Physics

Paul Miceli, Chair
College of Arts and Science
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https://physics.missouri.edu/

Physics is the science that studies the structure and properties of matter and transformations of energy. With math as the language and experimental verification as a guide, physical study has established the fundamental laws of nature that are the foundation of all natural science and technology. The study of physics includes learning the general principles and the phenomena that have been discovered and developing the skills that enable such knowledge to be advanced through research.

The Department of Physics and Astronomy offers a major in physics with either a Bachelor of Science or Bachelor of Arts Degree. The BS degree in Physics is designed to prepare students for scientific careers immediately upon graduation or for further training in graduate school. The BA degree provides a broad coverage of classical and modern physics while permitting a broader liberal arts education. It is normally selected by students who do not envision a professional career in physics, but plan to enter a professional school later in their academic career, e.g. medicine, dentistry or law, or who desire to pursue a teaching certificate. A minor in physics or astronomy is also available.

Physics education plays a pivotal role in such areas of burgeoning and societal importance as biomedical optical imaging/biomedicine, materials science, and homeland security. Therefore, the Department of Physics has introduced several new courses and electives to train undergraduate students in optical sciences, biological physics, materials sciences and nanotechnology.

Faculty

Professor S.J. Chen**, S. Guha**, K. Katti**, G. King**, S.M. Kopekin**, I. Kosztin**, A. Li**, P. Miceli**, S. Satpathy**, D.K. Singh**, C. Ullrich**, C. Wexler**, H. Yan**, P. Yu**, X. Zou**
Associate Professor G. Bian**, Y. Guo**, W.T. Montfrooij**,
Assistant Professor K. Cassidy**, P. Laurell**, A. Meng**, M. Mills**, C. Steinhardt**, P. Sukhachov**
Teaching Professor S. Bompadre*, Y. Zhang*
Assistant Teaching Professor S. Roland*
Assistant Research Professor T. Heitmann**
Professor Emeritus H.R. Chandrasekhar, M. Chandrasekhar, G. Forgacs, L. Godwin, B. Loftin, B. Mashhoon, P. Pfeifer, P. Plummer, J.J. Rhyne, D.J. Singh, H. Taub, C.W. Tompson, G. Vignale, S.A. Werner, H.W. White
Associate Professor Emeritus C.J. Peterson

* Graduate Faculty Member - membership is required to teach graduate-level courses, chair master's thesis committees, and serve on doctoral examination and dissertation committees.
** Doctoral Faculty Member - membership is required to chair doctoral examination or dissertation committees. Graduate faculty membership is a prerequisite for Doctoral faculty membership.

Undergraduate

- BA in Physics (https://catalog.missouri.edu/collegeofartsandscience/physics/ba-physics/)
- BS in Physics (https://catalog.missouri.edu/collegeofartsandscience/physics/bs-physics/)
  - with emphasis in Astronomy (https://catalog.missouri.edu/collegeofartsandscience/physics/bs-physics-emphasis-astronomy/)
  - with emphasis in Biological Physics (https://catalog.missouri.edu/collegeofartsandscience/physics/bs-physics-emphasis-biological-physics/)
  - with emphasis in Materials Science (https://catalog.missouri.edu/collegeofartsandscience/physics/bs-physics-emphasis-materials-science/)
- Minor in Physics (https://catalog.missouri.edu/collegeofartsandscience/physics/minor-physics/)

Director of Undergraduate Studies:
Prof. Silvia Bompadre (bompadres@missouri.edu)
320 Physics Building
(573)-882-5372
https://physics.missouri.edu/undergrad-program/

Candidates for BA/BS degrees must complete 120 credits with an average grade of C or better. For the BA in physics degree, students must complete 30 credits in physics and 19 credits in math and chemistry. For the BS in physics degree, students must complete 45 credits in physics and 25 credits in math and chemistry. In addition, students must meet all degree, college, and university requirements including University general education. All students who complete the BS degree in Physics automatically also complete a minor in Mathematics.

Elective Tracks and Emphasis Areas

Students have available a variety of courses from which they may select the required credits of physics electives for the BS or BA degree. The department offers tracks that allow students to specialize in astronomy, biological physics, condensed matter physics, computational physics, energy storage, materials science, nanomaterials, or optoelectronics. Students may wish to pursue one of these tracks, or follow a general track in which they can choose any of the courses that are listed and are not required courses. The department also offers emphasis areas in Astronomy, Biological Physics, and Materials Science. Students need to choose their physics electives courses from courses on these particular areas to obtain the emphasis. These emphasis areas are indicated in the student's degree.

Note: Tracks are not indicated on the diploma.

Departmental Honors

The departmental honors program in physics provides exceptional students with an opportunity to develop skills beyond the normal course work. It also acknowledges those students who have attained a level of achievement beyond what is normally expected of an undergraduate physics major.

To receive an honors degree with a major in physics, a student must meet the following criteria:

- Satisfy the BA or BS degree requirements
- Cumulative GPA of at least 3.30 and minimum GPA of 3.50 in Physics Department courses
- Complete a six credit hours research sequence, by signing up for PHYSCS 4950/ASTRON 4950 Undergraduate Research in Physics/Astronomy in the first (second) semester junior year and for PHYSCS 4950/ASTRON 4960 Senior Thesis (or PHYSCS 4950/ASTRON 4950 again) in the first (second) semester senior year. In PHYSCS 4950 /ASTRON 4950 students will work on a research project, either by doing research in a lab or by doing reading research and completing specific readings under the supervision of a faculty advisor.
- Present the results of the research project in a poster or in a paper prepared in the form of a scientific journal article at a regional or national meeting, to a faculty panel that will consist of no fewer than three Physics Department faculty members, or in a physics seminar.

In order to receive departmental honors recognition, the student must be recommended by the director of undergraduate studies. Upon recommendation, the Office of the University Registrar will be notified that the candidate has earned departmental honors recognition. This acknowledgement will appear on the student's diploma as well as on the transcript.

Second Language Alternative (BS)

Students who elect an undergraduate program leading to the BS degree with a major in Physics have an option regarding the College of Arts and Science second language requirement. This requirement of 12 or 13 credits (depending on the language studied) may be satisfied alternatively by the substitution of an approved specialization. This consists of a minimum of 12 credits at the 2000 level or above and may not include courses normally required of all physics majors. It is to be selected from an area with special relevance to physics and to the student's own interests and future plans.

Students have selected options in aerospace engineering, atmospheric science/geophysical fluid dynamics, radiation biology, chemistry, computer science, electrical engineering (circuits or computer hardware option), geology, nuclear engineering, material science, math and other areas. The choice and planning of an option must be done under the direction of the departmental undergraduate advisor.

Dual Degrees and Double Majors

Students may wish to pursue two baccalaureate dual degrees simultaneously. For example, this might include a BS in Physics and a BS in Engineering, which is the most common choice. In order to receive two baccalaureate degrees, a student must complete all the specified requirements for both degrees.

Another degree option is a single baccalaureate degree with two majors (double majors), which may be developed with the concurrence of appropriate advisors in the two departments. A notation of the successful completion of the two areas appears on the student's transcript. Both departments must be in the College of Arts and Sciences. Double major options often chosen by a physics major are chemistry, mathematics or geology. Mathematics is a particularly viable double major because the extensive mathematics component normally required in the BS degree with a major in physics, if coupled with a specialization area chosen from mathematics, nearly completes the BS degree with a major in mathematics.

Students pursuing a Bachelor of Science in Secondary Education, emphasis in Physics, have the option of receiving a BS in physics degree by completing 33 credits in physics and 19 hours in math and chemistry.

Careful planning, started early in the academic career, is required to meet the conditions of dual majors or dual degrees. Students who complete such programs obtain the maximum from their undergraduate experience.

Graduate

- MS in Physics (https://catalog.missouri.edu/collegeofartsandscience/physics/ms-physics/)
- PhD in Physics (https://catalog.missouri.edu/collegeofartsandscience/physics/phd-physics/)

Director of Graduate Studies:
Prof. Suchi Guha (guhas@missouri.edu)
422 Physics Building
(573)-884-3687
https://physics.missouri.edu/graduate-program/

About Physics

At the University of Missouri, the physics degrees are offered by the Department of Physics and Astronomy. Because the Department has a moderate size, graduate students are better able to maintain a close relationship with the faculty. Our facilities include various laboratories within the Physics Building as well as the Research Reactor. In certain cases, a student's work may be carried out at National Laboratories or in collaboration with other science and engineering departments.

The largest research area is in experimental and theoretical condensed-matter physics. Other research programs in which thesis work may be accomplished are biological physics and astronomy/astrophysics. Graduates have been very successful in continuing their careers in industry, national laboratories and academics.

Research Resources

The Department of Physics and Astronomy offers many opportunities for scientific research in internationally recognized programs. The main focus of research is in the areas of theoretical and experimental condensed matter physics, biological physics, and astrophysics. These research efforts are fostered by the existence of the University of Missouri Research Reactor (MURR), a 10 MW light-water moderated reactor that is the highest-power university research reactor in the country. Furthermore, many research activities involve facilities at National Laboratories such as Argonne, Oak Ridge, and NIST.

Financial Aid from the Program

The department of Physics and Astronomy is committed to the success of its incoming graduate students and several financial aid packages are available to give maximum support to students so that they can pursue their academic work free from financial problems. Incoming students are usually assigned as teaching assistants (TA), and in some special cases as research assistant (RA).

More Details

For more details on the graduate program please consult the departmental web site: https://physics.missouri.edu/graduate-program/

PHYSCS 1002: Topics in Physics and Astronomy - Biological Science
Study of selected topics in physics and astronomy. Subjects and earnable credit may vary from semester to semester.

Credit Hour: 1-3

PHYSCS 1007: Topics in Physics and Astronomy - Physical Science
Study of selected topics in physics and astronomy. Subjects and earnable credit may vary from semester to semester.

Credit Hour: 1-3

PHYSCS 1050: Concepts in Cosmology
(same as ASTRON 1050). This course explores the development of our understanding of the origin and evolution of the Universe. We will embark on a qualitative description of the Big Bang theory, the expansion of the universe and its current structure, the cosmic microwave background radiation, the existence of dark matter and dark energy and their implications for the Universe's ultimate fate.

Credit Hours: 3
PHYSCS 1050 - MOTR ASTR 100: Astronomy

PHYSCS 1100: Science and Inventions
This course covers the history of some of the most important inventions in science and their impact on past civilizations, current advances in science and inventions, funding and policies, and critical advances in technology required for future generations.

Credit Hour: 1

PHYSCS 1150: Concepts in Physics
Introduction to fundamental concepts of physics for non-science majors. Concepts include the conservation of energy, the second law of thermodynamics, and the special theory of relativity. Students learn to reason and apply these concepts through writing assignments.

Credit Hours: 3
PHYSCS 1150 - MOTR PHYS 100: Essentials in Physics

PHYSCS 1200: Everyday Wonders: Explaining How Ordinary Things Work
How does an airplane fly? How does a steel boat float? How does your phone know when you are swiping the screen? Many things that seem wondrous can be explained using basic principles of physics. In this course students develop concepts in simple machines, fluids, waves, optics, and electricity as they explore real-world applications using simulations and hands-on experiments.

Credit Hours: 4

PHYSCS 1200H: Everyday Wonders: Explaining How Ordinary Things Work - Honors
How does an airplane fly? How does a steel boat float? How does your phone know when you are swiping the screen? Many things that seem wondrous can be explained using basic principles of physics. In this course students develop concepts in simple machines, fluids, waves, optics, and electricity as they explore real-world applications using simulations and hands-on experiments.

Credit Hours: 4
Prerequisites: Honors eligibility required

PHYSCS 1210: College Physics I
This introductory college physics course uses algebra and trigonometry in developing some of the fundamental concepts of classical physics. Topics covered are vectors, kinematics, dynamics, gravity, momentum, energy, rotational kinematics, rotational dynamics, fluids, simple harmonic motion, waves and sound, and thermodynamics. Three lectures, one discussion, one lab weekly.

Credit Hours: 4
Prerequisites: MATH 1100
PHYSCS 1210 - MOTR PHYS 150L: Physics I with Lab

PHYSCS 1220: College Physics II
This introductory second semester college physics course uses algebra and trigonometry in developing some of the fundamental concepts of classical physics. Topics covered include electricity and magnetism, optics, and modern physics. Three lectures, one discussion, one lab weekly.

Credit Hours: 4
Prerequisites: Grade of C- or better in PHYSCS 1210

PHYSCS 1220H: College Physics II - Honors
This introductory second semester college physics course uses algebra and trigonometry in developing some of the fundamental concepts of classical physics. Topics covered include electricity and magnetism, optics, and modern physics. Three lectures, one discussion, one lab weekly.

Credit Hours: 4
Prerequisites: Grade of C- or better in PHYSCS 1210. Honors eligibility required

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PHYSCS 2002: Topics in Physics and Astronomy- Biological Science
Study of selected topics in physics and astronomy. Subjects and earnable credit may vary from semester to semester. Course may be repeated for credit.

Credit Hour: 1-3
Prerequisites: MATH 1100

PHYSCS 2002H: Topics in Physics and Astronomy- Biological Science - Honors
Study of selected topics in physics and astronomy. Subjects and earnable credit may vary from semester to semester. Course may be repeated for credit.

Credit Hour: 1-3
Prerequisites: MATH 1100; Honors eligibility required

PHYSCS 2007: Topics in Physics and Astronomy- Physical Science
Study of selected topics in physics and astronomy. Subjects and earnable credit may vary from semester to semester. Course may be repeated for credit.

Credit Hour: 1-3
Prerequisites: MATH 1100

PHYSCS 2007H: Topics in Physics and Astronomy- Physical Science - Honors
Study of selected topics in physics and astronomy. Subjects and earnable credit may vary from semester to semester. Course may be repeated for credit.

Credit Hour: 1-3
Prerequisites: MATH 1100; Honors eligibility required

PHYSCS 2010: Undergraduate Seminar in Physics
Introduction to the Physics Department and presentation of topics of current interest in physics by faculty and students. Intended for physics majors at the freshman or sophomore level only.

Credit Hour: 1
Recommended: for physics majors

PHYSCS 2200: Life and the Universe
This course explores the connection between our everyday existence and the underlying physics' processes. Students will look at processes - essential to life - ranging from the very small (atomic level) to the very large (universe), and the many length scales in between (cellular level and human being level) as will as make connections between the laws of physics and the numbers that go into them and the prerequisites for the existence of life.

Credit Hours: 3

PHYSCS 2330: Exploring the Principles of Physics
A hands-on course covering topics in Electricity, Magnetism, Forces, Motion and Energy. Pedagogy reflects styles used in K-12 classrooms; emphasis on inquiry, concept development, quantitative applications and technology. Enrollment limited to Elementary and Early Childhood Education majors who have completed MATH 1100 or higher.

Credit Hours: 4
Prerequisites: instructor's consent required

PHYSCS 2500: The Beautiful Invisible: Exploring Physics, Fiction, and Reality
This course explores the conceptual structure of modern physics from a humanistic perspective. Rather than describing the natural world "as it is", physical science weaves some key observations in a convincing and memorable narrative. It is not within its power to explain reality, but it can make it understandable, sometimes even predictable. Due to the presence of internal and external constraints, physical theories are akin to myths, i.e., fiction created by many authors over an extended period of time. The mythical character of a theory does not diminish its scientific validity - quite the contrary. Convincing myths are not easily found and better observations demand better myths. The mythical content of the theory is not some extraneous content that we introduce for the sake of popularization, but an essential part of the science itself.

Credit Hours: 3

PHYSCS 2750: University Physics I
First course in calculus-based physics for science and engineering students. Topics covered are vectors, translational and rotational kinematics, translational and rotational dynamics, energy, momentum, gravity, oscillations, waves, fluids and thermodynamics. Three lectures, one discussion, one lab weekly.

Credit Hours: 5
Prerequisites: Grade of C- or better in MATH 1500 or equivalent
Recommended: MATH 1700
PHYSCS 2750 - MOTR PHYS 200L: Advanced Physics I with Lab

PHYSCS 2750H: University Physics I - Honors
First course in calculus-based physics for science and engineering students. Topics covered are vectors, translational and rotational kinematics, translational and rotational dynamics, energy, momentum, gravity, oscillations, waves, fluids and thermodynamics. Three lectures, one discussion, one lab weekly. Graded on A-F basis only.

Credit Hours: 5

Prerequisites: Grade of C- or better in MATH 1500 or equivalent. Honors eligibility required
Recommended: MATH 1700

PHYSCS 2760: University Physics II
Second semester course in calculus-based physics for science and engineering students. Topics covered are electrostatics, circuits, magnetism, electromagnetic phenomena, optics, electromagnetic waves and relativity. Three lectures, one discussion, one lab weekly.

Credit Hours: 5
Prerequisites: Grade of C- or better in MATH 1700 and PHYSCS 2750
Recommended: MATH 2300

PHYSCS 2760H: University Physics II - Honors
Second semester course in calculus-based physics for science and engineering students. Topics covered are electrostatics, circuits, magnetism, electromagnetic phenomena, optics, electromagnetic waves and relativity. Three lectures, one discussion, one lab weekly.

Credit Hours: 5
Prerequisites: Grade of C- or better in MATH 1700 and PHYSCS 2750. Honors Eligibility required
Recommended: MATH 2300

PHYSCS 2888: Exploring Research in Physics
Introductory research course in physics where students develop research skills under the guidance of a faculty member. Course appears on transcript for zero credit and does not count toward full-time enrollment. No tuition or fees are charged. Graded on S/U basis only.

Credit Hours: 0
Prerequisites: instructor's consent

PHYSCS 3002: Topics in Physics and Astronomy - Biological Science
Study of selected topics in physics and astronomy. Subjects and earnable credit may vary from semester to semester. May be repeated 3 times for credit.

Credit Hour: 1-3
Prerequisites: PHYSCS 1210 or PHYSCS 2750

PHYSCS 3007: Topics in Physics and Astronomy -Physical Science
Study of selected topics in physics and astronomy. Subjects and earnable credit may vary from semester to semester. May be repeated 3 times for credit.

Credit Hour: 1-3
Prerequisites: PHYSCS 1210 or PHYSCS 2750

PHYSCS 3010: Introduction to Modern Astrophysics
(same as ASTRON 3010). Elements of stellar, and galactic astrophysics. Interpretation of observations and physical conditions of various astronomical objects including stars, gaseous nubulea and, galaxies.

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 3100: Teaching Physics
Introduces modeling and inquiry methods of teaching about force, motion, energy, electricity and magnetism. Students learn research-base physics teaching methods, including eliciting prior understanding, facilitating conceptual change, and active learning strategies.

Credit Hours: 3
Prerequisites: PHYSCS 1220 or PHYSCS 2760

PHYSCS 3150: Introduction to Modern Physics
Relativistic kinematics and Lorentz transformations; historical basis for quantum mechanics; atomic structure; physics of solids; nuclear structure and decay.

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 3150W: Introduction to Modern Physics - Writing Intensive
Relativistic kinematics and Lorentz transformations; historical basis for quantum mechanics; atomic structure; physics of solids; nuclear structure and decay.

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 3200: Physics of Space Explorations
The course provides an overview of the solar system, spaceflight history, a review of Newtonian physics and law of universal gravitation, the application of these laws to spacecraft launch, entry, and orbit, planetary trajectories, and other special topics. Three focused case studies of actual space missions are addressed. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: MATH 1100

PHYSCS 3500: Physics of Energy in Technology
Physics principles as they relate to energy technology, how physics principles enable applications and provide constraints. Introduction to aspects of materials performance, thermodynamics, semiconductor physics and nuclear physics. These are in the context of energy production, power plants, engines, nuclear energy, hydroelectric, solar

and wind. Students gain appreciation of physics principles and their roles in technology of importance for society. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: PHYSCS 2750

PHYSCS 3700: Introduction to Methods in Mathematical Physics
The course discusses the application of mathematical techniques that students need for upper-level physics courses. Topics include: applications of complex variables, second-order linear differential equations with applications to AC circuits, matrices/linear algebra, calculus of variations, Fourier transforms and vector analysis.

Credit Hours: 3
Prerequisites: PHYSCS 2760 and MATH 2300

PHYSCS 3850: Introduction to Computational Physics
This course introduces modern computational techniques for solving a variety of problems in different areas of physics and astronomy. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: PHYSCS 2760
Recommended: MATH 2300

PHYSCS 4020: Astrophysical Techniques
(same as ASTRON 4020; cross-leveled with PHYSCS 7020, ASTRON 7020). Elements of modern astronomical instruments, observations and analysis, with the emphasis in the optical regime. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 4050: Electronic Laboratory
(cross-leveled with PHYSCS 7050). Acquaints students with the foundations and techniques of electronics design, with emphasis on data acquisition and processing. Topics: circuits with discrete and integrated circuits, active and passive filters, amplifiers, power supplies, instrumentation and interfacing. Integrated lectures and labs. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 4060: Advanced Physics Laboratory I
This upper-level undergraduate laboratory course familiarizes students with the methods and procedures of experimental physics at an advanced level. The course covers principles of magnetism, graphic programming and interface techniques, weak-signal detection, and some modern physics discoveries such as, magneto-optical Kerr effect, digital holography and gamma-ray spectroscopy. Students work on research projects in the areas of condensed matter physics, materials science, modern spectroscopy, superconductivity, and quantum physics.

Credit Hours: 4
Prerequisites: PHYSCS 3150
Recommended: physics/engineering majors

PHYSCS 4060W: Advanced Physics Laboratory I - Writing Intensive
This upper-level undergraduate laboratory course familiarizes students with the methods and procedures of experimental physics at an advanced level. The course covers principles of magnetism, graphic programming and interface techniques, weak-signal detection, and some modern physics discoveries such as, magneto-optical Kerr effect, digital holography and gamma-ray spectroscopy. Students work on research projects in the areas of condensed matter physics, materials science, modern spectroscopy, superconductivity, and quantum physics.

Credit Hours: 4
Prerequisites: PHYSCS 3150
Recommended: physics/engineering majors

PHYSCS 4080: Major Themes in Classical Physics
Introduction to classical physics: mechanics, electromagnetism and thermodynamics, emphasizing the unity and the connections between different parts of it.

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 4080W: Major Themes in Classical Physics - Writing Intensive
Introduction to classical physics: mechanics, electromagnetism and thermodynamics, emphasizing the unity and the connections between different parts of it.

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 4100: Electricity and Magnetism I
Mathematical preliminaries, properties of charge distributions at rest and in motion, the field concept, introduces electromagnetic radiation.

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 4102: Topics on Physics and Astronomy-Biological/ Physical/Mathematics
Organized study of selected topics. Subjects and earnable credit may vary from semester to semester. Departmental consent for repetition.

Credit Hour: 1-3
Prerequisites: PHYSCS 2760 or instructor's consent

PHYSCS 4110: Light and Modern Optics
(cross-leveled with PHYSCS 7110). Interaction of light with matter, spectroscopic techniques, wave optics, interferometry, multilayer films, polarization, non-linear optics, design of optical instruments, matrix methods, waveguides, fiber optics, acousto-optic and photo-elastic modulation. Includes both lectures and laboratory.

Credit Hours: 4
Prerequisites: PHYSCS 2760

PHYSCS 4120: Introduction to Thermodynamics and Statistical Physics
Development of the concepts of temperature, heat, work, entropy, enthalpy and free energy. Applications to gases, liquids and solids. Development of statistical mechanical methods to solve thermodynamic problems for physical systems.

Credit Hours: 3
Prerequisites: PHYSCS 2760 and MATH 2300

PHYSCS 4140: Mechanics
Development of fundamental concepts, principles of mechanics using mathematical methods. Many problems used.

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 4150: Laser and Quantum Optics
(cross-leveled with PHYSCS 7150). This course offers a comprehensive introduction to concepts and principles of laser and quantum optics. It covers key topics such as laser principle, advanced laser technology, the nature and statistics of photons, and the quantum mechanical framework underlying quantum optical phenomena. The course also provides a discussion on emerging areas such as quantum information and its applications. In addition to lectures, students will gain practical experience through hands-on experiments, allowing them to directly apply the concepts learned in the class. The integration of theory and practice ensures a well-rounded understanding of quantum optics, equipping students with the essential knowledge needed for further development. Graded on A-F basis only.

Credit Hours: 4
Prerequisites: PHYSCS 3150 or instructor's consent required

PHYSCS 4190: Physics and Chemistry of Materials
(same as NU_ENG 4319, BIOL_EN 4480, CHEM 4490, BME 4480; cross-leveled with PHYSCS 7190, NU_ENG 7319, BIOL_EN 7480, CHEM 7490). Physics and Chemistry of Materials is a 3 credit hours course offered every spring semester for students from Physics, Chemistry, Engineering and Medical Departments and consists of lectures, laboratory demonstrations, two mid-term and one final exam. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: PHYSCS 2750, CHEM 1320 or equivalent, or instructor's consent

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PHYSCS 4230: Electron Microscopy and Microanalysis
(cross-leveled with PHYSCS 7230). This course covers the basic principles of Scanning Electron Microscopy, Scanning/Transmission Electron Microscopy, and various spectroscopic characterization methods in electron microscopy. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: PHYSCS 3150 or instructor's consent

PHYSCS 4250: Stellar Astrophysics
(same as ASTRON 4250). Basic astrophysics of stable and unusual stars, stellar systems. Investigates stellar dimensions, radiation, spectra, energy, evolution, populations; interstellar medium, stellar motions and aggregation.

Credit Hours: 3
Prerequisites: ASTRON 3010

PHYSCS 4350: Galactic Astronomy
(same as ASTRON 4350; cross-leveled with ASTRON 7350). Observational properties of normal galaxies and clusters of galaxies, Seyfert and emission-line structure and dynamics of galaxies; interacting galaxies, quasi-steller objects. Introduction to cosmology.

Credit Hours: 3
Prerequisites: PHYSCS 2760
Recommended: PHYSCS 4140

PHYSCS 4360: Extragalactic Astronomy
(same as ASTRON 4360; cross-leveled with ASTRON 7360, PHYSCS 7360). This course introduces students to the most basic knowledge of extragalactic astronomy, starting from Milky Way and extending to the most distant universe. Topics covered will include galaxy morphology and classification, groups and clusters of galaxies, active galactic nuclei, and galaxy formation and evolution.

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 4390: Problems in Physics
Problems in Physics

Credit Hour: 1-3

PHYSCS 4400: The Physics of Electronic Devices
(cross-leveled with PHYSCS 7400). This course is designed for graduate and undergraduate students of Physics and Electrical Engineering who have an interest in learning the basic physical idea underlying the operation of electronic devices. The course consists of lectures, handout lecture notes, problem sets, two mid-term and one final exam. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: PHYSCS 3150 or equivalent

PHYSCS 4410: Analysis of Biological Macromolecules and Biomaterials
(cross-leveled with PHYSCS 7410). This interdisciplinary, team-taught course introduces basic concepts and experimental techniques for studying bio-macromolecules and biomaterials. A Problem Based Learn/ Writing Intensive approach uses four modules: Proteins, membranes, cellular interactions and biomaterials.

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 4420: Introduction to Biomedical Imaging
(same as BIOL_EN 4420, BME 4420; cross-leveled with PHYSCS 7420, BIOL_EN 7420). This course offers a broad introduction to medical imaging. Topics to be covered include the physics basics and instrumentation of X-ray, CT, PET, SPECT, ultrasound, MRI, and optical imaging, as well as recent developments in biomedical imagining.

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 4450: Introduction to Cosmology
(same as ASTRON 4450; cross-leveled with PHYSCS 7450, ASTRON 7450). Develops the physical concepts necessary for understanding the major recent discoveries in cosmology, such as the acceleration of the universe and dark energy. No prior knowledge of general relativity is assumed. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: PHYSCS 3150 or equivalent

PHYSCS 4460: Interstellar Medium
(same as ASTRON 4460; cross-leveled with ASTRON 7750, PHYSCS 7750). The course discusses observational properties and physical and chemical processes occurring in the interstellar medium. Topics include interstellar diffuse and molecular clouds, HII regions, dust grains, interstellar chemistry, star formation, supernova remnants, and interstellar shock waves.

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 4500: Computational Biological Physics
(cross-leveled with PHYSCS 7500). Provides a practical introduction (hands-on approach) to the study of the structure and function of biomolecular systems by employing computational methods and theoretical concepts familiar from the physical sciences.

Credit Hours: 3
Prerequisites: PHYSCS 2760 or instructor's consent

PHYSCS 4510: Single Molecule Biophysics
(same as BIOCHM 4510; Cross-leveled with PHYSCS 7510, BIOCHM 7510). The course provides an overview of the biophysics of enzymes, nucleic acids and the cytoskeleton. Topics covered will include diffusion, molecular motors, polymerization and the cytoskelton and the polymer properties of nucleic acids and microtubules

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 4520: Introduction to Biophysics
(cross-leveled with PHYSCS 7520). This course introduces the study of biological systems from the perspective of a physicist. Students will learn how to relate the structure of a particular system and its constituents to its function. The treatment of molecular and cellular phenomena will be based on physical principles quantified through the necessary analytical tools. Prominent biophysical methods and their fundamental operating principles will also be discussed. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: PHYSCS 1220 or PHYSCS 2760 or instructor's consent

PHYSCS 4550: Cosmochemistry
(same as ASTRON 4550; cross-leveled with ASTRON 7550, PHYSCS 7550). Cosmic dust, stardust, spectra, energy, interstellar medium, meteorites, astromineralogy.

Credit Hours: 3
Prerequisites: ASTRON 3010

PHYSCS 4600: Semiconductor Optics
(cross-leveled with PHYSCS 7600). It is an introductory-level course in the field of optical processes in semiconductors (both inorganic and organic) and solid-state optoelectronics, designed both for graduate and undergraduate students of Physics, Chemistry and Electrical Engineering. Graded on A-F basis only.

Credit Hours: 3

Prerequisites: PHYSCS 3150

PHYSCS 4620: Introduction to Materials Science
This course on the science and technology of materials explores the interrelationship between processing, structure, properties (electrical, optical, magnetic), and performance. Observable properties of materials will be used to explore and understand the consequences of atomic- and molecular-level events. Structure-property correlations, including electronic, thermal, and mechanical properties, will be presented for different classes of materials including nanoscale materials. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: PHYSCS 3150

PHYSCS 4650: Modern Condensed Matter Physics
(cross-leveled with PHYSCS 7650). Introduces the basic concepts and gives an overview of the latest developments of modern condensed-matter physics as the forefront of (nano) science and technology. Combines lectures and computational laboratory, where students use and develop interactive computer simulations. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: PHYSCS 3150 or instructor's consent

PHYSCS 4680: Introduction to Density-Functional Theory
(cross-leveled with PHYSCS 7680). This course provides an introduction to density-functional theory (DFT), the most widely used technique for calculating the electronic structure of materials. The course covers the basic formalism of DFT and practical applications, including hands-on computational exercises. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: PHYSCS 3150 or instructor's consent

PHYSCS 4720: Nonlinear Dynamics
(cross-leveled with PHYSCS 7720). This course provides an introduction to nonlinear dynamical systems and chaos, with examples from physics, chemistry, biology and engineering. The emphasis will be on applications, using a combination of analytical, computational and intuitive geometrical methods. Topics covered include phase portraits, fixed point analysis, bifurcations, limit cycles, strange-attractors, iterated maps, period doubling, chaos, fractals, scaling and universality. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: MATH 4100 or instructor's consent
Recommended: MATH 4140

PHYSCS 4740: Quantum Computation and Quantum Information
This course introduces the main ideas and techniques of quantum computation - a fascinating and rapidly developing field of research. The course explains how the strange and counter-intuitive features of quantum mechanics can be harnessed to perform tasks that would be extremely time-consuming, or even impossible, if approached by classical means.

Credit Hours: 3
Prerequisites: PHYSCS 3150 or PHYSCS 3150W, MATH 4140, or instructor's consent

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PHYSCS 4800: Introduction to Quantum Mechanics I
Foundations of wave mechanics; wave packets; Schrodinger equation and I-D problems; operators and eigenfunctions, spherically symmetric systems.

Credit Hours: 3
Prerequisites: PHYSCS 3150 and MATH 4100

PHYSCS 4810: Introduction to Quantum Mechanics II
Review of quantum mechanics and units, forms of radiation, radiation detectors, spacetime symmetries, internal symmetries, nuclear structure and form factors, low-energy nuclear models, recent developments.

Credit Hours: 3
Prerequisites: PHYSCS 4800 or equivalent

PHYSCS 4850: Computational Methods in Physics
(cross-leveled with PHYSCS 7850). Use of modern computational techniques in solving a wide variety of problems in solid state, nuclear, quantum and statistical physics.

Credit Hours: 3
Prerequisites: PHYSCS 4800 or instructor's consent

PHYSCS 4888: Research in Physics
Research conducted in the field of physics under the mentorship of a faculty member. Course appears on transcript for zero credit and does not count toward full-time enrollment. No tuition or fees are charged. Graded on S/U basis only.

Credit Hours: 0
Prerequisites: instructor's consent
Recommended: PHYSCS 2760

PHYSCS 4940: Physics Internship
This internship course will provide students with work experience in a public/private company/lab organization that is relevant to the physics major. It will enable students to apply their academic knowledge and critical thinking skills in a work environment, while enhancing personal

and professional development. The internship is coordinated by a faculty member. Graded on S/U basis only.

Credit Hour: 0-3
Prerequisites: Instructor's Consent

PHYSCS 4950: Undergraduate Research in Physics
Special studies for advanced undergraduate students in physics covering subjects not included in courses regularly offered. Departmental consent for repetition.

Credit Hour: 1-3
Prerequisites: instructor's consent

PHYSCS 4960: Senior Thesis in Physics
Special studies for senior undergraduate students in physics. The course requires an oral or poster presentations, or faculty-guided writing of a senior thesis involving independent research.

Credit Hours: 3
Prerequisites: instructor's consent and 3 units of PHYSCS 4950. Departmental consent required for repetition

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PHYSCS 4985: Issues in Modern Physics and Engineering
Students are expected to write a major paper on a selected topic from modern physics or engineering. The paper will review the current state of the experimental and theoretical research on the topic at a level appropriate to their peers.

Credit Hours: 3
Prerequisites: PHYSCS 3150

PHYSCS 7020: Astrophysical Techniques
(same as ASTRON 7020; cross-leveled with PHYSCS 4020, ASTRON 4020). Elements of modern astronomical instruments, observations and analysis, with the emphasis in the optical regime. Graded on A-F basis only. .

Credit Hours: 3

PHYSCS 7050: Electronic Laboratory
(cross-leveled with PHYSCS 4050). Acquaints students with the foundations and techniques of electronics design, with emphasis on data acquisition and processing. Topics: circuits with discrete and integrated circuits, active and passive filters, amplifiers, power supplies, instrumentation and interfacing. Integrated lectures and labs. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 7085: Problems in Physics
Laboratory work involving study of literature of special experiments in physics. Introduces research methods.

Credit Hour: 1-99

PHYSCS 7110: Light and Modern Optics
(cross-leveled with PHYSCS 4110). Interaction of light with matter, spectroscopic techniques, wave optics, interferometry, multilayer films, polarization, non-linear optics, design of optical instruments, matrix methods, waveguides, fiber optics, acousto-optic and photo-elastic modulation. Includes both lectures and laboratory.

Credit Hours: 4
Prerequisites: PHYSCS 2760

PHYSCS 7150: Laser and Quantum Optics
(cross-leveled with PHYSCS 4150). This course offers a comprehensive introduction to concepts and principles of laser and quantum optics. It covers key topics such as laser principle, advanced laser technology, the nature and statistics of photons, and the quantum mechanical framework underlying quantum optical phenomena. The course also provides a discussion on emerging areas such as quantum information and its applications. In addition to lectures, students will gain practical experience through hands-on experiments, allowing them to directly apply the concepts learned in the class. The integration of theory and practice ensures a well-rounded understanding of quantum optics, equipping students with the essential knowledge needed for further development. Graded on A-F basis only.

Credit Hours: 4

PHYSCS 7180: Solar System Science
(same as GEOL 7180, ASTRON 7180; cross-leveled with GEOL 4180, ASTRON 4180, PHYSCS 4180). Investigates physical states, interior structures and comparative geology of solar systems bodies: planets, moons, asteroids, comets, sun. Solar system formation and evolution.

Credit Hours: 3
Prerequisites: PHYSCS 1220 or PHYSCS 2760 or instructor's consent

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PHYSCS 7190: Physics and Chemistry of Materials
(same as NU_ENG 7319, BIOL_EN 7480, CHEM 7490; cross-leveled with PHYSCS 4190, NU_ENG 4319, BIOL_EN 4480, CHEM 4490, BME 4480). Physics and Chemistry of Materials is a 3 credit hours course offered every spring semester for students from Physics, Chemistry, Engineering and Medical Departments and consists of lectures, laboratory demonstrations, two mid-term and one final exam. Graded on A-F basis only.

Credit Hours: 3

Prerequisites: PHYSCS 2750, CHEM 1320 or equivalent, or instructor's consent

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PHYSCS 7201: Topics in Physics
Organized study of selected topics. Subjects and earnable credit may vary from semester to semester

Credit Hour: 1-3
Prerequisites: Instructor's consent required

PHYSCS 7230: Electron Microscopy and Microanalysis
(cross-leveled with PHYSCS 4230). This course covers the basic principles of Scanning Electron Microscopy, Scanning/Transmission Electron Microscopy, and various spectroscopic characterization methods in electron microscopy. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: PHYSCS 3150 or instructor's consent

PHYSCS 7301: Topics in Astronomy and Astrophysics
Selected topics from solar system, stellar, galactic and extragalactic astronomy, and astrophysics. May be repeated for credit. Graded on A-F basis only.

Credit Hours: 3

PHYSCS 7360: Extragalactic Astronomy
(same as ASTRON 7360; cross-leveled with PHYSCS 4360, ASTRON 4360). This course introduces students to the most basic knowledge of extragalactic astronomy, starting from Milky Way and extending to the most distant universe. Topics covered will include galaxy morphology and classification, groups and clusters of galaxies, active galactic nuclei, and galaxy formation and evolution.

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 7400: Physics of Electronic Devices
(cross-leveled with PHYSCS 4400). This course is designed for graduate students of Physics and Electrical Engineering who have an interest in learning the basic physical idea underlying the operation of electronic devices. The course consists of lectures, handout lecture notes, problem sets, two mid-term and one final exam.

Credit Hours: 3
Prerequisites: PHYSCS 3150 or equivalent

PHYSCS 7410: Analysis of Biological Macromolecules and Biomaterials
(cross-leveled with PHYSCS 4410). This interdisciplinary, team-taught course introduces basic concepts and experimental techniques for studying bio-macromolecules and biomaterials. A Problem Based Learn/ Writing Intensive approach uses four modules: proteins, membranes, cellular interactions and biomaterials.

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 7420: Introduction to Biomedical Imaging
(same as BIOL_EN 7420; crossleveled with PHYSCS 4420, BIOL_EN 4420, BME 4420). This course offers a broad introduction to medical imaging. Topics to be covered include the physics basics and instrumentation of X-ray CT, PET, SPECT, ultrasound, MRI, and optical imaging, as well as recent developments in biomedical imaging.

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 7450: Introduction to Cosmology
(same as ASTRON 7450; cross-leveled with ASTRON 7450, PHYSCS 4450). Develops the physical concepts necessary for understanding the major recent discoveries in cosmology, such as the acceleration of the universe and dark energy. No prior knowledge of general relativity is assumed. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: PHYSCS 3150 or equivalent or instructor's consent

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PHYSCS 7500: Computational Biological Physics
(cross-leveled with PHYSCS 4500). Provides a practical introduction (hands-on approach) to the study of the structure and function of biomolecular systems by employing computational methods and theoretical concepts familiar from the physical sciences.

Credit Hours: 3
Prerequisites: PHYSCS 1220 or PHYSCS 2760 or instructor's consent

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PHYSCS 7510: Single Molecule Biophysics
(same as BIOCHM 7510; cross-leveled with PHYSCS 4510, BIOCHM 4510). The course provides an overview of the biophysics of enzymes, nucleic acids and the cytoskeleton. Topics covered will include diffusion, molecular motors, polymerization of the cytoskelton and the polymer properties of nucleic acids and microtubules

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 7520: Introduction to Biophysics
(cross-leveled with PHYSCS 4520). This course introduces the study of biological systems from the perspective of a physicist. Students will learn how to relate the structure of a particular system and its constituents to its function. The treatment of molecular and cellular phenomena will be based on physical principles quantified through the necessary analytical tools. Prominent biophysical methods and their fundamental operating principles will also be discussed. Graded on A-F basis only.

Credit Hours: 3

PHYSCS 7550: Cosmochemistry
(same as ASTRON 7550; cross-leveled with PHYSCS 4550, ASTRON 4550). Cosmic dust, stardust, spectra, energy, interstellar medium, meteorites, astromineralogy.

Credit Hours: 3
Prerequisites: ASTRON 3010

PHYSCS 7600: Semiconductor Optics
(cross-leveled with PHYSCS 4600). It is an introductory-level course in the field of optical processes in semiconductors (both inorganic and organic) and solid-state optoelectronics, designed both for graduate and undergraduate students of Physics, Chemistry and Electrical Engineering.

Credit Hours: 3
Prerequisites: PHYSCS 3150 or instructor's consent

PHYSCS 7650: Modern Condensed Matter Physics
(cross-leveled with PHYSCS 4650). Introduces the basic concepts and gives an overview of the latest developments of modern condensed matter physics as the forefront of (nano) science and technology. Combines lectures and computational laboratory, where students use and develop interactive computer simulations. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: PHYSCS 3150 or instructor's consent

PHYSCS 7680: Introduction to Density-Functional Theory
(cross-leveled with PHYSCS 4680). This course provides an introduction to density-functional theory (DFT), the most widely used technique for calculating the electronic structure of materials. The course covers the basic formalism of DFT and practical applications, including hands-on computational exercises. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: PHYSCS 3150 or instructor's consent

PHYSCS 7720: Nonlinear Dynamics
(cross-leveled with PHYSCS 4720). This course provides an introduction to nonlinear dynamical systems and chaos, with examples from physics, chemistry, biology and engineering. The emphasis will be on applications, using a combination of analytical, computational and intuitive geometrical methods. Topics covered include phase portraits, fixed point analysis, bifurcations, limit cycles, strange-attractors, iterated maps, period doubling, chaos, fractals, scaling and universality. Graded on A-F basis only.

Credit Hours: 3

PHYSCS 7750: Interstellar Medium
(same as ASTRON 7750; cross-leveled with ASTRON 4460, PHYSCS 7750). The course discusses observational properties and physical and chemical processes occurring in the interstellar medium. Topics include interstellar diffuse and molecular clouds, HII regions, dust grains, interstellar chemistry, star formation, supernova remnants, and interstellar shock waves.

Credit Hours: 3
Prerequisites: PHYSCS 2760

PHYSCS 7850: Computational Methods in Physics
(cross-leveled with PHYSCS 4850). Use of modern computational techniques in solving a wide variety of problems in solid state, nuclear, quantum and statistical physics.

Credit Hours: 3
Prerequisites: PHYSCS 4800 or instructor's consent

PHYSCS 8040: Study of Techniques of Teaching College Physics
Objectives, methods and problems related to teaching college physics. Some credit in this course is required for all students teaching physics. May repeat for 3 hours maximum.

Credit Hour: 1-3

PHYSCS 8090: Research in Physics
Graduate research. Graded on S/U Basis only.

Credit Hour: 1-99

PHYSCS 8101: Topics of Physics and Astronomy
Organized study of selected topics. Subjects and earnable credit may vary from semester to semester.

Credit Hour: 1-3
Prerequisites: instructor's consent. Departmental consent for repetition

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PHYSCS 8140: Introduction to Materials Science and Engineering
This course covers an overview of materials science and engineering topics for doctoral students. Concepts will include structure of materials, thermodynamics, kinetics, and quantum mechanics. Graded on A-F basis only.

Credit Hours: 3

PHYSCS 8150: Condensed Matter Physics I
Crystal structure, reciprocal lattice, phonons, neutron and x-ray scattering, free electron theory of metals, Fermi surfaces, energy bands, static properties of solids, semiconductors, devices, and quantum structures, optical properties, excitons, introduction to magnetism and superconductivity.

Credit Hours: 3
Prerequisites: PHYSCS 4800 or equivalent

PHYSCS 8160: Condensed Matter Physics II
The basic Hamiltonian, Phonons, theory of the electron gas, second quantization, Hartree and Hartree-Fock approximation, local-density method, tight-binding theory, electron-electron interaction and screening, Fermi liquid theory, transport properties, impurities, Green's function's, Localization, Quantum Hall effect, magnetism, superconductivity.

Credit Hours: 3
Prerequisites: PHYSCS 8150

PHYSCS 8170: Structure, Electronic Structure and Properties of Condensed Matter
This course covers the connections between the properties of matter and their atomic and electronic properties, especially by understanding macroscopic behaviors of condensed matter, such as magnetic ordering, vibrational properties, structural phase transitions, transport, optical properties and superconductivity. Graded on A-F basis only.

Credit Hours: 3
Recommended: PHYSCS 8150

PHYSCS 8180: Topological Phenomena in Condensed Matter Physics
Introduction to the rapidly growing field of topological physics in condensed matter systems. The course will present essential mathematical tools such as group theory and topology, and discuss a broad spectrum of newly-discovered topological phenomena including topological insulators, topological superconductivity, topological photonics and topological phononics. Graded on A-F basis only.

Credit Hours: 3
Recommended: a course in Quantum Mechanics

PHYSCS 8220: Applied Machine Learning in Physics
This course introduces students to the fundamental concepts, tools, and techniques used in machine learning as applied to problems in physics. The course is divided into two phases: an instructional phase focused on learning core tools and algorithms in modern machine learning, followed by a project phase where students apply their knowledge in small groups to a real-world physics problem. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: Introductory programming experience or instructor's consent required

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PHYSCS 8301: Topics in Astronomy and Astrophysics
Selected topics from solar system, stellar, galactic and extragalactic astronomy and astrophysics. May be repeated to a maximum of six hours.

Credit Hours: 3
Prerequisites: instructor's consent

PHYSCS 8310: College Science Teaching
(same as ASTRON 8310, BIO_SC 8724, LTC 8724). Study of learner characteristics, teaching strategies, and research findings related to teaching science at the post-secondary level.

Credit Hours: 3

PHYSCS 8350: Science Outreach: Public Understanding of Science
(same as LTC 8725, AN_SCI 8725) This course is aimed at promoting public understanding and appreciation of science. The students will develop presentations that increase awareness of the impact of science on many aspects of our daily lives.

Credit Hour: 1-2

PHYSCS 8410: Concepts in Nanoscale Materials: Interdisciplinary Science
This interdisciplinary course covers basic concepts in nanoscale materials, their characterization, and how and why they differ from conventional bulk materials. The course focuses on neutron scattering methods and uses lectures, problem-based modules, and writing assignments.

Credit Hours: 3
Prerequisites: PHYSCS 3150 and instructor's consent

PHYSCS 8420: X-ray and Neutron Scattering Methods for Studying Surfaces/Interfaces of Nanocrystalline Materials
This course develops the conceptual foundation of neutron and x-ray scattering methods for probing the structure of epitaxial films, nanomaterials and their buried interfaces. A particular emphasis is given

to the use of intense synchrotron x-ray radiation. Course graded on A-F basis only.

Credit Hours: 3

PHYSCS 8550: Stellar Structure and Evolution
(same as ASTRON 8550). Reviews of atomic and molecular spectra. Investigates quantum radiation law, emission and absorption processes, radiation transfer theory, continuous and discrete line spectra of stars, stellar composition.

Credit Hours: 3
Prerequisites: PHYSCS 4250, PHYSCS 4800, or instructor's consent

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PHYSCS 8610: Classical Mechanics
The interplay of dynamics and symmetry, Hamilton's principle and Noether's theorem, Lagrangian, Hamiltonian, Hamilton-Jacobi theories of mechanics in special relativity. Rigid body motion, small oscillation, canonical transformations and fields as continuous mechanical systems.

Credit Hours: 3
Prerequisites: PHYSCS 4140 or equivalent

PHYSCS 8620: Electrodynamics I
Electrostatic potential and fields, boundary-value problems in electrostatics, methods of images, Green's functions, multipole expansion, dielectrics, magnetostatics, magnetic materials, Maxwell's' equations, time-varying fields.

Credit Hours: 3
Prerequisites: PHYSCS 8610 or instructor's consent

PHYSCS 8640: Electrodynamics II
Electromagnetic wave propagation, reflection, refraction, wave guides, cavities antennas and diffraction, tensors, special relativity, the Lorentz group, dynamics of relativistic particles and fields radiation by moving charges, retardation, bremsstrahlung. Additional topics may include magnetohydrodynamics and plasma physics.

Credit Hours: 3
Prerequisites: PHYSCS 8620 or instructor's consent

PHYSCS 8660: Methods in Mathematical Physics
Concentrates on mathematical techniques used in modern physics. Infinite series, functions of a complex variable, differential equations, Fourier series and integral, etc.

Credit Hours: 3
Prerequisites: PHYSCS 4700 or instructor's consent

PHYSCS 8680: Thermodynamics and Statistical Mechanics
Thermodynamics as applied in physics, chemistry; laws of distribution; statistical methods of study matter, radiation.

Credit Hours: 3
Prerequisites: PHYSCS 8710 or concurrently

PHYSCS 8700: Non-Equilibrium Statistical Mechanics
This course provides an introduction to the theoretical and mathematical description of classical stochastic systems with examples from biophysics and condensed matter physics.

Credit Hours: 3
Prerequisites: PHYSCS 8680 or consent of instructor

PHYSCS 8710: Quantum Mechanics I
Non-relativistic quantum theory in Hilbert space. States and self-adjoint observables, unitary time evolution in various pictures, the path-integral, identical particles, Fock space, angular momentum and some pertubation theory.

Credit Hours: 3
Prerequisites: PHYSCS 8610

PHYSCS 8720: Quantum Mechanics II
More perturbation theory, variational methods, semi-classical methods and application to radiation theory, linear response theory and rudiments of relativistic quantum mechanics including the Klein-Gordan equation and the Dirac equation.

Credit Hours: 3
Prerequisites: PHYSCS 8710

PHYSCS 8801: Topics in Solid State Theory
Selected topics in solid-state theory, including various elementary excitations in solids and their interactions. May be elected more than once.

Credit Hours: 3
Prerequisites: instructor's consent

PHYSCS 8820: Relativity and Gravitation
Special and general theories of relativity. Discussion of accelerated observers and the principles of equivalence. Einstein's gravitational field equations, black holes, gravitational waves and cosmology.

Credit Hours: 3
Prerequisites: PHYSCS 8610, PHYSCS 8620

PHYSCS 9090: Research in Physics
Research leading to Ph.D. dissertation. Graded on a S/U basis only.

Credit Hour: 1-99
Prerequisites: PhD candidacy has been established