# DEPARTMENT OF PHYSICS AND ASTRONOMY

## Mission Statement

The mission of the Physics and Astronomy department is to provide science and engineering students at UTSA with a solid background in physics and problem-solving skills and equip students with invaluable research experience.

## General Information

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 (https://www.swri.org/), 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.

We strive to provide UTSA science and engineering students with a solid background in physics and problem-solving skills, critical to their future work, regardless of the nature of that work. We also aim to provide students with as much research experience as possible to better prepare them for their future careers. The jobs available to physics graduates are more varied than what most science graduate students can find. They range from pure science to engineering, finance, public policy, and education.

The academic environment in the Department fosters extensive mentoring of the students, individual contact with instructors, and advanced teaching methodologies. We also offer great opportunities for continuous graduate research. Many of our graduate students have publications in peer-reviewed journals and presentations at regional or national conferences. As a result, our students have been admitted to some of the top post-doc programs in the U.S. and found employment in the private sector as innovative teachers in public and private schools.

The central goals of the Physics and Astronomy Department are to:

- Become one of the outstanding programs of its kind in the country, in which teaching and research are carefully interwoven for the benefit of the students and the community.
- Encourage groups underrepresented in physics to consider physics or astronomy as their primary career path.
- Be responsive to the needs, both educational and research-related, indispensable in any career but particularly important in science.

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.



## 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.

A statement of purpose, a current résumé, and a minimum of two letters of recommendation from persons familiar with the applicant's undergraduate scholastic record must be sent to Graduate Admissions 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) iBT or the International English Language Testing System (IELTS). The English Language Assessment Procedure is a mandatory assessment for incoming international students whose TOEFL iBT scores are between 79 and 100 or whose IELTS score is below 7. See Student Policies, Admission Policies, for details.

### Degree Requirements – Thesis Option

The Master of Science degree in Physics with the Thesis Option requires the successful completion of a minimum of 30 semester credit hours. Candidates must complete the following:

| Code | Title | Credit Hours |
|---|---|---|
| A. Required courses (a minimum of 24 semester credit hours): | | 24 |
| PHY 5103 | Classical Mechanics I | |
| PHY 5203 | Electrodynamics I | |
| PHY 5303 | Statistical Mechanics | |
| PHY 5403 | Quantum Mechanics I | |

| | | |
|---|---|---|
| PHY 6983 | Master's Thesis (repeated for a total of 6 semester credit hours) | |
| 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. | | |
| PHY 7003 | Directed Research | |
| PHY 7013 | Research Seminar | |
| Students must attend the Research Seminar for three (3) full semesters during their graduate studies. However, no more than 3 semester credit hours may be applied to 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. | | 6 |
| 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** |

## Degree Requirements – Non-Thesis Option

The Master of Science degree in Physics with the Non-Thesis Option requires the successful completion of a minimum of 30 semester credit hours. Candidates for the degree must complete the following:

| Code | Title | Credit Hours |
|---|---|---|
| A. Required courses (21 semester credit hours): | | 21 |
| PHY 5103 | Classical Mechanics I | |
| PHY 5203 | Electrodynamics I | |
| PHY 5303 | Statistical Mechanics | |
| PHY 5403 | Quantum Mechanics I | |
| PHY 7003 | Directed Research (repeated for a total of 6 semester credit hours) | |
| PHY 7013 | Research Seminar | |
| Students must attend the Research Seminar for three (3) full semesters during their graduate studies. However, no more than 3 semester credit hours may be applied to the M.S. degree. | | |
| B. 9 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 credit hours of advanced undergraduate courses if appropriate for their program of study, if not taken as an undergraduate, and if 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. | | 9 |
| C. Students must pass a final oral comprehensive examination for completion of the degree program. The comprehensive examination is scheduled during the student's last semester of work and includes a written report of the research activity carried out in the 6 hours of Directed Research, as well as a seminar where the results of such research activity is presented. | | |
| **Total Credit Hours** | | **30** |

# Doctor of Philosophy Degree in Physics

The Department of Physics and Astronomy, in partnership with the Southwest Research Institute, offers opportunities for advanced studies and research leading to the Doctor of Philosophy (Ph.D.) degree in Physics. The Ph.D. in Physics is awarded to candidates who have displayed an in-depth understanding of the subject matter and demonstrated the ability to make an original contribution to knowledge in their field of specialty.

The regulations for this degree comply with the general University regulations (refer to Student Policies, General Academic Regulations, and the Graduate Catalog, Doctoral Degree Regulations).

### Concentration in Materials Science

The Materials Science Concentration in Physics expands upon the Physics Ph.D. core curriculum, which includes Classical Mechanics, Quantum Mechanics, Statistical Mechanics, and Electrodynamics, to include a required elective in Solid State Physics or Chemistry with three additional interdisciplinary elective requirements with foci in materials science. In addition to this materials-specific curriculum, students in the Physics Materials Science Concentration will have the opportunity to engage in a 10 week internship in either industry or government laboratories to expand their competencies in materials science. Students who complete the concentration degree plan emerge from the program with a deep understanding of the phenomenological complexities of materials with relevance to energy, environment, biomedical, electronic, transportation, and/or space industries.

## Admission Requirements

In addition to satisfying 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 undergraduate coursework and all graduate work, preferably in physics. A minimum of two letters of recommendation from persons familiar with the applicant's undergraduate (and graduate, where applicable) scholastic record must be sent to Graduate Admissions at the same time application is made for admission to UTSA, along with a statement of purpose and a current résumé. 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) iBT or the International English Language Testing System (IELTS). The English Language Assessment Procedure is a mandatory assessment for incoming international students whose TOEFL iBT scores are between 79 and 100 or an IELTS score below 7. See Student Policies, Admission Policies, for details.

## Degree Requirements

The Ph.D. in Physics 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

| Code | Title | Credit Hours |
|---|---|---|
| **A. Core Curriculum:** | | **12** |
| PHY 5103 | Classical Mechanics I | |
| PHY 5203 | Electrodynamics I | |
| PHY 5303 | Statistical Mechanics | |
| PHY 5403 | Quantum Mechanics I | |
| **B. Advanced Physics Electives:** | | **21** |
| Students should select 21 semester credit hours from the following courses or a max of 6 credits from graduate courses offered by other departments (e.g., Mathematics, Electrical and Computer Engineering, Chemistry, etc.). | | |
| Students may use the Concentration in Materials Science courses to fulfill elective requirements. | | |
| PHY 6103 | Classical Mechanics II | |
| PHY 6123 | Plasma Physics and Magnetohydrodynamics (MHD) | |
| PHY 6133 | Introduction to Scientific Writing | |
| PHY 6203 | Electrodynamics II | |
| PHY 6303 | Quantum Mechanics II | |
| PHY 6313 | Solid State Physics | |
| PHY 6323 | Nonlinear Optics and Lasers | |
| PHY 6403 | Fundamentals of Space Physics | |
| PHY 6413 | Fundamentals of Astronomy | |
| PHY 6503 | Mathematical Physics I | |
| PHY 6513 | Mathematical Physics II | |
| PHY 6523 | Computational Physics | |
| PHY 6623 | Space Physics Laboratory | |
| Topics courses may be repeated for credit as the topics vary. The student should consult their Graduate Advisor if in doubt. | | |
| PHY 7403 | Topics in Biophysics and Biomedical Physics | |
| PHY 7503 | Topics in Experimental Physics | |
| PHY 7603 | Topics in Condensed Matter Physics | |
| PHY 7703 | Topics in Space Physics | |
| PHY 7803 | Topics in Theoretical Physics | |
| PHY 7903 | Topics in Astrophysics | |
| PHY 7973 | Special Topics in Physics | |
| PHY 7983 | Current Topics in Physics | |
| **C. Doctoral Research:** | | **48** |
| PHY 7013 | Research Seminar | |
| | Students must attend the Research Seminar for a minimum of three (3) full semesters during their graduate studies. However, no more than 3 semester credit hours may be applied to the Ph.D. degree. | |
| Select a minimum of 6 hours of the following, prior to passing qualifying examination: | | |
| PHY 7001 | Directed Research | |
| PHY 7002 | Directed Research | |
| PHY 7003 | Directed Research | |
| Select a minimum of 27 hours of the following, after advancement to candidacy: | | |
| PHY 7101 | Doctoral Research | |
| PHY 7102 | Doctoral Research | |
| PHY 7103 | Doctoral Research | |
| Select 12 hours of the following: | | |
| PHY 7111 | Doctoral Dissertation [1] | |
| PHY 7112 | Doctoral Dissertation [1] | |
| PHY 7113 | Doctoral Dissertation [1] | |
| **Total Credit Hours** | | **81** |

[1] Students must enroll in PHY 7111-PHY 7113 Doctoral Dissertation each semester that they receive advice and/or assistance on their dissertation. However, no more than 12 semester credit hours will count toward the Ph.D. degree.

The entire program of study, including graduate courses offered by other departments, must be approved by the student's Dissertation Advisor, Dissertation Committee, and Graduate Program Committee and must be submitted to the Dean of the Graduate School for final approval.

## Concentration in Materials Science

| Code | Title | Credit Hours |
|---|---|---|
| **A. Required Fundamentals in Materials or Condensed Matter Physics** | | **3** |
| PHY 6313 | Solid State Physics | |
| **B. Elective Options for Materials Science Concentration** | | **9** |
| In addition to 9 credit hours of Advanced Physics Electives. | | |
| PHY 6523 | Computational Physics | |
| **Special Topics in Materials** | | |
| PHY 7503 | Topics in Experimental Physics | |
| PHY 7603 | Topics in Condensed Matter Physics (Nanotechnology) | |
| PHY 7973 | Special Topics in Physics (Electric Thin Films) | |
| **Elective Options offered in Other Departments** | | |
| ME 5013 | Topics in Mechanical Engineering (Corrosion Engineering) | |

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|---|---|
| MATE 5103 | Principles of Materials Engineering: Fundamentals of Structure, Chemistry, and Physical Properties |
| MATE 5113 | Functions, Evaluations and Synthesis Technology of Advanced Materials |
| MATE 5213 | Sensing and Sensor Materials |
| MATE 5223 | Structure-Chemistry-Property Relations in Materials Science and Engineering |
| MATE 5243 | Optic and Nonlinear Optical Materials |
| MATE 5253 | Magnetic Materials and Electromagnetic Engineering |
| ME 5453 | Advanced Strength of Materials |
| ME 5463 | Fracture Mechanics |
| ME 5483 | Finite Element Methods |
| CHE 5653 | Structure Determination Using Spectroscopic Methods |
| ME 5713 | Mechanical Behavior of Materials |
| ME 5743 | Composite Materials |
| CHE 5843 | Advanced Physical Chemistry |
| BME 6593 | Biomaterials for Drug Delivery/ Pharmacology |
| BME 6733 | Microfabrication and Application |
| BME 6903 | Biomaterials |
| BME 6913 | Biomaterials II |
| **Total Credit Hours** | **12** |

## Advancement to Candidacy

All students seeking a doctoral degree at UTSA must be admitted to candidacy. One of the requirements for admission to candidacy is successfully completing the Doctoral Qualifying Examination. Students should consult the University's Doctoral Degree Regulations (in the Graduate Catalog) for the other requirements. Additional details are described in the Department's Graduate Student Handbook.

## 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 handout for Ph.D. students. The oral portion covers the student's proposed research program and related fundamentals, must be taken within one year after passing the written portion of the qualifying examination, and will be evaluated by the student's Qualifying Examination Committee. 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 Dissertation with SwRI adjoint 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 be 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. This course has Differential Tuition. Course Fee: GS01 $90.

**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. This course has Differential Tuition. Course Fee: GS01 $90.

**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. This course has Differential Tuition. Course Fee: GS01 $90.

**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.) This course has Differential Tuition. Course Fee: GS01 $90.

**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. This course has Differential Tuition. Course Fee: GS01 $90; LRS1 $46.20; STSI $21.60.

**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. This course has Differential Tuition. Course Fee: GS01 $90.

**PHY 6133. Introduction to Scientific Writing. (3-0) 3 Credit Hours.**
Methods to overcome resistance to writing and approach to become productive scientific writers. Writing methods and techniques for manuscript, dissertation, thesis preparation. Fundamentals of funding proposal writing. Critical reading and reviewing. This course has Differential Tuition. Course Fee: GS01 $90.

**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. This course has Differential Tuition. Course Fee: GS01 $90; LRS1 $46.20; STSI $21.60.

**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. This course has Differential Tuition. Course Fee: GS01 $90; LRS1 $46.20; STSI $21.60.

**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. This course has Differential Tuition. Course Fee: GS01 $90.

**PHY 6323. 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. This course has Differential Tuition. Course Fee: GS01 $90.

**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 cosmic abundances, terrestrial magnetosphere, ionosphere and thermosphere, comparative planetary magnetospheres and atmospheres. This course has Differential Tuition. Course Fee: GS01 $90.

**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. This course has Differential Tuition. Course Fee: GS01 $90.

**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. This course has Differential Tuition. Course Fee: GS01 $90; LRS1 $46.20; STSI $21.60.

**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. This course has Differential Tuition. Course Fee: GS01 $90; LRS1 $46.20; STSI $21.60.

**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. This course has Differential Tuition. Course Fee: GS01 $90; LRS1 $46.20; STSI $21.60.

**PHY 6623. Space Physics Laboratory. (1-6) 3 Credit Hours.**
Prerequisite: Graduate standing or consent of instructor. Vacuum systems, detectors, charged and neutral particle instruments, magnetic and electric field instruments, imagers (optical, UV, X-ray), instrument control and on-board data processing systems, spacecraft systems, data processing and analysis. This course has Differential Tuition. Course Fee: GS01 $90.

**PHY 6953. Independent Study. (0-0) 3 Credit Hours.**
Prerequisite: Graduate standing and permission in writing (form available) from the instructor and the student's Graduate Advisor of Record. Independent reading, research, discussion, and/or writing under the direction of a faculty member. For students needing specialized work not normally or not often available as part of the regular course offerings. May be repeated for credit, but not more than 6 hours, regardless of discipline, will apply to the degree. This course has Differential Tuition. Course Fee: GS01 $90.

**PHY 6961. Comprehensive Examination. (0-0) 1 Credit Hour.**
Prerequisite: Approval of the appropriate Graduate Program Committee to take the Comprehensive Examination. Credit does not count toward total required hours for the M.S. degree. Independent study course for the purpose of taking the Comprehensive Examination. May be repeated as many times as approved by the Graduate Program Committee. Enrollment is required each term in which the Comprehensive Examination is taken if no other courses are being taken that term. The grade report for the course is either "CR" (satisfactory performance on the Comprehensive Examination) or "NC" (unsatisfactory performance on the Comprehensive Examination). This course has Differential Tuition. Course Fee: GS01 $30.

**PHY 6983. Master's Thesis. (0-0) 3 Credit Hours.**
Prerequisite: Permission from the Graduate Advisor of Record and thesis director. Thesis research preparation. May be repeated for credit, but not more than 6 hours will apply to the Master's degree. Credit will be awarded upon completion of the thesis. Enrollment is required each term in which the thesis is in progress. This course has Differential Tuition. Course Fee: GS01 $90.

**PHY 7001. Directed Research. (0-0) 1 Credit Hour.**
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. This course has Differential Tuition. Course Fee: GS01 $30.

**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. This course has Differential Tuition. Course Fee: GS01 $60; LRS1 $30.80; STSI $14.4.

**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. This course has Differential Tuition. Course Fee: GS01 $90.

**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. May be repeated for credit. 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. This course has Differential Tuition. Course Fee: GS01 $90.

**PHY 7101. Doctoral Research. (0-0) 1 Credit Hour.**
Prerequisite: Permission from 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. This course has Differential Tuition. Course Fee: GS01 $30.

**PHY 7102. Doctoral Research. (0-0) 2 Credit Hours.**
Prerequisite: Permission from 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. This course has Differential Tuition. Course Fee: GS01 $60.

**PHY 7103. Doctoral Research. (0-0) 3 Credit Hours.**
Prerequisite: Permission from 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. This course has Differential Tuition. Course Fee: GS01 $90.

**PHY 7111. Doctoral Dissertation. (0-0) 1 Credit Hour.**
Prerequisite: Permission from 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. This course has Differential Tuition. Course Fee: GS01 $30.

**PHY 7112. Doctoral Dissertation. (0-0) 2 Credit Hours.**
Prerequisite: Permission from 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. This course has Differential Tuition. Course Fee: GS01 $60; LRS1 $30.80; STSI $14.40.

**PHY 7113. Doctoral Dissertation. (0-0) 3 Credit Hours.**
Prerequisite: Permission from 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. This course has Differential Tuition. Course Fee: GS01 $90.

**PHY 7403. Topics in Biophysics and Biomedical Physics. (3-0) 3 Credit Hours.**
Prerequisite: Graduate standing or consent of instructor; Topic 2 prerequisite: Completion of Topics class in Biophysical Chemistry. 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. 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. This course has Differential Tuition. Course Fee: GS01 $90; LRS1 $46.20; STSI $21.60.

**PHY 7503. Topics in Experimental 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: Microstructural and Physical Property Characterizations. Diffraction physics, X-ray diffraction, electron microscopy, Raman spectroscopy, Rutherford Backscattering Spectrum, transport property characterization, microwave property measurements, dielectric and piezoelectric property measurements, and optical property measurements. Topic 2: Nonlinear Optics. Quantum optics, light scattering, ultra-fast photonics, fiber optics, lasers, electromagnetically-induced transparency, incoherent interactions, photonic band gaps. Topic 3: Waves in Complex Media. Transport in random and periodic materials and structures, closed and open systems, diffusion and wave localization, photonic band gaps. Topic 4: Physics of Thin Films and Applications. Vacuum physics and technology, fundamentals of physical and chemical depositions, kinetic and dynamic growth theory, rf/dc sputtering, MBE, etc. Topic 5: Molecular Physics and Fundamentals of Spectroscopy. Molecular electronic states, rotation vibration and potential curves of diatomic molecules, spectra of diatomic molecules, rotations and vibration of polyatomic molecules, electronic states of polyatomic molecules, spectra of polyatomic molecules, perturbations in molecular spectra, molecules and clusters, experimental techniques in molecular physics. This course has Differential Tuition. Course Fee: GS01 $90.

**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: Topic 1: Advanced Condensed Matter Physics. Second quantization for bosons and fermions, phonons and phonon-phonon interactions, Bloch electrons and band theory, density functional theory, electron-phonon interactions, superconductivity, critical phenomena, quantum fluids, spin glasses, quantum wells and quantum dots, quantum Hall effect. Topic 2: Nanophysics. Quantum nature of the nanostructure, quantum confinement in low-dimensional systems; single electron phenomena and electron states in nanotubes, interference in diffusive transport, nonequilibrium transport and nanodevices. Introduction to nanofabrication and cross-roads between nanotechnology and biotechnology; nanostructure transmission including quantized conductance and transport. Topic 3: Group Theory Applications in Condensed Matter. Tensors, matrices, point group, space group, and color group representations for symmetry in ferroelectric states and magnetic states, phase transitions, etc. Topic 4: Surface and Interface Physics. Thermodynamics of multicomponent systems for surface and interface segregation, crystal surface and interface structures and energy, adsorption and nucleation, electronic surface states, scanning probe microscopy, collective phenomena at interfaces, junction and heterostructures. Topic 5: Stochastic Processes in Physical and Chemical Systems. Stochastic Langevin dynamics, quantum Langevin dynamics, electronic transport and noise characteristics in nanostructures, diffusion and crystal growth, chemical reactions, statistical mechanics of laser systems. This course has Differential Tuition. Course Fee: GS01 $90.

**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, end 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. This course has Differential Tuition. Course Fee: GS01 $90; DL01 $75.

**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. This course has Differential Tuition. Course Fee: GS01 $90.

**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. This course has Differential Tuition. Course Fee: GS01 $90.

**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. This course has Differential Tuition. Course Fee: GS01 $90.

**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. This course has Differential Tuition. Course Fee: GS01 $90.