysis, Einstein field equations, the Schwarzschild solution, Newtonian limit, orbits, black holes, gravitational waves. Introduction to cosmology. Topic 2: Advanced Condensed Matter Physics. Quantum theory of many-body systems, Green's functions at zero and finite temperatures, electron-phonon interactions. Topic 3: Introduction to Quantum Field Theory. Canonical field quantization, path integral quantization, Feynman diagrams, basics of renormalization, introduction to quantum electrodynamics. Topic 4: Gauge Theories. Basics of field quantization and Feynman rules, renormalization group, quantum electrodynamics, quantum chromodynamics spontaneous symmetry breaking, electroweak theory. Additional topics may include topological solitons, effective Lagrangians, unified theories, and introduction to supersymmetry. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 7903. Topics in Astrophysics. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. May be repeated for credit as topics vary. Topics may include the following: Topic 1: Stellar Astrophysics. Advanced discussion of one or more topics from: stellar structure, physics of accretion disks, physics of star formation and the interstellar medium, structure of collapsed stars and supernova remnants, radiative transport and photoionization. Topic 2: Galactic and Extragalactic Astrophysics. Density wave theory and structure of spiral galaxies. Active galaxies, clusters of galaxies, large-scale structure. Topic 3: Cosmology. Basics of general relativity. The cosmological principle and Friedmann models, thermal history of the universe, structure formation, the cosmic microwave background, baryonic structures formation, dark matter and dark energy, particle physics and the early universe, inflationary cosmology. Topic 4: Astrobiology. Conditions necessary for life, extra-solar planets, discovery strategies and techniques for extrasolar planets and results to date. Basic stellar evolution and nucleosynthesis impacts on development of life on Earth. Topic 5: Astrophysics Fluid Dynamics. Lagrangian, Eulerian, and smooth-particle formulations, rotation, vorticity, circulations, convection, magnetohydrodynamics, shocks, stellar rotation, photon fluid dynamics, relativistic fluids, mass transfer. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 7973. Special Topics in Physics. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. An organized course offering the opportunity for specialized study which may not normally or not often be available as part of the regular course offerings. May be repeated for credit as topics vary. Course Fees: GS01 $90; LRS1 $15; STSI $15.

PHY 7983. Current Topics in Physics. (3-0) 3 Credit Hours.
Research and critical analysis of the relevant current research literature in relevant Physics topics. Analysis and discussion of ongoing research projects. May be repeated for credit as topics vary. Course Fees: GS01 $90; LRS1 $15; STSI $15.