

Department of Physics and Astronomy

The degree programs offered by the Department of Physics and Astronomy reflect its policy of offering the opportunity for a comprehensive education of the highest quality, individualized to the needs and interests of the students. Completion of a Bachelor's degree in Physics allows students entry into one of the highly specialized areas in science and technology, and the ability to apply for positions in industry and government, as well as entry into professional and graduate schools.

- B.S. degree in Physics (p. 1)
- B.A. degree in Physics (p. 3)

Bachelor of Science Degree in Physics

The Bachelor of Science (B.S.) degree in Physics provides opportunities for preparation for careers in industry and governmental agencies and for graduate study in physics or related fields.

The minimum number of semester credit hours required for this degree, including the Core Curriculum requirements, is 120. At least 39 of the total semester credit hours required for the degree must be at the upper-division level. All major and support work courses (including math, chemistry and computer science courses) must be completed with a grade of "C-" or better.

All candidates seeking this degree must fulfill the Core Curriculum requirements and the degree requirements, which are listed below.

Core Curriculum Requirements (42 semester credit hours)

Students seeking the B.S. degree in Physics must fulfill University Core Curriculum requirements in the same manner as other students. The courses listed below satisfy both major requirements and Core Curriculum requirements; however, if these courses are taken to satisfy both requirements, then students may need to take additional courses in order to meet the minimum number of semester credit hours required for this degree.

MAT 1214 may be used to satisfy the core requirement in Mathematics as well as a major requirement. PHY 1943 and PHY 1963 may be used to satisfy the core requirement in Life and Physical Sciences as well as major requirements.

Core Curriculum Component Area Requirements (<http://catalog.utsa.edu/undergraduate/bachelorsdegreeregulations/degrequirements/corecurriculumcomponentarearequirements>)

First Year Experience Requirement	3
Communication	6
Mathematics	3
Life and Physical Sciences	6
Language, Philosophy and Culture	3
Creative Arts	3
American History	6
Government-Political Science	6
Social and Behavioral Sciences	3

Component Area Option	3
Total Credit Hours	42

Gateway Courses

Students pursuing the B.S. degree in Physics must successfully complete each of the following Gateway Courses with a grade of "C-" or better in no more than two attempts. A student who is unable to successfully complete these courses within two attempts, including dropping a course with a grade of "W" or taking an equivalent course at another institution, will be required to change his or her major.

PHY 2103 & PHY 2111	Modern Physics and Modern Physics Laboratory
PHY 2823	Mathematical Physics I
PHY 3203	Classical Mechanics I

Degree Requirements

A. Physics and Astronomy courses

1. Required courses completed with a grade of "C-" or better:		
PHY 1943 & PHY 1951	Physics for Scientists and Engineers I and Physics for Scientists and Engineers I Laboratory	4
PHY 1963 & PHY 1971	Physics for Scientists and Engineers II and Physics for Scientists and Engineers II Laboratory	4
PHY 2103 & PHY 2111	Modern Physics and Modern Physics Laboratory	4
PHY 2823	Mathematical Physics I	3
PHY 3203	Classical Mechanics I	3
PHY 3293	Thermal Physics	3
PHY 3343	Physics Research Laboratory	3
PHY 3423	Electricity and Magnetism	3
PHY 3443	Modern Optics	3
PHY 3513	Electrodynamics	3
PHY 3583	Mathematical Physics II	3
PHY 4263	Quantum Mechanics I	3
PHY 4423	Quantum Mechanics II	3
PHY 4983	Unifying Concepts in Physics	3
2. 9 additional approved semester credit hours selected from the following (a maximum of 6 hours from either PHY 4911-3 or PHY 4953 may apply to this requirement):		9
AST 3013	Fundamentals of Astronomy	
AST 3023	Introduction to Astrophysics	
PHY 3143	Introduction to Computational Physics	
PHY 3313	Materials Physics	
PHY 3453	Lasers: Theory and Applications	
PHY 3603	Cosmology	
PHY 4013	Relativity: Special and General	
PHY 4203	Classical Mechanics II	
PHY 4563	Biophotonics	
PHY 4603	Crystallography and Materials Characterization	
PHY 4623	Nanotechnology	
PHY 4653	Introduction to Micro and Nanotechnology	
PHY 4703	Renewable Energy: Solar Energy Convertors	
PHY 4833	Molecular Biophysics	

PHY 4843	Condensed Matter Theory	
PHY 4911	Independent Study	
PHY 4953	Special Studies in Physics	
PHY 4993	Honors Research	

B. Required courses in the College of Sciences

1. Required courses (excluding physics):

CHE 1103	General Chemistry I	3
CHE 1113	General Chemistry II	3
CHE 1121	General Chemistry I Laboratory	1
CS 1063	Introduction to Computer Programming I	3
or CS 1173	Data Analysis and Visualization	
or CS 2073	Computer Programming with Engineering Applications	
MAT 1214	Calculus I	4
MAT 1224	Calculus II	4
MAT 2214	Calculus III	4
MAT 2233	Linear Algebra	3
MAT 3613	Differential Equations I	3

2. Additional approved courses in the College of Sciences. 5

Total Credit Hours 87

Course Sequence Guide for B.S. Degree in Physics

This course sequence guide is designed to assist students in completing their UTSA undergraduate Physics degree requirements. *This is merely a guide and students must satisfy other requirements of this catalog and meet with their academic advisor for individualized degree plans.* Progress within this guide depends upon such factors as course availability, individual student academic preparation, student time management, work obligations, and individual financial considerations. Students may choose to take courses during Summer terms to reduce course loads during long semesters.

B.S. in Physics – Recommended Four-Year Academic Plan

First Year

Fall		Credit Hours
AIS 1203	Academic Inquiry and Scholarship (core)	3
CHE 1103 or CHE 1143	General Chemistry I or Principles of Chemistry I	3
CHE 1121	General Chemistry I Laboratory ¹	1
CS 1063 or CS 1173 or CS 2073	Introduction to Computer Programming I or Data Analysis and Visualization or Computer Programming with Engineering Applications	3
MAT 1214	Calculus I (core and major)	4
WRC 1013	Freshman Composition I (Q) (core)	3
Credit Hours		17

Spring

CHE 1113 or CHE 1153	General Chemistry II or Principles of Chemistry II	3
MAT 1224	Calculus II	4

PHY 1943	Physics for Scientists and Engineers I (core and major)	3
PHY 1951	Physics for Scientists and Engineers I Laboratory	1
WRC 1023	Freshman Composition II (Q) (core)	3
Credit Hours		14

Second Year

Fall

MAT 2214	Calculus III	4
MAT 2233	Linear Algebra	3
PHY 1963	Physics for Scientists and Engineers II (core and major)	3
PHY 1971	Physics for Scientists and Engineers II Laboratory	1
POL 1013	Introduction to American Politics (core)	3
Credit Hours		14

Spring

MAT 3613	Differential Equations I	3
PHY 2103	Modern Physics	3
PHY 2111	Modern Physics Laboratory	1
PHY 2823	Mathematical Physics I	3
PHY 3203	Classical Mechanics I	3
American History core		3
Credit Hours		16

Third Year

Fall

PHY 3293	Thermal Physics	3
PHY 3423	Electricity and Magnetism	3
PHY 3443	Modern Optics	3
PHY 3583	Mathematical Physics II	3
POL 1133 or POL 1213	Texas Politics and Society (core) or Civil Rights in Texas and America	3
Credit Hours		15

Spring

PHY 3343	Physics Research Laboratory	3
PHY 3513	Electrodynamics	3
PHY 4263	Quantum Mechanics I	3
Language, Philosophy & Culture core		3
Social & Behavioral Sciences core		3
Credit Hours		15

Fourth Year

Fall

PHY 4423	Quantum Mechanics II	3
College of Sciences elective		3
Upper-division AST or PHY elective ²		3
Upper-division AST or PHY elective ²		3
American History core		3
Credit Hours		15

Spring

PHY 4983	Unifying Concepts in Physics	3
College of Sciences elective		2

Upper-division AST or PHY elective ²	3
Creative Arts core	3
Component Area Option core	3
Credit Hours	14
Total Credit Hours	120

¹ This laboratory course includes a lecture component as indicated on the University Schedule of Classes.

² From section A.2. of degree requirements.

Note: Some courses are only offered once a year; Fall or Spring. Check with the Department of Physics and Astronomy for scheduling of courses.

Bachelor of Arts Degree in Physics

The Bachelor of Arts (B.A.) degree in Physics provides opportunities for careers in several professional fields. It is not recommended for students planning to pursue graduate studies in physics or related fields.

The minimum number of semester credit hours required for this degree, including the Core Curriculum requirements, is 120. Thirty-nine of the total semester credit hours required for the degree must be at the upper-division level.

All majors in physics are required to complete all required and elective physics courses with a grade of "C-" or better.

All candidates seeking this degree must fulfill the Core Curriculum requirements and the degree requirements, which are listed below.

Core Curriculum Requirements (42 semester credit hours)

Students seeking the B.A. degree in Physics must fulfill University Core Curriculum requirements in the same manner as other students. The courses listed below satisfy both degree requirements and Core Curriculum requirements; however, if these courses are taken to satisfy both requirements, then students may need to take additional courses in order to meet the minimum number of semester credit hours required for this degree.

MAT 1214 may be used to satisfy the core requirement in Mathematics as well as a major requirement. PHY 1943 and PHY 1963 may be used to satisfy the core requirement in Life and Physical Sciences as well as major requirements.

Core Curriculum Component Area Requirements (<http://catalog.utsa.edu/undergraduate/bachelorsdegreeregulations/degerequirements/corecurriculumcomponentarearequirements>)

First Year Experience Requirement	3
Communication	6
Mathematics	3
Life and Physical Sciences	6
Language, Philosophy and Culture	3
Creative Arts	3
American History	6
Government-Political Science	6
Social and Behavioral Sciences	3
Component Area Option	3
Total Credit Hours	42

Gateway Courses

Students pursuing the B.A. degree in Physics must successfully complete each of the following Gateway Courses with a grade of "C-" or better in no more than two attempts. A student who is unable to successfully complete these courses within two attempts, including dropping a course with a grade of "W" or taking an equivalent course at another institution, will be required to change his or her major.

PHY 2103 & PHY 2111	Modern Physics and Modern Physics Laboratory
PHY 2823	Mathematical Physics I
PHY 3203	Classical Mechanics I

Degree Requirements

A. Physics and Astronomy courses

1. Required courses completed with a grade of "C-" or better:

PHY 1943 & PHY 1951	Physics for Scientists and Engineers I and Physics for Scientists and Engineers I Laboratory	4
PHY 1963 & PHY 1971	Physics for Scientists and Engineers II and Physics for Scientists and Engineers II Laboratory	4
PHY 2103 & PHY 2111	Modern Physics and Modern Physics Laboratory	4
PHY 2823	Mathematical Physics I	3
PHY 3203	Classical Mechanics I	3
PHY 3293	Thermal Physics	3
PHY 3343	Physics Research Laboratory	3
PHY 3423	Electricity and Magnetism	3

2. Select two additional courses from the following: 6

AST 3013	Fundamentals of Astronomy	
AST 3023	Introduction to Astrophysics	
PHY 3143	Introduction to Computational Physics	
PHY 3313	Materials Physics	
PHY 3443	Modern Optics	
PHY 3603	Cosmology	
PHY 4013	Relativity: Special and General	
PHY 4263	Quantum Mechanics I	
PHY 4843	Condensed Matter Theory	

B. Required courses in the College of Sciences

1. Required courses (excluding physics):

CHE 1103	General Chemistry I	3
CHE 1113	General Chemistry II	3
CHE 1121	General Chemistry I Laboratory	1
CS 1063	Introduction to Computer Programming I	3
or CS 1173	Data Analysis and Visualization	
or CS 2073	Computer Programming with Engineering Applications	
MAT 1214	Calculus I	4
MAT 1224	Calculus II	4
MAT 2214	Calculus III	4

2. Additional approved courses from the College of Sciences. 32

Total Credit Hours	87
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Course Sequence Guide for B.A. Degree in Physics

This course sequence guide is designed to assist students in completing their UTSA undergraduate Physics degree requirements. *This is merely a guide and students must satisfy other requirements of this catalog and meet with their academic advisor for individualized degree plans.* Progress within this guide depends upon such factors as course availability, individual student academic preparation, student time management, work obligations, and individual financial considerations. Students may choose to take courses during Summer terms to reduce course loads during long semesters.

B.A. in Physics – Recommended Four-Year Academic Plan

First Year

Fall		Credit Hours
AIS 1203	Academic Inquiry and Scholarship (core)	3
CHE 1103 or CHE 1143	General Chemistry I or Principles of Chemistry I	3
CHE 1121	General Chemistry I Laboratory ¹	1
CS 1063 or CS 1173 or CS 2073	Introduction to Computer Programming I (or Data Analysis and Visualization, or Computer Programming with Engineering Applications) or Data Analysis and Visualization or Computer Programming with Engineering Applications	3
MAT 1214	Calculus I (core and major)	4
WRC 1013	Freshman Composition I (Q) (core)	3
Credit Hours		17

Spring

CHE 1113 or CHE 1153	General Chemistry II or Principles of Chemistry II	3
MAT 1224	Calculus II	4
PHY 1943	Physics for Scientists and Engineers I (core and major)	3
PHY 1951	Physics for Scientists and Engineers I Laboratory	1
WRC 1023	Freshman Composition II (Q) (core)	3
College of Sciences elective ²		2
Credit Hours		16

Second Year

Fall		Credit Hours
MAT 2214	Calculus III	4
PHY 1963	Physics for Scientists and Engineers II (core and major)	3
PHY 1971	Physics for Scientists and Engineers II Laboratory	1
Social & Behavioral Sciences core		3
American History core		3
Credit Hours		14

Spring

PHY 2103	Modern Physics	3
PHY 2111	Modern Physics Laboratory	1
PHY 2823	Mathematical Physics I	3
PHY 3203	Classical Mechanics I	3
American History core		3
Component Area Option core		3
Credit Hours		16

Third Year

Fall

PHY 3293	Thermal Physics	3
PHY 3423	Electricity and Magnetism	3
College of Sciences elective ²		3
College of Sciences elective ²		3
Language, Philosophy & Culture core		3
Credit Hours		15

Spring

PHY 3343	Physics Research Laboratory	3
POL 1133 or POL 1213	Texas Politics and Society (or Civil Rights in Texas and America (core)) or Civil Rights in Texas and America	3
College of Sciences elective ²		3
College of Sciences elective ²		3
Credit Hours		12

Fourth Year

Fall

POL 1013	Introduction to American Politics (core)	3
College of Sciences elective ²		3
College of Sciences elective ²		3
College of Sciences elective ²		3
Upper-division AST or PHY elective ³		3
Credit Hours		15

Spring

College of Sciences elective ²		3
College of Sciences elective ²		3
College of Sciences elective ²		3
Upper-division AST or PHY elective ³		3
Creative Arts core		3
Credit Hours		15
Total Credit Hours		120

¹ This laboratory course includes a lecture component as indicated on the University Schedule of Classes.

² At least 18 semester credit hours of College of Sciences electives must be at the upper-division level.

³ From section A.2. of degree requirements.

Note: Some courses are only offered once a year; Fall or Spring. Check with the Department of Physics and Astronomy for scheduling of courses.

- Minor in Astronomy/Astrophysics (p. 5)
- Minor in Physics (p. 5)

Minor in Astronomy/Astrophysics

The Department of Physics and Astronomy offers a Minor in Astronomy/Astrophysics, which serves to increase the value of the student's major concentration. The minor provides a more comprehensive foundation in physics to those wishing to teach science at the middle and high school levels through applications of important physics concepts. Further, it is a key Science, Technology, Engineering and Mathematics (STEM) subject, due to its critical science, technology, and math components, combined with a popular appeal. All students pursuing the Minor in Astronomy/Astrophysics must complete 20 semester credit hours.

A. Required Courses

AST 3013	Fundamentals of Astronomy	3
AST 3023	Introduction to Astrophysics	3
PHY 1943 & PHY 1951	Physics for Scientists and Engineers I and Physics for Scientists and Engineers I Laboratory	4
PHY 1963 & PHY 1971	Physics for Scientists and Engineers II and Physics for Scientists and Engineers II Laboratory	4

B. Select two of the following courses

AST 3033	Observational Techniques in Astronomy	6
AST 3103	Observational Astronomy Laboratory	
PHY 3603	Cosmology	
AST 4203	Stellar Astrophysics	
AST 4953	Special Studies in Astronomy	

Total Credit Hours		20
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To declare a Minor in Astronomy/Astrophysics, obtain advice, or seek approval of substitutions for course requirements, students should consult their academic advisor.

Minor in Physics

The Department of Physics and Astronomy also offers a Minor in Physics, which serves to increase the value of the student's major concentration. It also provides a more solid foundation in physics to those wishing to teach science at the middle and high school levels. All students pursuing the Minor in Physics must complete 21 semester credit hours.

Required courses:

PHY 1943 & PHY 1951	Physics for Scientists and Engineers I and Physics for Scientists and Engineers I Laboratory	4
PHY 1963 & PHY 1971	Physics for Scientists and Engineers II and Physics for Scientists and Engineers II Laboratory	4
PHY 2103 & PHY 2111	Modern Physics and Modern Physics Laboratory	4
PHY 3203	Classical Mechanics I	3
PHY 3293	Thermal Physics	3
PHY 3423	Electricity and Magnetism	3

Total Credit Hours		21
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To declare a Minor in Physics, obtain advice, or seek approval of substitutions for course requirements, students should consult their academic advisor.

Astronomy (AST) Courses

AST 1013. Introduction to Astronomy. (3-0) 3 Credit Hours. (TCCN = ASTR 1303)

Prerequisite: MAT 1023 or MAT 1073. A descriptive course including the development of astronomy, its methods, and the motions, laws, and evolution of the solar system. Topics include general properties and types of stars, unusual stellar objects such as quasars and black holes, galaxies, evolution, and cosmology. Occasional evening viewing sessions are held. May apply toward the Core Curriculum requirement in Life and Physical Sciences. Generally offered: Fall, Spring, Summer. Course Fees: LRC1 \$12; LRS1 \$15; MEPA \$18; STSI \$15.

AST 1031. Introduction to Astronomy Laboratory. (1-2) 1 Credit Hour. (TCCN = ASTR 1103)

Prerequisite: Completion of or concurrent enrollment in AST 1013, or consent of instructor. This course is an introduction to practical observational techniques, using the school's telescopes as well as student-built classical instruments and exercises in the use of the telescope and certain other astronomical instruments, including simple observations, measurements, and photography. Topics include in-class projects on spectroscopy, stellar positions, solar heating, planetary motions, solar and astrophotography, star clusters, galaxies, and cosmology. Generally offered: Fall, Spring. Course Fees: IUP1 \$20; LRS1 \$5; STSI \$5.

AST 1033. Exploration of the Solar System. (3-0) 3 Credit Hours. (TCCN = ASTR 1304)

Prerequisite: MAT 1023 or MAT 1073. A descriptive course of modern studies of the solar system, including a survey of the properties of the planets and smaller bodies (asteroids and comets) and current theories of the origin of planetary systems. Topics include results from the latest satellite, robotic, and human exploration of space, origin of life in the solar system, existence of other planetary systems, possibilities of space colonization, and the search for extraterrestrial life (techniques and possibilities of communication with other intelligences). May apply toward the Core Curriculum requirement in Life and Physical Sciences. Generally offered: Fall, Spring. Course Fees: LRC1 \$12; LRS1 \$15; MEPA \$18; STSI \$15.

AST 1043. Current Topics in Astronomy. (3-0) 3 Credit Hours.

Prerequisite: MAT 1023 or MAT 1073. Astronomy receives considerable attention from the media and the public in general. It allows us to ask fundamental questions about who we are, where we come from, and where we will end up as a world. This course will concentrate on the areas of astronomy that are currently most covered by the media—planet detection and interpretation, recent NASA spacecraft missions, supermassive black holes, gamma-ray bursters, dark matter and dark energy in the Universe, and other significant developments that arise during the semester. This course will cover each of these in depth, but will also concentrate on the reaction that the media has had on them. The media and public often have an uncanny ability to probe directly to the main reasons for why scientists study a particular problem. The student who completes this course will be expected to not only have a better scientific understanding of the current hot topics in astronomy, but also understand how the media can actually drive science in general.

AST 1113. Astronomy for Educators. (3-0) 3 Credit Hours.

Prerequisite: MAT 1023 or MAT 1073. This is a one-semester introductory survey course on modern astronomy, specially designed for education majors. During the semester, students will develop course materials for classroom instruction appropriate for K-12 education. Correcting common misconceptions in astronomy and current teaching strategies will be discussed to help students master the course material and become effective teachers.

AST 3001. Undergraduate Astronomy Seminar. (1-0) 1 Credit Hour.

Prerequisite: Completion of or concurrent enrollment in AST 3023 or consent of instructor. Designed for physics and astronomy majors. Discussions about current astronomical research, with different topics emphasized each semester. May be repeated twice for credit when the topics vary. Offered on a credit/no-credit basis only.

AST 3013. Fundamentals of Astronomy. (3-0) 3 Credit Hours.

Prerequisites: PHY 1963 (or PHY 1923 in previous catalogs) and MAT 1224 (or MAT 1193 and STA 1403) completed with a grade of "C-" or better. This is a one-semester introductory survey course on modern astronomy for science and engineering majors. Students need to be comfortable with solving problems and using math as a tool to help master the course material. Students concerned about their problem-solving and math skills should consider taking AST 1013 instead, which is intended for non-science majors. Among the topics covered are the celestial sphere, basic orbit theory, stellar parameters, binary stars and light curves, and basic introduction to stellar spectral classification. (Formerly AST 2063. Credit cannot be earned for both AST 3013 and AST 2063.) Generally offered: Summer. Course Fees: LRS1 \$15; MEPA \$18; STSI \$15.

AST 3023. Introduction to Astrophysics. (3-0) 3 Credit Hours.

Prerequisites: AST 3013 and PHY 2103 or consent of instructor. Topics include an introduction to stellar structure and evolution, stellar atmospheres, collapsed stars, galactic structure, introduction to cosmology, etc. (Formerly AST 3003 and PHY 4003. Credit cannot be earned for more than one of the following: AST 3003, AST 3023 or PHY 4003.) Course Fees: LRS1 \$15; MEPA \$18; STSI \$15.

AST 3033. Observational Techniques in Astronomy. (3-0) 3 Credit Hours.

Prerequisite: Completion of or concurrent enrollment in AST 3023 or consent of instructor. Properties of stars and starlight; principles of radiation; interpretation of stellar spectra. Observational techniques such as photometry, spectroscopy, telescopes and detectors; variable stars; binary stars. In addition to classical visual observations, topics span the electromagnetic spectrum, including radio, infrared, X-ray, and gamma-ray measurements in astronomy.

AST 3043. Astrochemistry. (3-0) 3 Credit Hours.

Prerequisite: AST 3023 or consent of instructor. An interdisciplinary course that explores astrochemistry: the study of molecules in space. Where are they? How did they get there? What roles do they play in controlling or influencing astrophysical processes? The chemistry of interstellar molecules is one of modern astronomy's best tools for probing the processes of star and planet formation. Organic molecules formed in space and delivered to Earth's primordial surface may have contributed to the origin of terrestrial life. Through a combination of observational spectroscopy and imaging, theoretical modeling and controlled laboratory studies, the secrets of the cosmic chemical cauldron are beginning to be unlocked. This course involves readings in astronomy, chemistry, and biology.

AST 3103. Observational Astronomy Laboratory. (0-6) 3 Credit Hours.

Prerequisite: Completion of, with a grade of "C-" or better, or concurrent enrollment in AST 3033 or consent of instructor. An introduction to practical observational techniques in astronomy designed for physical science students. Topics include basic observational techniques and modern instrumentation in astronomy including astrophotography, photometry, and spectroscopy of solar system, stellar and deep-space objects. Under the supervision of the course instructor, the students will use the 0.4-m telescope and other instrumentation on the campus observatory. Course Fee: STSI \$15.

AST 4203. Stellar Astrophysics. (3-0) 3 Credit Hours.

Prerequisite: AST 3023 or consent of instructor. Topics include properties and evolution of stars, stellar atmospheres, stellar spectra, nuclear reactions, stellar models, equations of state, radiative transfer, nucleosynthesis in stars, supernovae, and degenerate stars. Course Fees: LRS1 \$15; STSI \$15.

AST 4303. Solar System Astrophysics. (3-0) 3 Credit Hours.

Prerequisite: AST 3023 or consent of instructor. Modern studies of the solar system, including properties of the planets and smaller bodies, and the origin of planetary systems. Topics include the solar system, its formation, structure, and evolution; orbital dynamics, surfaces, interiors, atmospheres, magnetospheres, and other properties of the sun, the planets and their satellites; comets and asteroids; origin of planetary systems; extra-solar systems. (Formerly titled "The Solar System.") Course Fee: STSI \$15.

AST 4953. Special Studies in Astronomy. (3-0) 3 Credit Hours.

Prerequisites: AST 3023 and consent of instructor. An organized course offering the opportunity for specialized study not normally or not often available as part of the regular course offerings. Special Studies may be repeated for credit when the topics vary, but not more than 6 semester credit hours, regardless of discipline, will apply to a bachelor's degree. Course Fee: STSI \$15.

Physics (PHY) Courses

PHY 1013. Universes. (3-0) 3 Credit Hours. (TCCN = PHYS 1310)

Prerequisite: MAT 1023 or MAT 1073 or consent of instructor. This course is an introduction to contemporary physics and cosmology. The goal is to study some of the profound discoveries in fundamental physics made during the 20th century, and how they have shaped our modern conception of the universe and of our place in it. Topics discussed include Einstein's theories of special and general relativity, quantum physics, modern cosmology (including the very early universe), and the standard model of elementary particles and forces. May not be applied toward the B.S. degree in Physics without prior written approval of the department. May apply toward the Core Curriculum requirement in Life and Physical Sciences. Course Fees: LRC1 \$12; LRS1 \$15; MEPA \$18; STSI \$15.

PHY 1603. Algebra-based Physics I. (3-0) 3 Credit Hours. (TCCN = PHYS 1301)

Prerequisite: MAT 1023 or MAT 1073 completed with a grade of "C-" or better. Concurrent enrollment in PHY 1611 is recommended. The first of a two-part, algebra-based introduction to physics for biology and other majors that do not require calculus-based physics. Topics include mechanics, thermodynamics, vibrations and waves. Generally offered: Fall, Spring, Summer. Course Fees: LRS1 \$15; MEPA \$18; STSI \$15.

PHY 1611. Algebra-based Physics I Laboratory. (1-4) 1 Credit Hour. (TCCN = PHYS 1101)

Prerequisite: Completion of or concurrent enrollment in PHY 1603. Laboratory accompanies PHY 1603; uses modern data acquisition and analysis tools to study the classic physics experiments that underlie the concepts discussed in PHY 1603. Generally offered: Fall, Spring, Summer. Course Fees: IUP1 \$20; LRS1 \$5; STSI \$5.

PHY 1623. Algebra-based Physics II. (3-0) 3 Credit Hours. (TCCN = PHYS 1302)

Prerequisite: PHY 1603 completed with a grade of "C-" or better. Concurrent enrollment in PHY 1631 is recommended. The second of a two-part, algebra-based introduction to physics for biology and other majors that do not require calculus-based physics. Topics include electricity, magnetism, optics, relativity, and quantum physics. Generally offered: Fall, Spring, Summer. Course Fees: LRS1 \$15; MEPA \$18; STSI \$15.

PHY 1631. Algebra-based Physics II Laboratory. (1-4) 1 Credit Hour. (TCCN = PHYS 1102)

Prerequisites: PHY 1611 completed with a grade of "C-" or better and completion of or concurrent enrollment in PHY 1623. Laboratory accompanies PHY 1623; uses modern data acquisition and analysis tools to study the classic physics experiments that underlie the concepts discussed in PHY 1623. Generally offered: Fall, Spring, Summer. Course Fees: IUP1 \$20; LRS1 \$5; STSI \$5.

PHY 1943. Physics for Scientists and Engineers I. (3-1) 3 Credit Hours. (TCCN = PHYS 2325)

Prerequisites: MAT 1193 or MAT 1214 completed with a grade of "C-" or better; completion of or concurrent enrollment in MAT 1224 (if student took MAT 1214) or STA 1403 (if student took MAT 1193) is required. Concurrent enrollment in PHY 1951 is recommended. The first of a two-part, calculus-based introduction to classical physics, designed for physical sciences, mathematics, and engineering majors. Topics include mechanics and Newton's laws, conservation laws, gravitation, rotational motion and rigid bodies, oscillations and waves. Classes meet weekly for three hours of lecture and one hour of recitation. May apply toward the Core Curriculum requirement in Life and Physical Sciences. (Formerly PHY 1903 and PHY 1904. Credit cannot be earned for more than one of the following: PHY 1903, PHY 1904, or PHY 1943.) Generally offered: Fall, Spring. Course Fees: LRC1 \$12; LRS1 \$15; MEPA \$18; STSI \$15.

PHY 1951. Physics for Scientists and Engineers I Laboratory. (1-4) 1 Credit Hour.

Prerequisite: Completion of, with a grade of "C-" or better, or concurrent enrollment in PHY 1943. Laboratory to accompany PHY 1943; uses modern data acquisition and analysis tools to study the classic physics experiments that underlie the concepts discussed in PHY 1943. (Credit cannot be earned for both PHY 1951 and PHY 1911.) Generally offered: Fall, Spring. Course Fees: IUP1 \$20; LRS1 \$5; STSI \$5.

PHY 1963. Physics for Scientists and Engineers II. (3-1) 3 Credit Hours. (TCCN = PHYS 2326)

Prerequisites: PHY 1943 and MAT 1224 (or MAT 1193 and STA 1403) completed with grades of "C-" or better. Concurrent enrollment in PHY 1971 is recommended. The second of a two-part, calculus-based introduction to classical physics, designed for physical sciences, mathematics, and engineering majors. Topics include an introduction to thermal physics, electricity and magnetism, fundamentals of circuits, electromagnetic induction, AC circuits, electromagnetic waves, and Maxwell's equations. Classes meet weekly for three hours of lecture and one hour of recitation. May apply toward the Core Curriculum requirement in Life and Physical Sciences. (Formerly PHY 1923 and PHY 1924. Credit cannot be earned for more than one of the following: PHY 1923, PHY 1924, or PHY 1963.) Generally offered: Fall, Spring. Course Fees: LRC1 \$12; LRS1 \$15; MEPA \$18; STSI \$15.

PHY 1971. Physics for Scientists and Engineers II Laboratory. (1-4) 1 Credit Hour.

Prerequisites: PHY 1951 completed with a grade of "C-" or better and completion of or concurrent enrollment in PHY 1963. Laboratory to accompany PHY 1963; uses modern data acquisition and analysis tools to study the classic physics experiments that underlie the concepts discussed in PHY 1963. (Credit cannot be earned for both PHY 1971 and PHY 1931.) Generally offered: Fall, Spring. Course Fees: IUP1 \$20; LRS1 \$5; STSI \$5.

PHY 2103. Modern Physics. (3-0) 3 Credit Hours.

Prerequisites: PHY 1963, MAT 2214 (completed with a grade of "C-" or better), and completion of or concurrent enrollment in PHY 3203, or consent of instructor. Topics include special relativity, Planck's Radiation Law, elements of quantum mechanics, atomic and molecular structures, spectra, the atomic nucleus, nuclear reactions, and an introduction to elementary particles. (Formerly PHY 3103. Credit cannot be earned for both PHY 2103 and PHY 3103.) Generally offered: Fall, Spring. Course Fees: LRS1 \$15; STSI \$15.

PHY 2111. Modern Physics Laboratory. (1-4) 1 Credit Hour.

Prerequisites: PHY 1963, PHY 1971, and completion of, with a grade of "C-" or better, or concurrent enrollment in PHY 2103. Laboratory to accompany PHY 2103; Uses modern data acquisition and analysis tools to study the classic physics experiments that underlie the concepts discussed in PHY 2103. Generally offered: Fall, Spring. Course Fees: IUP1 \$20; LRS1 \$5; STSI \$5.

PHY 2823. Mathematical Physics I. (3-0) 3 Credit Hours.

Prerequisites: MAT 2214 and PHY 1963, or consent of instructor. Topics may include vector analysis, introduction to complex variables, Fourier series, ordinary differential equations, linear algebra, and selected application to problems in mechanics and electromagnetic theory. (Formerly PHY 3823. Credit cannot be earned for both PHY 2823 and PHY 3823.) Generally offered: Fall, Spring. Course Fees: LRS1 \$15; MEPA \$18; STSI \$15.

PHY 3003. Current Research Topics in Physics. (3-0) 3 Credit Hours.

Prerequisites: PHY 1623 and PHY 1631, or PHY 1963 and PHY 1971, completed with a grade of "C-" or better. This course provides students the opportunity to acquire knowledge in contemporary physics through the study and class discussions of selected topics and recent articles. Subjects may include one or more of the following: special and general relativity, elements of quantum mechanics, atomic and molecular physics, solid state, biophysics, nuclear physics, introduction to elementary particles, astrophysics and cosmology, etc. May not be applied toward the B.S. or B.A. degree in Physics without prior written approval of the department. Course Fees: LRS1 \$15; MEPA \$18; STSI \$15.

PHY 3143. Introduction to Computational Physics. (3-0) 3 Credit Hours.

Prerequisites: PHY 2103, PHY 2823, and PHY 3203, or consent of instructor. This course introduces the computer techniques used to solve (and improve the understanding of) physical problems that may be intractable by the standard pencil and paper analytical approach. Topics may include numerical solution of differential equations, numerical integration, eigenvalue problems, use of computer algebra systems such as Mathematica or Maple, Monte Carlo methods, computer visualization of physical problems, etc. Examples are taken from classical and quantum mechanics, electrodynamics, statistical mechanics, and solid state physics. May be applied toward a B.S. degree in Physics with approval of the physics advisor. (Formerly titled "Computer Visualization of Physics.") Course Fees: LRS1 \$15; STSI \$15.

PHY 3203. Classical Mechanics I. (3-0) 3 Credit Hours.

Prerequisites: PHY 1963 and completion of, with a grade of "C-" or better, or concurrent enrollment in PHY 2823, or consent of instructor. Topics include Newtonian mechanics, oscillations, central-force motion, gravitation, Hamiltonian and Lagrangian dynamics. Generally offered: Fall, Spring. Course Fees: LRS1 \$15; STSI \$15.

PHY 3293. Thermal Physics. (3-0) 3 Credit Hours.

Prerequisites: PHY 1963 and PHY 2823, or consent of instructor. Topics include fundamentals of thermodynamics: entropy, free energy, phase transitions, and thermodynamic potentials; equilibrium, Maxwell-Boltzmann, Bose-Einstein, and Fermi-Dirac distribution functions; derivation of macroscopic equilibrium thermodynamics from statistical mechanics. Generally offered: Fall. Course Fees: LRS1 \$15; STSI \$15.

PHY 3313. Materials Physics. (3-0) 3 Credit Hours.

Prerequisite: PHY 2103 or consent of instructor. Topics covered include crystal structure and band theory, density functional theory, a survey of properties of metals and semiconductors, phonons, electron-phonon interaction and superconductivity. (Formerly titled "Solid State Physics.") Generally offered: Spring. Course Fees: LRS1 \$15; STSI \$15.

PHY 3343. Physics Research Laboratory. (0-6) 3 Credit Hours.

Prerequisites: PHY 1971, PHY 2103 and PHY 2111. This course provides students majoring in physics the opportunity to acquire knowledge in advanced experimental techniques gained through actual participation in real-world physics research labs. (Formerly titled "Advanced Physics Laboratory.") Course Fees: IUP1 \$20; LRS1 \$15; STSI \$15.

PHY 3423. Electricity and Magnetism. (3-0) 3 Credit Hours.

Prerequisites: PHY 1963, PHY 2823, and completion of (with a grade of "C-" or better) or concurrent enrollment in MAT 3613, or consent of instructor. Topics include vector calculus, electrostatics, magnetostatics, Faraday's Law, and solutions to Laplace's equation. Generally offered: Spring. Course Fees: LRS1 \$15; STSI \$15.

PHY 3443. Modern Optics. (3-0) 3 Credit Hours.

Prerequisite: PHY 3423 or consent of instructor. Topics include reflection, refraction, absorption, polarization, and diffraction of light, filters, lasers, nonlinear properties, and Fourier optics. Generally offered: Fall. Course Fees: LRS1 \$15; STSI \$15.

PHY 3453. Lasers: Theory and Applications. (3-0) 3 Credit Hours.

Prerequisite: PHY 2103 or consent of instructor. Topics include basic principles and designs of lasers: Einstein A and B coefficients; semiclassical laser theory; the phase-coherent nature of the stimulated emission process; and laser efficiency. Various applications of lasers, such as laser-induced fluorescence, light wave communications, holography, surgery, and laser fusion. Course Fees: LRS1 \$15; STSI \$15.

PHY 3513. Electrodynamics. (3-0) 3 Credit Hours.

Prerequisites: PHY 2823 and PHY 3423, or consent of instructor. Continuation of the material started in PHY 3423. Topics include Maxwell's equations, electromagnetic waves, wave guides, and radiation from accelerated charges. Generally offered: Spring. Course Fees: LRS1 \$15; STSI \$15.

PHY 3583. Mathematical Physics II. (3-0) 3 Credit Hours.

Prerequisite: PHY 2823 or consent of instructor. Topics may include series solutions of differential equations, partial differential equations of physics, special functions, integral transforms and introduction to tensor calculus. Applications may include topics in classical and quantum mechanics, electrostatics and electrodynamics. (Formerly PHY 4823. Credit cannot be earned for both PHY 3583 and PHY 4823.) Generally offered: Spring. Course Fees: LRS1 \$15; MEPA \$18; STSI \$15.

PHY 3603. Cosmology. (3-0) 3 Credit Hours.

Prerequisites: PHY 1963 and PHY 2103, or consent of instructor. This course is an introduction to physical cosmology. Topics include large-scale structure, expansion and age of the universe; non-Euclidean spaces, big bang cosmology, baryogenesis, nucleosynthesis, and cosmic microwave background radiation; particle physics and inflationary cosmology. (Formerly PHY 4033. Credit cannot be earned for both PHY 3603 and PHY 4033.) Course Fees: LRS1 \$15; MEPA \$18; STSI \$15.

PHY 4013. Relativity: Special and General. (3-0) 3 Credit Hours.

Prerequisites: PHY 2823 and PHY 3203, or consent of instructor. Topics include special relativity: Lorentz transformations, four-vectors, geometry of flat space-time, relativistic dynamics. General relativity: Principle of equivalence, introduction to tensor calculus, Einstein's field equations, Schwarzschild's solution, black holes. Introduction to cosmology. Course Fees: LRS1 \$15; STSI \$15.

PHY 4203. Classical Mechanics II. (3-0) 3 Credit Hours.

Prerequisite: PHY 3203 or consent of instructor. Topics may include nonlinear oscillations and chaos, systems of particles and collisions, non-inertial frames, rigid bodies, coupled oscillations, continuous systems and waves. Course Fees: LRS1 \$15; STSI \$15.

PHY 4263. Quantum Mechanics I. (3-0) 3 Credit Hours.

Prerequisites: PHY 2103, PHY 3203, MAT 2233, and completion of or concurrent enrollment in PHY 3583, or consent of instructor. Topics include the time-independent Schrodinger equation; operator methods, and the postulates of quantum mechanics; one-dimensional potentials; quantum harmonic oscillator; angular momentum and spin; entanglement and its applications; quantum mechanics in three dimensions and the hydrogen atom. Generally offered: Fall, Spring. Course Fees: LRS1 \$15; STSI \$15.

PHY 4423. Quantum Mechanics II. (3-0) 3 Credit Hours.

Prerequisite: PHY 3583 and PHY 4263, or consent of instructor. Topics include identical particles; time-independent perturbation theory; WKB approximation, time-dependent perturbation theory, the variational principle; the adiabatic approximation and Berry's phase; scattering. Generally offered: Spring. Course Fees: LRS1 \$15; STSI \$15.

PHY 4563. Biophotonics. (3-0) 3 Credit Hours.

Prerequisite: PHY 3443 or consent of instructor. Topics including basic concepts of optical radiation interacting with biological materials will be covered. Discussion of how the unique properties of photons are exploited to understand the biological structure and its function. Photon absorption and emission in biological materials will be considered to explain their applications, including optical imaging as a noninvasive diagnosis tool, photodynamic therapy (PDT), etc. Course Fee: STSI \$15.

PHY 4603. Crystallography and Materials Characterization. (3-0) 3 Credit Hours.

Prerequisite: PHY 2103 or consent of instructor. This course will describe the basics of crystal description and will discuss the characterization methods such as x-ray electron and neutron diffraction.

PHY 4623. Nanotechnology. (3-0) 3 Credit Hours.

Prerequisite: PHY 2103 or consent of instructor. This course will describe the fundamentals of nanotechnology, including properties of matter at the nanometric size.

PHY 4653. Introduction to Micro and Nanotechnology. (3-0) 3 Credit Hours.

Prerequisite: PHY 3423 or consent of instructor. Survey of micro and nanofabrication techniques, scaling laws, mechanical, optical, electrical, magnetic and thermal transducers, microfluidic applications, and nanostructures. Structures produced in the laboratory include microactuators, nanoparticles and microfluidics. This course differs from PHY 4623 in that it is oriented more toward fabrication techniques, rather than fundamentals. (Credit cannot be earned for both PHY 4653 and EE 4523.).

PHY 4703. Renewable Energy: Solar Energy Convertors. (3-0) 3 Credit Hours.

Prerequisite: PHY 2103 or consent of instructor. Topics include physics of photovoltaic cells, semiconductors, solar energy convertors, thin film solar cells, nanostructures for solar energy conversion, dye-sensitized photovoltaic cells, fuels from water and sunlight, strategies for high efficiency.

PHY 4833. Molecular Biophysics. (3-0) 3 Credit Hours.

Prerequisites: CHE 1113 and one of the following: PHY 2103, CHE 3804, or CHE 3854. Topics include interaction between molecules, principles of thermodynamics (enthalpy, entropy, free energy) applied to biomolecules, Brownian motion and diffusion of molecules, structure of proteins, and principles of quantum mechanics. Biophysical techniques: absorption spectroscopy, transient absorption, fluorescence spectroscopy, fluorescence lifetime, FTIR spectroscopy, linear and circular dichroism, x-ray crystallography, and atomic force microscopy. Generally offered: Spring. Course Fee: STSI \$15.

PHY 4843. Condensed Matter Theory. (3-0) 3 Credit Hours.

Prerequisites: PHY 3313 and PHY 4263, or consent of instructor. This course offers an introduction to the basic concepts of the quantum condensed matter theory, such as lattice dynamics, elementary excitations, linear response theory, symmetry breaking in Fermi and Bose systems: the physics of superconductivity and superfluidity.

PHY 4911. Independent Study. (0-0) 1 Credit Hour.

Prerequisite: Permission in writing (form available) of the instructor, the student's advisor, the Department Chair, and Dean of the College in which the course is offered. Independent reading, research, discussion, and/or writing under the direction of a faculty member. May be repeated for credit, but not more than 6 semester credit hours, regardless of discipline, will apply to a bachelor's degree in physics. Course Fees: LRS1 \$5; STSI \$5.

PHY 4912. Independent Study. (0-0) 2 Credit Hours.

Prerequisite: Permission in writing (form available) of the instructor, the student's advisor, the Department Chair, and Dean of the College in which the course is offered. Independent reading, research, discussion, and/or writing under the direction of a faculty member. May be repeated for credit, but not more than 6 semester credit hours, regardless of discipline, will apply to a bachelor's degree in physics. Course Fee: STSI \$10.

PHY 4913. Independent Study. (0-0) 3 Credit Hours.

Prerequisite: Permission in writing (form available) of the instructor, the student's advisor, the Department Chair, and Dean of the College in which the course is offered. Independent reading, research, discussion, and/or writing under the direction of a faculty member. May be repeated for credit, but not more than 6 semester credit hours, regardless of discipline, will apply to a bachelor's degree in physics. Generally offered: Spring. Course Fees: LRS1 \$15; STSI \$15.

PHY 4953. Special Studies in Physics. (3-0) 3 Credit Hours.

Prerequisite: Consent of instructor. An organized course offering the opportunity for specialized study not normally or not often available as part of the regular course offerings. Special Studies may be repeated for credit when the topics vary, but not more than 6 semester credit hours, regardless of discipline, will apply to a bachelor's degree. Generally offered: Spring. Course Fees: LRS1 \$15; STSI \$15.

PHY 4983. Unifying Concepts in Physics. (3-0) 3 Credit Hours.

Prerequisites: PHY 3293, PHY 3513, PHY 4263, and completion with a grade of "C-" or better or concurrent enrollment in PHY 3583, or consent of instructor. This advanced course is designed to help the students develop a more mature and coherent understanding of the whole discipline through an in-depth exploration of the major branches of physics and their theoretical interconnections. Generally offered: Fall. Course Fees: LRS1 \$15; MEPA \$18; STSI \$15.

PHY 4993. Honors Research. (0-0) 3 Credit Hours.

Prerequisites: Enrollment limited to candidates for College Honors during their last two semesters; approval by the College Honors Committee. Supervised research and preparation of an honors thesis. May be repeated once with approval. Course Fees: LRS1 \$15; STSI \$15.