

# ASTROPHYSICS

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## Contact Information

### Physics and Astronomy

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Astrophysics (ASTR) is a major offered by the Department of Physics and Astronomy. This Bachelor of Science degree with a major in Astrophysics provides preparation for employment or further study in physics, astrophysics, and related technical and quantitative fields.

## Bachelor's Program

- [Bachelor of Science \(BS\) Degree with a Major in Astrophysics](https://ga.rice.edu/programs-study/departments-programs/natural-sciences/physics-astronomy/astrophysics-bs/)

Graduate opportunities in Astronomy and in Astrophysics are included under [Physics and Astronomy](https://ga.rice.edu/programs-study/departments-programs/natural-sciences/physics-astronomy/#graduatetext) (<https://ga.rice.edu/programs-study/departments-programs/natural-sciences/physics-astronomy/#graduatetext>).

## Chair, Department of Physics and Astronomy

Christopher M. Johns-Krull

## Professors

Darin Acosta  
 David Alexander  
 Matthew G. Baring  
 Anthony A. Chan  
 Pengcheng Dai  
 F. Barry Dunning  
 Karl M. Ecklund  
 Franciscus Johannes Maria Geurts  
 Jason H. Hafner  
 Naomi J. Halas  
 Patrick M. Hartigan  
 Huey W. Huang  
 Randall G. Hulet  
 Christopher M. Johns-Krull  
 Thomas C. Killian  
 Anatoly B. Kolomeisky  
 Junichiro Kono  
 Eugene H. Levy  
 Edison P. Liang  
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Emilia Morosan  
 Peter Nordlander  
 Jose Nelson Onuchic  
 B. Paul Padley  
 Han Pu  
 Patricia H. Reiff  
 Jabus B. Roberts Jr.  
 Gustavo E. Scuseria  
 Qimiao Si  
 Frank R. Toffoletto  
 Peter C. Wolynes

## Associate Professors

Mustafa Amin  
 Stephen J. Bradshaw  
 Stanley A. Dodds  
 Matthew S. Foster  
 Kaden Hazzard  
 Ching-Hwa Kiang  
 Wei Li  
 Andriy Nevidomskyy

## Assistant Professors

Andrea Isella  
 Andrew Long  
 Guido Pagano  
 Evelyn Tang  
 Christopher Tunnell  
 Ming Yi

## Professors Emeriti

Paul A. Cloutier  
 Thomas W. Hill  
 Neal F. Lane  
 Carl Rau  
 Richard A. Wolf

## Assistant Teaching Professors

Robert Beaird  
 Michael Cone  
 Jared Stenson  
 Lam Yu

## Associate Research Professors

Petr Chaguine  
 Pablo P. Yepes

## Adjunct Faculty

James L. Burch  
 Franklin R. Chang Diaz  
 Stefan Kirchner  
 Hui Li  
 Carolyn Sumners  
 Jon C. Weisheit  
 Jian-Xin Zhu

*For Rice University degree-granting programs:*

To view the list of official course offerings, please see [Rice's Course Catalog \(https://courses.rice.edu/admweb!/SWKSCAT.cat?p\\_action=cata\)](https://courses.rice.edu/admweb!/SWKSCAT.cat?p_action=cata).

To view the most recent semester's course schedule, please see [Rice's Course Schedule \(https://courses.rice.edu/admweb!/SWKSCAT.cat\)](https://courses.rice.edu/admweb!/SWKSCAT.cat).

## Astronomy (ASTR)

### ASTR 100 - EXPLORING THE COSMOS

**Short Title:** EXPLORING THE COSMOS

**Department:** Physics and Astronomy

**Grade Mode:** Standard Letter

**Course Type:** Seminar

**Credit Hour:** 1

**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.

**Course Level:** Undergraduate Lower-Level

**Description:** Introduction to concepts, methods and discoveries of astronomy and astrophysics, with a theme to be chosen from the frontier topics of modern astrophysics. Will emphasize student presentations. Designed for first year students interested in science or engineering, but other majors are welcome.

### ASTR 101 - STARS, GALAXIES, AND THE UNIVERSE

**Short Title:** STARS, GALAXIES & THE UNIVERSE

**Department:** Physics and Astronomy

**Grade Mode:** Standard Letter

**Course Type:** Lecture

**Distribution Group:** Distribution Group III

**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.

**Course Level:** Undergraduate Lower-Level

**Description:** An introductory course for students in academic programs. The formation, evolution, and death of stars; the composition and evolution of galaxies; the structure and evolution of the universe. Mutually Exclusive: Cannot register for ASTR 101 if student has credit for ASTR 201.

### ASTR 102 - EXPLORATION OF THE SOLAR SYSTEM

**Short Title:** EXPLORATION OF THE SOLAR SYSTEM

**Department:** Physics and Astronomy

**Grade Mode:** Standard Letter

**Course Type:** Lecture

**Distribution Group:** Distribution Group III

**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.

**Course Level:** Undergraduate Lower-Level

**Description:** The physical processes governing the nature and behavior of the various Solar System bodies are discussed with a focus on the origins, evolution and fate of the Solar System and its parts. This broader context leads to a deeper understanding of the Earth as a life-supporting planet. Mutually Exclusive: Cannot register for ASTR 102 if student has credit for ASTR 202.

### ASTR 230 - ASTRONOMY LAB

**Short Title:** ASTRONOMY LAB

**Department:** Physics and Astronomy

**Grade Mode:** Standard Letter

**Course Type:** Laboratory

**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.

**Course Level:** Undergraduate Lower-Level

**Description:** A hands-on introduction to modern techniques of observational astronomy. Students use telescopes, CCDs, and computers to obtain and analyze their own images and spectra of solar system, galactic, and extragalactic objects. The course employs the campus observatory, dark sky observing sites, and state of the art data analysis

## Physics (PHYS)

### PHYS 100 - EXPLORING PHYSICS

**Short Title:** EXPLORING PHYSICS

**Department:** Physics and Astronomy

**Grade Mode:** Standard Letter

**Course Type:** Seminar

**Credit Hour:** 1

**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.

**Course Level:** Undergraduate Lower-Level

**Description:** Introduction to concepts, methods, debates, and discoveries of physics, with a theme to be chosen from one of many fields of modern physics research. Designed for students interested in understanding science. This includes both science and non-science majors.

### PHYS 101 - MECHANICS (WITH LAB)

**Short Title:** MECHANICS (WITH LAB)

**Department:** Physics and Astronomy

**Grade Mode:** Standard Letter

**Course Type:** Lecture/Laboratory

**Distribution Group:** Distribution Group III

**Credit Hours:** 4

**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.

**Course Level:** Undergraduate Lower-Level

**Corequisite:** PHYS 103

**Description:** A calculus-based introduction to mechanics. Includes classes and lab exercises on kinematics, Newton's Laws, work and energy, conservation laws and rotational motion. Primarily for physical science and engineering students. May receive credit for only one of PHYS 101, 111, 125, AP Physics 1 (Phys 141) and AP Physics-C MECH. Students must register for PHYS 103.

### PHYS 102 - ELECTRICITY & MAGNETISM (WITH LAB)

**Short Title:** ELECTRICITY&MAGNETISM W/LAB

**Department:** Physics and Astronomy

**Grade Mode:** Standard Letter

**Course Type:** Lecture/Laboratory

**Distribution Group:** Distribution Group III

**Credit Hours:** 4

**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.

**Course Level:** Undergraduate Lower-Level

**Corequisite:** PHYS 104

**Description:** A calculus-based introduction to electricity and magnetism. Includes classes and lab exercises on electric and magnetic fields, Maxwell's equations in integral form, and AC and DC circuits. Primarily for physical science and engineering students. May receive credit for only one of PHYS 102, 112, 126, AP Physics 2 (PHYS 142) and AP Physics-C E&M. Students must also register for PHYS 104.

### PHYS 103 - MECHANICS DISCUSSION

**Short Title:** MECHANICS DISCUSSION

**Department:** Physics and Astronomy

**Grade Mode:** Satisfactory/Unsatisfactory

**Course Type:** Seminar

**Credit Hours:** 0

**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.

**Course Level:** Undergraduate Lower-Level

**Corequisite:** PHYS 101

**Description:** Small group discussion section to extend and reinforce concepts presented in PHYS 101. Students must also register for PHYS 101.

### PHYS 104 - ELECTRICITY AND MAGNETISM DISCUSSION

**Short Title:** E & M DISCUSSION

**Department:** Physics and Astronomy

**Grade Mode:** Satisfactory/Unsatisfactory

**Course Type:** Seminar

**Credit Hours:** 0

**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.

**Course Level:** Undergraduate Lower-Level

**Corequisite:** PHYS 102

**Description:** Small group discussion section to extend and reinforce concepts presented in PHYS 102. Students must also register for PHYS 102.

### PHYS 111 - HONORS MECHANICS (WITH LAB)

**Short Title:** HONORS MECHANICS (WITH LAB)

**Department:** Physics and Astronomy

**Grade Mode:** Standard Letter

**Course Type:** Lecture/Laboratory

**Distribution Group:** Distribution Group III

**Credit Hours:** 4

**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.

**Course Level:** Undergraduate Lower-Level

**Description:** A more intensive treatment of topics covered in PHYS 101, intended for physical science and engineering students with strong high school backgrounds in physics and particularly calculus. May receive credit for only one of PHYS 101, 111, 125, AP Physics 1 (Phys 141) and AP Physics-C MECH.

### PHYS 112 - HONORS ELECTRICITY & MAGNETISM (WITH LAB)

**Short Title:** HONORS E&M (WITH LAB)

**Department:** Physics and Astronomy

**Grade Mode:** Standard Letter

**Course Type:** Lecture/Laboratory

**Distribution Group:** Distribution Group III

**Credit Hours:** 4

**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.

**Course Level:** Undergraduate Lower-Level

**Description:** A more intensive treatment of topics covered in PHYS 102, intended for physical science and engineering students with strong high school backgrounds in physics and particularly calculus. May receive credit for only one of PHYS 102, 112, 126, AP Physics 2 (PHYS 142), and AP Physics-C, E&M.

**PHYS 116 - SEMINAR IN PHYSICS AND ASTRONOMY AT RICE AND BEYOND****Short Title:** SEMINAR IN PHYS & ASTRO @ RICE**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Seminar**Credit Hour:** 1**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Lower-Level**Description:** This half-semester seminar course will meet in the first half of the Spring semester to introduce prospective and current science and engineering majors to the exciting research in physics and astronomy at Rice and beyond. The course will provide students with the context to think about how the facts presented in physics and astronomy textbooks are applied to real-world research. Undergraduate students in a small group will meet weekly with a graduate student to explore a published research article by a local lab, learning about what was done and why it was important. Toward the end of the course, the group will tour the lab that produced the featured article. All students are eligible to enroll in PHYS 116 regardless of the intended area of study.**PHYS 125 - GENERAL PHYSICS (WITH LAB)****Short Title:** GENERAL PHYSICS (WITH LAB)**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture/Laboratory**Distribution Group:** Distribution Group III**Credit Hours:** 4**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Lower-Level**Corequisite:** PHYS 127**Description:** A calculus-based survey of mechanics primarily intended for bioscience and premedical students. Includes classes and lab exercises on kinematics, Newton's Laws, work and energy, rotational motion, fluids, oscillations and waves. May receive credit for only one of PHYS 101, 111, 125, AP Physics 1 (Phys 141), and AP Physics-C, MECH.**PHYS 126 - GENERAL PHYSICS II (WITH LAB)****Short Title:** GENERAL PHYSICS II (WITH LAB)**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture/Laboratory**Distribution Group:** Distribution Group III**Credit Hours:** 4**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Lower-Level**Prerequisite(s):** PHYS 125 or PHYS 101 or PHYS 111 or PHYS 141**Corequisite:** PHYS 128**Description:** A calculus-based survey of E&M and optics primarily intended for bioscience and premedical students. Includes classes and lab exercises on wave and ray optics, electric field and potential, magnetic fields and induction, and DC circuits. May receive credit for only one of PHYS 102, 112, 126, AP Physics 2 (PHYS 142), and AP Physics-C, E&M.**PHYS 127 - GENERAL PHYSICS DISCUSSION****Short Title:** GENERAL PHYSICS DISCUSSION**Department:** Physics and Astronomy**Grade Mode:** Satisfactory/Unsatisfactory**Course Type:** Seminar**Credit Hours:** 0**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Lower-Level**Corequisite:** PHYS 125**Description:** Small group discussion section to extend and reinforce concepts presented in PHYS 125. Students must also register for PHYS 125.**PHYS 128 - GENERAL PHYSICS II DISCUSSION****Short Title:** GEN PHYSICS II DISCUSSION**Department:** Physics and Astronomy**Grade Mode:** Satisfactory/Unsatisfactory**Course Type:** Seminar**Credit Hours:** 0**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Lower-Level**Corequisite:** PHYS 126**Description:** Small group discussion section to extend and reinforce concepts presented in PHYS 126. Students must also register for PHYS 126.**PHYS 141 - CONCEPTS IN PHYSICS I****Short Title:** CONCEPTS IN PHYSICS I**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Distribution Group:** Distribution Group III**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Lower-Level**Description:** For AP or pre-matriculation transfer credit only. May receive credit for only one of PHYS 101, PHYS 111, PHYS 125, AP Physics 1, and AP Physics-C (Mech).**PHYS 142 - CONCEPTS IN PHYSICS II****Short Title:** CONCEPTS IN PHYSICS II**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Distribution Group:** Distribution Group III**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Lower-Level**Description:** For AP or pre-matriculation transfer credit only. May receive credit for only one of PHYS 102, PHYS 112, PHYS 126, AP Physics 2, and AP Physics-C (E&M).

**PHYS 143 - PHYSICS FOR CITIZENSHIP****Short Title:** PHYSICS FOR CITIZENSHIP**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Distribution Group:** Distribution Group III**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Lower-Level**Description:** Physics is critical to our understanding of nuclear weapons, radiation, electronics, energy and global warming. The most interesting and important topics in physics, with applications to current events will be presented. Topics covered may include energy and conservation, radioactivity, nuclear physics, the Theory of Relativity, lasers, explosions and quantum physics.**PHYS 144 - THE PHYSICS OF MUSIC AND SOUND****Short Title:** THE PHYSICS OF MUSIC AND SOUND**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Distribution Group:** Distribution Group III**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Lower-Level**Description:** This course explores our scientific understanding of sound and music by studying the properties of sound and its production by a variety of musical instruments. Additional topics include an analysis of musical scales, the physiology of hearing, and the technology of sound reproduction. For non-science and non-engineering majors.**PHYS 145 - TRACES OF LIFE****Short Title:** TRACES OF LIFE**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Distribution Group:** Distribution Group III**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Lower-Level**Description:** The basic physics behind the scientific instruments used to detect life, whether in a medical clinic, a laboratory, or the natural world.**PHYS 201 - WAVES, LIGHT, AND HEAT****Short Title:** WAVES, LIGHT, AND HEAT**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Lower-Level**Prerequisite(s):** (PHYS 101 or PHYS 111 or PHYS 125 or PHYS 141) and (PHYS 102 or PHYS 112 or PHYS 126 or PHYS 142)**Description:** Mathematical descriptions of fundamental topics of classical physics: oscillations, mechanical waves, electromagnetic waves, physical optics and thermodynamics.**PHYS 202 - MODERN PHYSICS****Short Title:** MODERN PHYSICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Lower-Level**Prerequisite(s):** (PHYS 101 or PHYS 111 or PHYS 125 or PHYS 141) and (PHYS 102 or PHYS 112 or PHYS 126 or PHYS 142)**Description:** An introductory course in modern physics. Topics include special relativity, early quantum theory, quantum mechanics, atomic physics, statistical physics, nuclear and particle physics. The course is descriptive in nature with emphasis on phenomena rather than on calculations.**PHYS 231 - ELEMENTARY PHYSICS LAB****Short Title:** ELEMENTARY PHYSICS LAB**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Laboratory**Credit Hour:** 1**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Lower-Level**Description:** Laboratory on waves, optics and modern physics.**PHYS 238 - SPECIAL TOPICS****Short Title:** SPECIAL TOPICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture/Laboratory, Internship/Practicum, Independent Study, Laboratory, Lecture, Seminar**Credit Hours:** 1-4**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Lower-Level**Description:** Topics and credit hours may vary each semester. Contact department for current semester's topic(s). Repeatable for Credit.**PHYS 301 - INTERMEDIATE MECHANICS****Short Title:** INTERMEDIATE MECHANICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 4**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** PHYS 201**Description:** Classical mechanics and appropriate mathematical methods. Emphasis on problem solving.

**PHYS 302 - INTERMEDIATE ELECTRODYNAMICS****Short Title:** INTERMEDIATE ELECTRODYNAMICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 4**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** PHYS 201**Description:** Classical electrodynamics and appropriate mathematical methods. Emphasis on problem solving.**PHYS 311 - INTRODUCTION TO QUANTUM PHYSICS I****Short Title:** INTRO TO QUANTUM PHYSICS I**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** PHYS 202**Description:** Fundamentals of quantum mechanics and applications to atomic and molecular structure.**PHYS 312 - INTRODUCTION TO QUANTUM PHYSICS II****Short Title:** INTRO TO QUANTUM PHYSICS II**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Description:** Continuation of PHYS 311.**PHYS 331 - JUNIOR PHYSICS LAB I****Short Title:** JUNIOR PHYSICS LAB I**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Laboratory**Credit Hours:** 2**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Description:** Lab exercises in electronics, noise reduction, statistics and particle counting.**PHYS 332 - JUNIOR PHYSICS LAB II****Short Title:** JUNIOR PHYSICS LAB II**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Laboratory**Credit Hours:** 2**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Description:** Lab exercises illustrating topics in the upper-division physics curriculum.**PHYS 355 - INTRODUCTION TO BIOLOGICAL PHYSICS****Short Title:** INTRO TO BIOLOGICAL PHYSICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Description:** Tools for physical reasoning and mathematical modeling as appropriate for biological systems. Topics include: dimensional analysis and conversion between different forms of energy, virus dynamics, microswimmers, randomness and diffusion, cooperativity in macromolecules, and nerve impulses.**PHYS 411 - INTRODUCTION TO NUCLEAR AND PARTICLE PHYSICS****Short Title:** INTRO NUCLEAR&PARTIC PHYSICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** PHYS 311**Description:** Survey of history and current state of nuclear and particle physics. The emphasis is on experimental results and how they led to our current understanding of the strong and electroweak interactions. Some recent advances are discussed in detail. Graduate/Undergraduate Equivalency: PHYS 542. Mutually Exclusive: Cannot register for PHYS 411 if student has credit for PHYS 542.**PHYS 412 - SOLID STATE PHYSICS****Short Title:** SOLID STATE PHYSICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** (PHYS 311 and PHYS 425) or ELEC 361**Description:** Introduction to topics in solid state physics, including crystal structure, lattice vibrations, electronic band structure and transport.**PHYS 413 - INTRODUCTION TO GENERAL RELATIVITY****Short Title:** INTRO TO GENERAL RELATIVITY**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** PHYS 301 (may be taken concurrently)**Description:** The material in this course will focus on understanding gravity as a manifestation of curved spacetime, and explore its implications. Graduate/Undergraduate Equivalency: PHYS 513. Recommended Prerequisite(s): MATH 211, MATH 212 Mutually Exclusive: Cannot register for PHYS 413 if student has credit for PHYS 513.

**PHYS 416 - COMPUTATIONAL PHYSICS****Short Title:** COMPUTATIONAL PHYSICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Description:** Use of computational techniques to solve selected physics problems. Examine benefits and pitfalls of doing physics by computation. Graduate/Undergraduate Equivalency: PHYS 517. Mutually Exclusive: Cannot register for PHYS 416 if student has credit for PHYS 517.**PHYS 425 - STATISTICAL & THERMAL PHYSICS****Short Title:** STATISTICAL & THERMAL PHYSICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** PHYS 301 and PHYS 311**Description:** Includes classical thermodynamics; classical & quantum statistical mechanics; Fermi, Bose, and classical gases; magnetic systems; and phase equilibria.**PHYS 449 - PROJECTS IN DATA-ENABLED PHYSICS THROUGH DATA SCIENCE AND MACHINE LEARNING****Short Title:** DATA-ENABLED PHYSICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture/Laboratory**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** PHYS 202**Description:** Project-based course where teams of students explore physics through the lens of data. Students will learn about data analysis and best practices. Students without prior programming experience should contact the instructor. Graduate/Undergraduate Equivalency: PHYS 549. Recommended Prerequisite(s): COMP 130 or COMP 140 or CAAM 210 Mutually Exclusive: Cannot register for PHYS 449 if student has credit for PHYS 549.**PHYS 461 - INDEPENDENT RESEARCH****Short Title:** INDEPENDENT RESEARCH**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Research**Credit Hours:** 1-6**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Description:** Mentored research under the supervision of a Physics and Astronomy faculty member. To register, students must provide a research plan approved by the faculty mentor. Instructor Permission Required. Repeatable for Credit.**PHYS 465 - REU RESEARCH IN PHYSICS AND ASTRONOMY****Short Title:** REU RESEARCH IN PHYS & ASTR**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Research**Credit Hours:** 1-3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Description:** Repeatable for Credit.**PHYS 477 - SPECIAL TOPICS****Short Title:** SPECIAL TOPICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Internship/Practicum, Laboratory, Lecture, Seminar, Independent Study, Lecture/Laboratory**Credit Hours:** 1-4**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Description:** Topics and credit hours may vary each semester. Contact department for current semester's topic(s). Repeatable for Credit.**PHYS 480 - INTRODUCTION TO PLASMA PHYSICS****Short Title:** INTRODUCTION TO PLASMA PHYSICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** PHYS 302**Description:** Fundamental processes in cosmic and laboratory plasmas. Basic plasma characteristics, charged particle motion, waves in plasmas, magnetohydrodynamics, kinetic theory. Graduate/Undergraduate Equivalency: PHYS 580. Mutually Exclusive: Cannot register for PHYS 480 if student has credit for PHYS 580.**PHYS 491 - UNDERGRADUATE RESEARCH****Short Title:** UNDERGRADUATE RESEARCH**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Research**Credit Hours:** 2**Restrictions:** Enrollment limited to students with a class of Junior or Senior. Enrollment is limited to students with a major in Astronomy, Astrophysics, Chemical Physics or Physics. Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** PHYS 301 and PHYS 302 and PHYS 311**Description:** Research projects conducted under supervision of departmentally approved faculty. Open to juniors and seniors majoring in physics and astronomy. May be repeated for credit. PHYS 493/494 must be taken concurrently with PHYS 491/492 when used in partial fulfillment of B.S. degree requirements. Repeatable for Credit.

**PHYS 492 - UNDERGRADUATE RESEARCH****Short Title:** UNDERGRADUATE RESEARCH**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Research**Credit Hours:** 2**Restrictions:** Enrollment limited to students with a class of Junior or Senior. Enrollment is limited to students with a major in Astronomy, Astrophysics, Chemical Physics or Physics. Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** PHYS 491**Description:** Research projects conducted under supervision of departmentally approved faculty culminating in a thesis. Open to juniors and seniors majoring in physics and astronomy. May be repeated for credit. PHYS 493/494 must be taken concurrently with PHYS 491/492 when used in partial fulfillment of B.S. degree requirements. Repeatable for Credit.**PHYS 493 - UNDERGRADUATE RESEARCH SEMINAR****Short Title:** UNDERGRADUATE RESEARCH SEMINAR**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Seminar**Credit Hour:** 1**Restrictions:** Enrollment limited to students with a class of Junior or Senior. Enrollment is limited to students with a major in Astronomy, Astrophysics, Chemical Physics or Physics. Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** PHYS 301 and PHYS 302 and PHYS 311**Description:** Weekly seminar for juniors and seniors in which presentations on research topics and/or topics in the scientific literature will be given. Open to juniors and seniors majoring in physics and astronomy. Repeatable for Credit.**PHYS 494 - UNDERGRADUATE RESEARCH SEMINAR****Short Title:** UNDERGRADUATE RESEARCH SEMINAR**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Seminar**Credit Hour:** 1**Restrictions:** Enrollment limited to students with a class of Junior or Senior. Enrollment is limited to students with a major in Astronomy, Astrophysics, Chemical Physics or Physics. Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.**Course Level:** Undergraduate Upper-Level**Prerequisite(s):** PHYS 493**Description:** Weekly seminar for juniors and seniors in which presentations on research topics and/or topics in the scientific literature will be given. Open to juniors and seniors majoring in physics and astronomy department. Repeatable for Credit.**PHYS 501 - PHYSICS OF HAM RADIO FOR TEACHERS****Short Title:** PHYSICS OF HAM RADIO TEACHERS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate**Description:** Fundamentals of electromagnetic waves and propagation, the ionosphere and space weather. Basic electronics, antenna design and safety, magnetism. Provides information necessary to pass the "Technician" level of ham radio license. Non-calculus mathematics. Other topics include: use of GPS, geocaching. Mutually Exclusive: Cannot register for PHYS 501 if student has credit for PHYS 401.**PHYS 510 - MAGNETOSPHERIC PHYSICS****Short Title:** MAGNETOSPHERIC PHYSICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate**Description:** Plasma physics of the earth's magnetosphere, including interactions of the magnetosphere with the solar wind and the ionosphere. The emphasis is on large-scale phenomena, but small scale (kinetic) physics is discussed in cases where it affects the large-scale phenomena.**PHYS 512 - QUANTUM MATERIALS ENGINEERING****Short Title:** QUANTUM MATERIALS ENGINEERING**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Course Level:** Graduate**Description:** Introduction to the basic concepts of useful quantum (non-classical) properties of materials, as well as experimental techniques to engineer materials, with an emphasis on various optical spectroscopy. Students are encouraged to have prior exposure to quantum mechanics and electronic properties of solids (or equivalent) before enrollment, although the principles will be refreshed at the beginning of the course. Cross-list: MSNE 512. Recommended Prerequisite(s): Quantum Mechanics; Physical Properties of Solids or Solid State Physics.**PHYS 513 - INTRODUCTION TO GENERAL RELATIVITY****Short Title:** INTRO TO GENERAL RELATIVITY**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate**Description:** The material in this course will focus on understanding gravity as a manifestation of curved spacetime, and explore its implications. Graduate/Undergraduate Equivalency: PHYS 413. Mutually Exclusive: Cannot register for PHYS 513 if student has credit for PHYS 413.

**PHYS 515 - CLASSICAL DYNAMICS**

**Short Title:** CLASSICAL DYNAMICS  
**Department:** Physics and Astronomy  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** Lagrangian and Hamiltonian Dynamics. Continuum Mechanics. Introduction to Fluid Mechanics.

**PHYS 516 - MATHEMATICAL METHODS**

**Short Title:** MATHEMATICAL METHODS  
**Department:** Physics and Astronomy  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** Survey of analytical methods used by research physicists and astronomers. Includes complex variables, ordinary differential equations, infinite series, evaluation of integrals, integral transforms, normal-mode analysis, special functions, partial differential equations, eigenfunctions, Green's functions, and variational calculus.

**PHYS 517 - COMPUTATIONAL PHYSICS**

**Short Title:** COMPUTATIONAL PHYSICS  
**Department:** Physics and Astronomy  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** Use of computational techniques to solve selected physics problems. Examine benefits and pitfalls of doing physics by computation. Requires completion of project using a low-level programming language. Graduate/Undergraduate Equivalency: PHYS 416. Mutually Exclusive: Cannot register for PHYS 517 if student has credit for PHYS 416.

**PHYS 519 - PLASMA KINETIC THEORY**

**Short Title:** PLASMA KINETIC THEORY  
**Department:** Physics and Astronomy  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** Plasma kinetic equations (Klimontovich, Liouville, BBGKY, Balescu-Lenard, Fokker-Planck, Vlasov), Vlasov theory of waves and instabilities, connections to fluid plasma models.

**PHYS 521 - QUANTUM MECHANICS I**

**Short Title:** QUANTUM MECHANICS I  
**Department:** Physics and Astronomy  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** Graduate level course on non-relativistic quantum mechanics. Topics include early quantum theory, one-dimensional systems, matrix formulation, quantum dynamics, symmetries and conservation laws, bound states, scattering, spin, and identical particles, perturbation theory.

**PHYS 522 - QUANTUM MECHANICS II**

**Short Title:** QUANTUM MECHANICS II  
**Department:** Physics and Astronomy  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** Continuation of PHYS 521.

**PHYS 526 - STATISTICAL PHYSICS**

**Short Title:** STATISTICAL PHYSICS  
**Department:** Physics and Astronomy  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** Selected topics in statistical mechanics, including phase transitions and transport phenomena.

**PHYS 532 - CLASSICAL ELECTRODYNAMICS**

**Short Title:** CLASSICAL ELECTRODYNAMICS  
**Department:** Physics and Astronomy  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** Maxwell's equations, wave propagation, special relativity and covariant formulation, charged-particle dynamics, and radiation.

**PHYS 533 - NANOSTRUCTURE AND NANOTECHNOLOGY I**

**Short Title:** NANOSTRUCTURE/NANOTECHNOLOG  
**Department:** Physics and Astronomy  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** Physics of structures and devices at the nanometer scale. After a review of solid state physics, topics include nanostructured materials, nanoelectronics, and nanomagnetism. Emphasis on relevance of nanophysics to current and future technologies.

**PHYS 534 - NANOSTRUCTURE AND NANOTECHNOLOGY II**

**Short Title:** NANOSTRUCTURE&NANOTECHNOLOGY II  
**Department:** Physics and Astronomy  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** Physics of structures and devices at the nanometer scale. Topics include nanomechanics, bionanotechnology, advanced sensors and photonics. Continuation of PHYS 533.

**PHYS 535 - CRYSTALLOGRAPHY AND DIFFRACTION****Short Title:** CRYSTALLOGRAPHY & DIFFRACTION**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

**Description:** Study of crystals by diffraction techniques, focusing on x-ray, with an overview of electron and neutron diffraction as well as complementary techniques. Provides mathematical foundations and nomenclature for diffraction and related phenomena. Includes basics of crystallographic analysis and surface/point/space group symmetry, experiment design (courses, geometry, detectors), and data analysis and interpretation. Required for undergraduate MSNE major. Meets with MSNE 435 (additional work for the graduate version). Cross-list: MSNE 535.

**PHYS 537 - METHODS OF EXPERIMENTAL PHYSICS I****Short Title:** METHODS EXPERIMENTAL PHYSICS I**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture/Laboratory**Credit Hours:** 4**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

**Description:** A course to familiarize students with basic experimental techniques that are common in academic and industrial laboratories. Topics will include lab safety, mechanical design, LabVIEW(TM) programming, statistics, laboratory electronics, particle detection and vacuum technology. PHYS 537 and PHYS 538 may be taken independently of each other.

**PHYS 538 - METHODS OF EXPERIMENTAL PHYSICS II****Short Title:** METH EXPERIMENTAL PHYSICS II**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture/Laboratory**Credit Hours:** 4**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

**Description:** A course to familiarize students with basic experimental techniques that are common in academic and industrial laboratories. Topic will include computer interfacing and data acquisition, charged particle optics, light optics, thermal measurement and control, and cryogenics. PHYS 537 and PHYS 538 may be taken independently of each other.

**PHYS 539 - CHARACTERIZATION AND FABRICATION AT THE NANOSCALE****Short Title:** CHARACTER&FABRICATN NANOSCALE**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

**Description:** Introduction to study and creation of nanoscale structures, emphasizing relevant physical principles. Techniques covered include optical, X-ray, electron-based and scanned-probe characterization, as well as patterning, deposition and removal of material.

**PHYS 541 - RADIATIVE PROCESSES****Short Title:** RADIATIVE PROCESSES**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

**Description:** Radiation processes and their applications to astrophysical phenomena and space science. The course treats radiative transfer, radiation from moving charges, relativistic covariance and kinematics, bremsstrahlung, synchrotron radiation, Compton scattering, some plasma effects, and radiative transitions in atoms and molecules.

**PHYS 542 - INTRODUCTION TO NUCLEAR AND PARTICLE PHYSICS****Short Title:** INTRO NUCLEAR&PARTIC PHYSICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate**Prerequisite(s):** PHYS 311

**Description:** Survey of history and current state of nuclear and particle physics with the emphasis on experimental results and how they led to our current understanding of the strong and electroweak interactions. Some recent advances are discussed in detail. Requires completion of a Monte Carlo simulation project. Graduate/Undergraduate Equivalency: PHYS 411. Mutually Exclusive: Cannot register for PHYS 542 if student has credit for PHYS 411.

**PHYS 543 - PHYSICS OF QUARKS AND LEPTONS****Short Title:** PHYSICS OF QUARKS AND LEPTONS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate**Description:** A continuation of PHYS 542.**PHYS 549 - PROJECTS IN DATA-ENABLED PHYSICS THROUGH DATA SCIENCE AND MACHINE LEARNING****Short Title:** DATA-ENABLED PHYSICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture/Laboratory**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

**Description:** Project-based course where teams of students explore physics through the lens of data. Students will learn about data analysis and best practices. Students without prior programming experience should contact the instructor. Graduate/Undergraduate Equivalency: PHYS 449. Mutually Exclusive: Cannot register for PHYS 549 if student has credit for PHYS 449.

**PHYS 551 - BIOLOGICAL PHYSICS**

**Short Title:** BIOLOGICAL PHYSICS  
**Department:** Physics and Astronomy  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** Introduction to biological physics. Review of basic physical concepts. Cells and their components. Diffusion and random walks. Entropy and energy concepts and their roles in biological systems. Modern experimental methods. Applications to biological macromolecules.

**PHYS 552 - TOPICS IN BIOLOGICAL PHYSICS**

**Short Title:** TOPICS IN BIOLOGICAL PHYSICS  
**Department:** Physics and Astronomy  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** Topics will be selected based on special or current research interests.

**PHYS 561 - GENERAL RELATIVITY**

**Short Title:** GENERAL RELATIVITY  
**Department:** Physics and Astronomy  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Prerequisite(s):** PHYS 532  
**Description:** Study of Einstein's theory of gravitation, including cosmological models.

**PHYS 563 - INTRODUCTION TO SOLID STATE PHYSICS I**

**Short Title:** INTRO TO SOLID STATE PHYSICS I  
**Department:** Physics and Astronomy  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** Fundamental concepts of crystalline solids, including crystal structure, band theory of electrons, and lattice vibration theory. Cross-list: ELEC 563.

**PHYS 564 - INTRODUCTION TO SOLID STATE PHYSICS II**

**Short Title:** INTRO SOLID STATE PHYSICS II  
**Department:** Physics and Astronomy  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** Continuation of PHYS 563, including scattering of waves by crystals, transport theory, and magnetic phenomena. Cross-list: ELEC 564.

**PHYS 566 - SURFACE PHYSICS**

**Short Title:** SURFACE PHYSICS  
**Department:** Physics and Astronomy  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** An introduction to surface- and low-dimensional physics covering experimental surface physics and ultra-high vacuum technology, crystal structure, chemical analysis, epitaxy, nanoscale electronic and magnetic structures and devices, elementary excitations, optical properties and nanoscale sensitive magnetic and non-magnetic spectroscopies.

**PHYS 567 - QUANTUM MATERIALS**

**Short Title:** QUANTUM MATERIALS  
**Department:** Physics and Astronomy  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Prerequisite(s):** (PHYS 425 or PHYS 526) and (PHYS 311 or PHYS 521)  
**Description:** This course uses real data on archetypal materials to illustrate the thermodynamic and transport properties of solids, and principles of materials synthesis. The goal is building a phenomenological understanding of topics including the origin of magnetism; interactions and long range order; phase transitions (magnetism; superconductivity); quantum oscillations and Landau levels.

**PHYS 568 - QUANTUM PHASE TRANSITIONS**

**Short Title:** QUANTUM PHASE TRANSITIONS  
**Department:** Physics and Astronomy  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** Introductory course for graduate students. Topics include the concepts of classical and quantum phase transitions, mean field theory, renormalization group and quantum phase transitions in magnetic, fermionic, and bosonic systems.

**PHYS 569 - ULTRAFAST OPTICAL PHENOMENA**

**Short Title:** ULTRAFAST OPTICAL PHENOMENA  
**Department:** Physics and Astronomy  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** This course covers the generation, propagation, and measurement of short laser pulses, of duration less than one picosecond. Concepts include mode locking, the effects of dispersion, optical pulse amplification, and time-domain non-linear optical phenomena. Intended as an introduction to ultrafast phenomena for graduate students or advanced undergraduates; a basic understanding of electromagnetic waves and of quantum mechanics is assumed. Cross-list: ELEC 569.

**PHYS 571 - MODERN ATOMIC PHYSICS****Short Title:** MODERN ATOMIC PHYSICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate**Description:** This is an introductory course at the graduate level.

Topics to be discussed include: atomic structure, principles of lasers, fundamental interactions of atoms with electro-magnetic radiation, including coherent effects, laser spectroscopy, quantum optics, and laser cooling and trapping of atoms, and Bose-Einstein condensation.

**PHYS 572 - FUNDAMENTALS OF QUANTUM OPTICS****Short Title:** FUNDAMENTALS OF QUANTUM OPTICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

**Description:** Discussion of quantization and statistical properties of light fields; interaction between atoms and light; non-classical states; basic laser theory; quantum effects of nonlinear optics; introduction to atom optics.

**PHYS 580 - INTRODUCTION TO PLASMA PHYSICS****Short Title:** INTRODUCTION TO PLASMA PHYSICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

**Description:** Fundamental processes in cosmic and laboratory plasmas. Basic plasma characteristics, charged particle motion, waves in plasmas, magnetohydrodynamics, kinetic theory. Includes a substantial computational project related to plasma physics. Graduate/Undergraduate Equivalency: PHYS 480. Mutually Exclusive: Cannot register for PHYS 580 if student has credit for PHYS 480.

**PHYS 600 - ADVANCED TOPICS IN PHYSICS****Short Title:** ADVANCED TOPICS IN PHYSICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

**Description:** Lecture/seminars which treat topics of departmental interest. Repeatable for Credit.

**PHYS 601 - FRONTIERS IN CONDENSED MATTER PHYSICS****Short Title:** FRONTIERS IN CONDENSED MATTER**Department:** Physics and Astronomy**Grade Mode:** Satisfactory/Unsatisfactory**Course Type:** Seminar**Credit Hour:** 1**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

**Description:** This seminar will serve as an introduction to current research topics in modern condensed matter physics. Lectures will be given by experts in condensed matter physics at Rice, Columbia University, and other international locations. Repeatable for Credit.

**PHYS 605 - COMPUTATIONAL ELECTRODYNAMICS AND NANOPHOTONICS****Short Title:** ELECTRODYNAMICS & NANOPHOTONIC**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

**Description:** This course covers computational and numerical methods for calculating electromagnetic fields and propagation in complex geometries on the nano and microscale. Methods include the finite difference time domain method, boundary element methods, Greens functions methods, finite element methods, the discrete dipole approximation and relaxation methods. Cross-list: ELEC 605. Repeatable for Credit.

**PHYS 610 - BIOLOGICAL AND MOLECULAR SIMULATION****Short Title:** METHODS OF MOLECULAR SIMUL**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

**Prerequisite(s):** CHBE 611 or BIOC 589 or BIOE 589 or BIOS 589 or CHEM 520 or PHYS 526

**Description:** Modern simulation techniques for classical atomistic systems. Review of statistical mechanical systems. Monte Carlo and molecular dynamics simulation techniques. Extensions of the basic methods to various ensembles. Applications to simulations of large molecules such as proteins. Advanced techniques for simulation of complex systems, including constraint satisfaction, cluster moves, biased sampling, and random energy models. Cross-list: BIOE 610.

**PHYS 622 - QUANTUM FIELD THEORY****Short Title:** QUANTUM FIELD THEORY**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

**Description:** An introduction to relativistic quantum field theory. Topics include: quantization of scalar, spinor, and vector fields; Feynman diagrams; gauge theories, including QED and QCD; renormalization; and functional-integral methods.

**PHYS 643 - CELL MECHANICS, MECHANOTRANSDUCTION AND THE CELL MICROENVIRONMENT****Short Title:** MECHANOTRANSDUCTION**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

**Description:** Mechanotransduction is a fundamental process essential for living systems and plays a fundamental role in cell signaling, cancer metastasis and stem cell differentiation. Additionally, fundamental biological processes such as endocytosis cell fusion and cell migration are driven by a coordinated interplay of molecular interactions that drive membrane deformation. This course will survey the current understanding of mechanotransduction and the mechanical properties of cells and their microenvironment, including membrane and cytoskeletal mechanics. Experimental approaches for measuring and manipulating the material properties of cells and their environment; including optical, electrical and magnetic techniques will be covered. A variety of application will be covered, including manipulation in engineering of mechanotransduction pathways to drive cell migration and stem cell differentiation. Instructor Permission Required. Cross-list: BIOE 643.

**PHYS 663 - CONDENSED MATTER THEORY: APPLICATIONS****Short Title:** CONDENSED MATTER THEORY: APPLICATIONS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate**Description:** Applications of techniques developed in PHYS 664.**PHYS 664 - CONDENSED MATTER THEORY: MANY-BODY FORMALISM****Short Title:** COND MATTR THRY:MANY BODY FORM**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

**Description:** Formal structure of many-body theory as used in condensed matter physics.

**PHYS 665 - TOPOLOGY IN MODERN QUANTUM PHYSICS AND FIELD THEORY****Short Title:** TOPOLOGY IN QUANTUM PHYSICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Lecture**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate**Prerequisite(s):** PHYS 521

**Description:** Topology plays an increasingly important role in modern quantum physics, and its applications to a variety of topics range from the theory of liquid crystals to topological defects in quantum field theory. This course will introduce some key notions from topology, such as homotopy and homology, and differential geometry and discuss their applications in quantum physics, from the theory of vortices in superconductors, to monopoles in non-Abelian gauge theories, to instantons in Yang–Mills theory. The course also covers the concepts of topological insulators and superconductors that have become an important part of the vocabulary of modern condensed matter physics. The course may be useful for students pursuing research in condensed matter and AMO physics, as well as high-energy physicists interested in topological defects in quantum field theory.

**PHYS 677 - SPECIAL TOPICS****Short Title:** SPECIAL TOPICS**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Internship/Practicum, Laboratory, Lecture, Seminar, Lecture/Laboratory, Independent Study**Credit Hours:** 1-4**Restrictions:** Enrollment is limited to Graduate or Visiting Graduate level students.**Course Level:** Graduate

**Description:** Topics and credit hours vary each semester. Contact department for current semester's topic(s). Repeatable for Credit.

**PHYS 700 - TEACHING PRACTICUM****Short Title:** TEACHING PRACTICUM**Department:** Physics and Astronomy**Grade Mode:** Standard Letter**Course Type:** Internship/Practicum**Credit Hours:** 3**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

**Description:** Supervised teaching for graduate students. Repeatable for Credit.

**PHYS 710 - GRADUATE SEMINAR IN PHYSICS AND ASTRONOMY****Short Title:** GRAD SEMINAR IN PHYS & ASTR**Department:** Physics and Astronomy**Grade Mode:** Satisfactory/Unsatisfactory**Course Type:** Seminar**Credit Hour:** 1**Restrictions:** Enrollment is limited to Graduate level students.**Course Level:** Graduate

**Description:** Participation in department colloquia and additional sessions on topics of interest to entering graduate students. Required of all Physics and Astronomy graduate students during their first Fall semester at Rice.

**PHYS 800 - GRADUATE RESEARCH**

**Short Title:** GRADUATE RESEARCH

**Department:** Physics and Astronomy

**Grade Mode:** Standard Letter

**Course Type:** Research

**Credit Hours:** 1-15

**Restrictions:** Enrollment is limited to Graduate level students.

**Course Level:** Graduate

**Description:** Thesis research under the supervision of department faculty.

Repeatable for Credit.

## Description and Code Legend

*Note: Internally, the university uses the following descriptions, codes, and abbreviations for this academic program. The following is a quick reference:*

### Course Catalog/Schedule:

- Course offerings/subject code for Astronomy: ASTR
- Course offerings/subject code for Physics: PHYS

### Department Description and Code

- Physics and Astronomy: PHYS

### Undergraduate Degree Description and Code

- Bachelor of Science degree: BS

### Undergraduate Major Description and Code

- Major in Astrophysics (attached to the BS degree): ASTR

### CIP Code and Description<sup>1</sup>

- ASTR Major/Program: CIP Code/Title: 40.0202 - Astrophysics

<sup>1</sup> Classification of Instructional Programs (CIP) 2020 Codes and Descriptions from the National Center for Education Statistics: <https://nces.ed.gov/ipeds/cipcode/>