Physics and Astronomy

General Information
The Department’s faculty members have a diversity of interests and are active in various experimental and theoretical research areas. Students successfully completing this program will obtain an understanding of basic physics concepts, mathematical and problem-solving skills needed to solve basic physics problems, experimental skills in physics, astrophysics, or biophysics, and the ability to analyze and interpret scientific data and write scientific papers or reports.

Degrees and Areas of Concentration
The Department of Physics and Astronomy offers superb course work leading to the following baccalaureate degrees:

- B.A. in Physics
- B.S. in Physics with emphasis areas of
  - Astrophysics
  - Engineering Physics
  - General Physics
  - Biophysics (pending CBHE approval)
  - Optical Biophysics
- B.A. or B.S. in Physics with Master's Level Coursework for Secondary Teacher Certification
- B.S. in Secondary Education with Emphasis in Physics.

The Department of Physics and Astronomy also offers the following graduate degree programs:

- Master of Science in Physics: The M.S. program combines a sound basis in the fundamental areas of classical and modern physics from both a theoretical and an applied perspective. The program is designed to enable students with undergraduate backgrounds in physics or other technical areas to further their professional development and maintain and improve their technical development. Students receiving a M.S. in physics will obtain an understanding of advanced physics concepts and mathematical and problem-solving skills needed to solve advanced physics problems. Students are strongly encouraged to be involved with faculty research programs that will develop experimental skills in physics, astrophysics, or biophysics as well as experience in analyzing and interpreting scientific data and the writing of scientific papers, reports, or theses. The writing of a thesis is optional.
- Ph.D. in Physics: The Ph.D. degree is offered in cooperation with the Missouri University of Science and Technology Physics Department. Students must satisfy the Missouri S&T admission standards, and the Missouri S&T Qualifying Exam in Physics is required of University of Missouri-St. Louis Ph.D. students. However, all course work and dissertation research may be completed while the student is in residence at UMSL. In addition to obtaining an understanding of advanced physics concepts and mathematical and problem-solving skills needed to solve advanced physics problems, Ph.D. students are expected to conduct independent scientific research in physics, astrophysics, or biophysics while learning to analyze and interpret scientific data and write scientific papers, reports, and a dissertation.

Fellowships and Scholarships

The Department of Physics and Astronomy offers a number of scholarships and awards.

- Physics & Astronomy Alumni Scholarship is available to new physics majors with outstanding ACT or SAT scores or continuing physics majors with outstanding academic records.
- The Richard D. Schwartz Scholarship is available to full-time junior/senior physics majors in good standing.
- The Don C. and Susan P. Winter Endowed Scholarship in Physics & Astronomy is available to physics majors with a minimum ACT score of 24 or who have a minimum GPA of 3.0.
- The Pierre Lacledge/Physics & Astronomy Alumni Scholarship for undergraduate physics majors is available to physics majors who are also accepted into the Pierre Lacledge Honors College.
- The Junior Alumni Award is awarded to physics majors who attain a 3.5 average or better in Physics 2111 and 2112. The award is given to the student in the semester they enroll in Physics 3200. Transfer students must take Physics 2112 on this campus to be eligible for this scholarship.
- The Senior Alumni Award is given to the outstanding physics major at the senior level with the highest GPA among the senior class.
- The Jeffrey Earl Award is given to an outstanding graduating senior every May.
- Undergraduate Research Awards are available for undergraduate physics majors who conduct a research project with a faculty mentor. Students receiving this award are required to enroll for at least one credit hour of Physics 3390 and present their research results at the campus Undergraduate Research Symposium in April.
- Teaching Assistantships with stipends may also be available to qualifying students to prepare them for the independent effort required in industry or graduate school.
- NASA Research Internships for the summer and academic year are available to those B.A. and B.S. degree candidates in Physics with an overall grade point average of 3.2. They must also successfully complete at least 3 credits of PHYS 3390 (Research).

Career Outlook
Many of our students have been successful in subsequent graduate studies in astrophysics and meteorology, as well as physics. Our alumni have pursued graduate studies and earned doctorate degrees at institutions such as Cornell University, MIT, University of Wisconsin, University of Chicago and Washington University. Students who have elected for careers in industry are now working in a variety of settings for such firms as Emerson Electric, Hewlett Packard, IBM, Boeing and MEMC Electronic Materials (now SunEdison). Several former students are currently teaching physics in high schools around the St. Louis area.

Undergraduate Studies

General Education Requirements
Majors must complete the university and college general education requirements (http://bulletin.umsl.edu/generaleducationrequirements).
Any of the following courses may be used to satisfy the physical science requirement:

- **ASTRON 1001** Cosmic Evolution Introductory Astronomy 4
- **ASTRON 1001A** Cosmic Evolution/Introduction Astronomy 3
- **ASTRON 1011** Planets and Life in the Universe 3
- **ASTRON 1012** The Violent Universe and the New Astronomy 3
- **ASTRON 1050** Introduction to Astronomy I 3
- **ASTRON 1051** Introduction to Astronomy II 3
- **ATM SCI 1121** The Search for Extraterrestrial Life 3
- **ATM 1001** Elementary Meteorology 4
- **GEOL 1001** General Geology 4
- **GEOL 1001A** General Geology 4
- **GEOL 1002** Historical Geology 4
- **GEOL 1002A** Historical Geology Lecture 3
- **PHYSICS 1011** Basic Physics I 4
- **PHYSICS 1011A** Basic Physics I 3
- **PHYSICS 1012** Basic Physics II 4
- **PHYSICS 1012A** Basic Physics II 3
- **PHYSICS 2111** Physics: Mechanics and Heat 5
- **PHYSICS 2112** Physics: Electricity, Magnetism, and Optics 5

### Undergraduate Studies

**Declaring the Physics Major**

Students seeking to major in physics are first designated as ‘pre-physics majors’ until they have completed both PHYSICS 2111 and PHYSICS 2112 or equivalent courses. Upon successful completion of PHYSICS 2111 and PHYSICS 2112 with grades of C or better, students will be allowed to declare physics as their major. Each of these courses must be completed successfully within two attempts.

**Degree Requirements**

All physics majors in all programs must complete the physics core curriculum with the exception that majors pursuing the Physics Education option are not required to take PHYSICS 1099 and CMP SCI 1250. In addition to the core courses, each individual program has its own specific requirements. Required Physics, Mathematics, Chemistry, Biology, Optometry and Computer Science courses for a major or minor in physics may not be taken on a satisfactory/unsatisfactory grading basis.

**Core Curriculum**

The following physics courses are required:

- **PHYSICS 1099** Windows On Physics 1099
- **PHYSICS 2111** Physics: Mechanics And Heat 2111
- **PHYSICS 2112** Physics: Electricity, Magnetism, And Optics 2112
- **PHYSICS 3200** Mathematical Methods Of Theoretical Physics 3200
- **PHYSICS 3221** Mechanics 3221
- **PHYSICS 3223** Electricity And Magnetism 3223
- **PHYSICS 3231** Introduction To Modern Physics I 3231

Also required are:

- **MATH 1800** Analytic Geometry And Calculus I
- **MATH 1900** Analytic Geometry And Calculus II
- **MATH 2000** Analytic Geometry And Calculus III
- **MATH 2020** Introduction To Differential Equations
- **CHEM 1111** Introductory Chemistry I
- **CHEM 1112** Introductory Chemistry II
- **CMP SCI 1250** Introduction To Computing

Total Hours 49

Note: Students are urged to begin the calculus sequence [MATH 1800, Analytic Geometry and Calculus I] as soon as possible to avoid delays in graduation.

Students with experience in digital computer programming may be excused from CMP SCI 1250.

**Bachelor of Arts in Physics**

The B.A. program is tailored to students wishing to preserve the option for specialization in graduate school without sacrificing the advantages of a liberal arts education. In addition to the core curriculum, including the foreign language requirement, at least three electives at the 3000 or 4000 levels must be completed. It is recommended that at least one of these three electives include ASTRON 4322, PHYSICS 4311, or PHYSICS 4347 for the required capstone course. The Department of Physics and Astronomy will accept the three-course sequence in American Sign Language as a substitution for the foreign language requirement for the degree. At least 31 hours of physics courses, but no more than 45 hours, are required.

**Bachelor of Science in Physics**

The B.S. degree provides students with six options: general physics, astrophysics, engineering physics, medical physics, optical biophysics or physics education.

**General Physics Option**

This option may be elected by students desiring a greater concentration in physics and mathematics and is recommended for students wishing to enter graduate study in physics. At least 50 hours are required. In addition to the core curriculum, the following physics courses are required:

**Physics**

- **PHYSICS 4310** Modern Electronics 4310
- **PHYSICS 4311** Advanced Physics Laboratory I 4311
- **PHYSICS 4323** Modern Optics 4323
- **PHYSICS 4331** Intro To Quantum Mechanics 4331
- **PHYSICS 4341** Thermal And Statistical Physics 4341
- **PHYSICS 4350** Computational Physics 4350

Select three electives at or above the 4000 level in physics or astronomy.

**Astronomy**

- **ASTRON 1050** Introduction To Astronomy I 1050
- **ASTRON 1051** Introduction To Astronomy II 1051

**Mathematics**

- **MATH 2450** Elementary Linear Algebra 2450

Select one elective in mathematics at or above the 3000 level, or in computer science at or above the 2000 level.

**Chemistry**
Astrophysics Option

Students who have interests in the aerospace sciences or anticipate graduate studies in astrophysics may elect this option. At least 48 hours must be taken. In addition to the core curriculum, the following physics courses are required:

**Physics**
- PHYSICS 4323 Modern Optics 3
- PHYSICS 4331 Intro To Quantum Mechanics 3
- PHYSICS 4341 Thermal And Statistical Physics 3
- PHYSICS 4350 Computational Physics 3

**Astronomy**
- ASTRON 1050 Introduction To Astronomy I 3
- ASTRON 1051 Introduction To Astronomy II 3
- ASTRON 4301 Astrophysics 3
- ASTRON 4322 Observational Astronomy 4

Select one physics elective at or above the 4000 level. 1

**Mathematics**
- MATH 2450 Elementary Linear Algebra 3

Total Hours 31

1 With consent of the astronomy adviser, there may be substitution of ASTRON 1001, ASTRON 1001A, ASTRON 1011 or ASTRON 1012 for ASTRON 1050 or ASTRON 1051.

Engineering Physics Option

Students interested in careers in the research and development field of industry should consider this option. This program exposes the student to a basic engineering curriculum, as well as to areas of physics with industrial applications, such as electronics, modern optics, and linear analysis. At least 49 hours, but no more than 51, are required. In addition to the core curriculum, the following courses are required:

**Joint Engineering**
- ENGR 2310 Statics 3
- ENGR 2320 Dynamics 3

**Joint Electrical Engineering**
- J E ENGR 2300 Introduction To Electrical Networks 3

**Physics**
- PHYSICS 4310 Modern Electronics 3
- PHYSICS 4311 Advanced Physics Laboratory I 3
- PHYSICS 4323 Modern Optics 3
- PHYSICS 4331 Intro To Quantum Mechanics 3
- PHYSICS 4341 Thermal And Statistical Physics 3

**Mathematics**
- MATH 1320 Applied Statistics I 3
- MATH 2450 Elementary Linear Algebra 3

Select one elective in mathematics at or above the 3000 level, or in a computer science at or above the 2000 level. 3

Total Hours 33

Optical Biophysics Option

This program is designed for students wanting to obtain a strong biophysics emphasis that will also prepare them for the optometry program at UMSL. This 3+4 program allows students to complete their B.S. in physics and Doctor of Optometry degrees in seven years. Students can complete their B.S. in physics degree in their fourth year while starting coursework in the College of Optometry. A total of 55 hours in physics, biology, and optometry courses are required. In addition to the physics core curriculum, the following courses are required:

**Physics**
- PHYSICS 4341 Thermal And Statistical Physics 3

**Biology**
- BIOL 1831 Introductory Biology: From Molecules To Organisms 5
- BIOL 1821 Introductory Biology: Organisms And The Environment 5

**Chemistry**
- CHEM 1121 Introductory Chemistry II 5
- CHEM 2612 Organic Chemistry I 3

Total Hours 36
Minor in Physics

Students may complete a minor in physics with the flexibility of emphasis on classical physics, modern physics, or a combination of the two areas. The following physics courses are required:

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Course Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYSICS 1099</td>
<td>Windows On Physics</td>
<td>1</td>
</tr>
<tr>
<td>PHYSICS 2111</td>
<td>Physics: Mechanics And Heat</td>
<td>5</td>
</tr>
<tr>
<td>PHYSICS 2112</td>
<td>Physics: Electricity, Magnetism, And Optics</td>
<td>5</td>
</tr>
<tr>
<td>PHYSICS 3200</td>
<td>Mathematical Methods Of Theoretical Physics</td>
<td>3</td>
</tr>
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Select two additional emphasis courses from the following:

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYSICS 3221</td>
<td>Mechanics</td>
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<tr>
<td>PHYSICS 3223</td>
<td>Electricity And Magnetism</td>
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<tr>
<td>PHYSICS 3231</td>
<td>Introduction To Modern Physics I</td>
</tr>
<tr>
<td>PHYSICS 4310</td>
<td>Modern Electronics</td>
</tr>
</tbody>
</table>

Total Hours 20

A GPA of at least 2.0 is required in courses presented for a minor. It is required that a student completes a minimum of 6 hours of graded work in 2000 level or above courses on the UMSL campus.

Graduate Studies

Admission Requirements

The Department requires applicants to have adequate backgrounds in such areas as mechanics, thermodynamics, electromagnetism, optics, electronics, and modern physics. Students admitted to the program with deficiencies in these areas are required to take appropriate undergraduate courses. If necessary, a remedial program is determined in consultation with the department graduate studies director at the time of application for admission.

Graduate Degree Requirements

Master's

A student must complete 30 credit hours in graduate physics courses with at least 15 of these at the 5000 or 6000 level. Writing a thesis is optional. A maximum of six (3) credit hours of Research, PHYSICS 6490, may be counted toward the minimum 15 hours with (or without) the thesis option. Students must pass a comprehensive examination, which includes a defense of the thesis for students who have chosen to write one. A grade point average of 3.0 must be maintained during each academic year. Students must complete their degree program within 130 percent of the semester hour requirements for the degree. The requirements must be fulfilled within six years from the time of admission. Two-thirds of required graduate credit must be taken in residence. There is no foreign language requirement.

Typical Program

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<tr>
<th>Semester</th>
<th>Course Title</th>
<th>Hours</th>
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<tr>
<td>First Semester</td>
<td>PHYSICS: 6000 level and 4000, 5000 level course</td>
<td>6</td>
</tr>
<tr>
<td>Second Semester</td>
<td>PHYSICS: 6000 level and 4000, 5000 level course</td>
<td>6</td>
</tr>
<tr>
<td>Third Semester</td>
<td>PHYSICS: 6000 level and 4000, 5000 level course</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>PHYSICS 6490</td>
<td>3</td>
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</table>
Career Outlook
Many of our students have been successful in subsequent graduate studies in astronomy and atmospheric science, biomedical engineering, medical physics, and patent law, as well as in physics. Our alumni have pursued graduate studies and earned doctorate degrees at institutions such as Cornell University, University of Wisconsin, Washington University, and University of Chicago. The many students who elected a career in industry are now working in a variety of settings for such firms as International Business Machines, Emerson Electric, MEMC Electronic Materials, Motorola, A T & T, Hewlett-Packard, Boeing, and the National Center for Atmospheric Research. Several former students are currently teaching physics in high schools around the St. Louis area.

Sample Four Year Plans
Physics BA (p. 5)  Physics BS (p. 5)

Physics BA

<table>
<thead>
<tr>
<th>First Year</th>
<th>Hours Spring</th>
<th>Hours</th>
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<tr>
<td>INTDSC 1003</td>
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<td>PHYSICS 1099</td>
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<td>ENGL 1100</td>
<td>3 CHEM 1111</td>
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<tr>
<td>MATH 1030</td>
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<td>Foreign Language 1001</td>
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<tr>
<th>Second Year</th>
<th>Hours Spring</th>
<th>Hours</th>
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<tbody>
<tr>
<td>PHYSICS 2111</td>
<td>5 PHYSICS 2112</td>
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<td>MATH 1900</td>
<td>5 MATH 2000</td>
<td>5</td>
</tr>
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<td>CMP SCI 1250</td>
<td>3 General Education</td>
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<td>Foreign Language 2101</td>
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<th>Third Year</th>
<th>Hours Spring</th>
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<td>PHYSICS 3200</td>
<td>3 PHYSICS 3221</td>
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</tr>
<tr>
<td>PHYSICS 3231</td>
<td>3 PHYSICS 3223</td>
<td>3</td>
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<tr>
<td>MATH 2020</td>
<td>3 ENGL 3100</td>
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</tr>
<tr>
<td>General Education</td>
<td>6 General Education</td>
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<th>Fourth Year</th>
<th>Hours Spring</th>
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<tr>
<td>PHYSICS 3000+ level elective</td>
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<tr>
<td>General Education</td>
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<td>Elective or minor</td>
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</table>

Total Hours: 123

1  INTDSC 1003 is required only for first-time freshmen and transfer students with less than 24 college credits.

Please Note: This plan is an example of what a four year plan could look like for a typical student. Placement exam scores in math as well as the completion of coursework may change the plan. It should not be used in the place of regular academic advising appointments. All students are encouraged to meet with their advisor each semester. All requirements are subject to change.
Physics BS

First Year

<table>
<thead>
<tr>
<th>Fall</th>
<th>Hours</th>
<th>Spring</th>
<th>Hours</th>
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<tr>
<td>MATH 1035</td>
<td>2</td>
<td>MATH 1800</td>
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</tr>
<tr>
<td>CHEM 1111</td>
<td>5</td>
<td>ASTRON 1051</td>
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<tr>
<td>ENGL 1100</td>
<td>3</td>
<td>General Education</td>
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<tr>
<td>PHYSICS 1099</td>
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Second Year

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<tr>
<th>Fall</th>
<th>Hours</th>
<th>Spring</th>
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<tbody>
<tr>
<td>MATH 1900</td>
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<td>PHYSICS 2112</td>
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<td>CMP SCI 1250</td>
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<td>PHYSICS 2111</td>
<td>5</td>
<td>MATH 2450</td>
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<tr>
<td>General Education</td>
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Third Year

<table>
<thead>
<tr>
<th>Fall</th>
<th>Hours</th>
<th>Spring</th>
<th>Hours</th>
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<tbody>
<tr>
<td>MATH 2020</td>
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<td>PHYSICS 3221</td>
<td>3</td>
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<td>PHYSICS 3200</td>
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<td>PHYSICS 3231</td>
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<td>PHYSICS 4341</td>
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<td>General Education</td>
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<td>PHYSICS 4000+ level elective</td>
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Fourth Year

<table>
<thead>
<tr>
<th>Fall</th>
<th>Hours</th>
<th>Spring</th>
<th>Hours</th>
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<tbody>
<tr>
<td>PHYSICS 4331</td>
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<td>PHYSICS 4310</td>
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<td>PHYSICS 4311</td>
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<tr>
<td>PHYSICS 4000+ level elective</td>
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<td>PHYSICS 4000+ level elective</td>
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<tr>
<td>PHYSICS 4350, MATH 4030, or</td>
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<td>General Education</td>
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<tr>
<td>MATH 4230</td>
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<td>ENGL 3100</td>
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<td>18</td>
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</tbody>
</table>

Total Hours: 129

1 INTDSC 1003 is required only for first-time freshmen and transfer students with less than 24 college credits.

Please Note: This plan is an example of what a four year plan could look like for a typical student. Placement exam scores in math as well as the completion of coursework may change the plan. It should not be used in the place of regular academic advising appointments. All students are encouraged to meet with their advisor each semester. All requirements are subject to change.

Astronomy Courses

ASTRON 1001 Cosmic Evolution/Introduction Astronomy: 3 semester hours
Overview of astronomy, from the planets to the Big Bang. Topics include the celestial motions, planets and the formation of the solar system, stars and stellar evolution, galaxies, and cosmology. Students will be introduced to the latest discoveries and how they affect our understanding of the universe. The format is three classroom hours and one 2-hour laboratory session per week to enhance lecture material.

ASTRON 1001A Cosmic Evolution/Introduction Astronomy: 3 semester hours
Overview of astronomy, from the planets to the Big Bang. Topics include the celestial motions, planets and the formation of the solar system, stars and stellar evolution, galaxies, and cosmology. Students will be introduced to the latest discoveries and how they affect our understanding of the universe. Three classroom hours per week. Same as ASTRON 1001 without the laboratory.

ASTRON 1011 Planets and Life in the Universe: 3 semester hours
Man's concept of the solar system from Stonehenge to Einstein; geology and meteorology of the planets of our solar system, with particular attention to results from the space program; exobiology—study of the possibilities of life on other worlds and the best method of communicating with it. Three lecture hours per week.

ASTRON 1012 The Violent Universe and the New Astronomy: 3 semester hours
A nontechnical course focusing on recent results which larger telescopes and the space program have made available. Pulsars, x-ray stars, and black holes; radio astronomy, our galaxy, and interstellar molecules; exploding galaxies and quasars; origin of the expanding universe. Three lecture hours and one observing session per week.

ASTRON 1050 Introduction to Astronomy I: 3 semester hours
Prerequisites: MATH 1030 and MATH 1035. A survey of the history of astronomy from the ancient times to the present. Theories for the formation and evolution of the solar system and the general features of the solar system and planetary motions are discussed. The physical concept of gravity is presented. The detailed properties of the planets, comets, and asteroids are reviewed, concentrating on recent results from space missions.

ASTRON 1051 Introduction to Astronomy II: 3 semester hours
Prerequisites: MATH 1030 and MATH 1035. A survey of astronomy beyond the solar system. Topics include stars and stellar evolution, neutron stars, and black holes. The physical concept of light and the design of telescopes is discussed in detail. The structure of the Milky Way Galaxy and the large scale structure of the universe are explored. Dark matter, quasars, and active galactic nuclei are discussed in the context of theories for the formation and evolution of the universe. Course does not need to be taken in sequence with ASTRON 1050.

ASTRON 1121 The Search for Extraterrestrial Life: 3 semester hours
Prerequisite: ASTRON 1001 or ASTRON 1011. Are we alone? The possibility of life in the universe in addition to our own will be explored. Our discussion of the chances for extraterrestrial life will be built around the current theories of chemical, biological, and cultural evolution which have led to our own technological civilization on Earth. Strategies for communication with extraterrestrial intelligence will be discussed.

ASTRON 4301 Astrophysics: 3 semester hours
Prerequisite: PHYSICS 3231 or consent of instructor. A moderately technical introduction to astrophysics. Topics will include: physics of stellar interiors and atmospheres; interpretation of stellar spectra; stellar evolution; radio astronomy; and cosmology.

ASTRON 4322 Observational Astronomy: 4 semester hours
Prerequisite: ASTRON 1050, ASTRON 1051 and PHYSICS 3231. Tools of the astronomer: telescopes, spectroscopy, photoelectric photometry. Students will work on a number of projects which will enable them to develop expertise in obtaining, reducing, and analyzing astronomical observations. Student night observing will be an important part of the course. This course is primarily for persons who are astronomy or physics majors or who have some equivalent background.
Atmospheric Science Courses

**ATM SCI 1001 Elementary Meteorology: 4 semester hours**
Prerequisites: MATH 1020 or equivalent. An elementary course covering atmospheric phenomena, weather, and climate. Topics included are temperature, pressure, and moisture distributions in the atmosphere and dynamical effects such as radiation, stability, storms, and general circulation. Four classroom hours per week with one hour being a learning enhancement session to include demonstrations and exercises on problem solving.

**ATM SCI 1001A Elementary Meteorology: 3 semester hours**
Prerequisite: MATH 1020 or equivalent. An elementary course covering atmospheric phenomena, weather, and climate. Topics included are temperature, pressure, and moisture distributions in the atmosphere and dynamical effect such as radiation, stability, storms, and general circulation. Same as ATM SCI 1001 without the learning enhancement session.

Geology Courses

**GEOL 1001 General Geology: 4 semester hours**
Earth materials and processes, including geological aspects of the resource/energy problem. Laboratory involves identification of common rocks and minerals.

**GEOL 1001A General Geology: 4 semester hours**
Earth materials and processes, including geological aspects of the resource/energy problem. Laboratory involves identification of common rocks and minerals.

**GEOL 1001L General Geology Lab: 1 semester hour**
This geology laboratory involves identification of common rocks and minerals.

**GEOL 1002 Historical Geology: 4 semester hours**
Study of changes in Geography, climate and life through geological time; origin of and continents, oceans basins, and mountains in light of continental drift. Laboratory primarily involves description and identification of fossils. Three hours of lecture and two hours of lab.

**GEOL 1002A Historical Geology Lecture: 3 semester hours**
Study of changes in geography, climate and life through geological time; origin of continents, ocean basins, and mountains in light of continental drift. Same as GEOL 1002 without the laboratory.

**GEOL 1053 Oceanography: 3 semester hours**
The atmospheric and ocean circulations; the chemistry and geology of the deep sea; and their effects on the distribution of marine organisms.

Physics Courses

**PHYSICS 1001 How Things Work: 3 semester hours**
Can baseball players hit home runs more easily when the weather is hot and humid? This course provides a practical introduction to understanding common life experiences by using physical intuition and basic ideas of physics. Powerful scientific principles are demonstrated through topics ranging from airplane wings to compact disk players, from lightning strikes to lasers.

**PHYSICS 1011 Basic Physics I: 4 semester hours**
Prerequisites: MATH 1030 and MATH 1035, MATH 1100 or MATH 1800 strongly recommended. A course specifically designed for students in health and life sciences covering the topics in classical mechanics such as kinematics, Newton’s laws, energy, momentum and oscillations. This course will not fulfill the PHYSICS 2111 requirement for physics, chemistry, and engineering majors. Three classroom hours and two hours of laboratory per week.

**PHYSICS 1011A Basic Physics I: 3 semester hours**
Prerequisites: MATH 1030 and MATH 1035, MATH 1100 or MATH 1800 strongly recommended. A course specifically designed for students in health and life sciences, covering the topics of classical mechanics, heat and sound. Will not fulfill the PHYSICS 2111 requirement for physics, chemistry, and engineering majors. Three classroom hours per week. There is no laboratory associated with this course.

**PHYSICS 1012 Basic Physics II: 4 semester hours**
Prerequisites: PHYSICS 1011. A continuation of PHYSICS 1011. A course specifically designed for students in health and life sciences covering electricity, magnetism, light, optics and waves. This course will not fulfill the PHYSICS 2112 requirement for physics, chemistry, and engineering majors. Three classroom hours and two hours of laboratory per week.

**PHYSICS 1012A Basic Physics II: 3 semester hours**
Prerequisites: PHYSICS 1011 or PHYSICS 1011A. A continuation of PHYSICS 1011. A course specifically designed for students in health and life sciences covering the topics of electricity, magnetism, light and radiation. Will not fulfill the PHYSICS 2112 requirement for physics, chemistry, and engineering majors. Three classroom hours. There is no laboratory associated with this course.

**PHYSICS 1099 Windows on Physics: 1 semester hour**
A seminar designed to introduce physics majors to research areas in physics and physics-related fields in the Department of Physics and Astronomy. In addition to fundamental areas of physics, the areas of astrophysics, biophysics, materials science, and nanotechnology will be included. Career opportunities for students with physics degrees will be discussed and the physics curriculum will be reviewed. The course meets weekly and is required of all physics majors and minors who are transfer students.

**PHYSICS 2010 Introduction to Inquiry Approaches to STEM Education (STEP I): 1 semester hour**
Same as CHEM 2010, BIOL 2010, MATH 2010, and SEC ED 2010. Prerequisites: Concurrent enrollment BIOL 1821, BIOL 1831, CHEM 1111, CHEM 1121, PHYSICS 2111, PHYSICS 2112, MATH 1800, or MATH 1900 or have a declared STEM major. Students who want to explore teaching careers become familiar with lesson plan development by writing, teaching and observing lessons in a local school class. Students build and practice inquiry-based lesson design skills and become familiar with and practice classroom management in the school setting. As a result of the STEP I experiences students should be able to decide whether to continue to explore teaching as a career and ultimately finishing the remainder of the WE TEACH MO curriculum leading to teacher certification. The classroom observations and teaching represent a major field component and requires at least one two hour block of free time during the school day once a week.
PHYSICS 2111 Physics: Mechanics and Heat: 5 semester hours
Prerequisites: MATH 1900 (may be taken concurrently). An introduction to the phenomena, concepts, and laws of mechanics and heat for physics majors and students in other departments. Three classroom hours, one hour discussion, and two hours of laboratory per week.

PHYSICS 2112 Physics: Electricity, Magnetism, and Optics: 5 semester hours
Prerequisites: PHYSICS 2111 and MATH 2000 (MATH 2000 may be taken concurrently). A phenomenological introduction to the concepts and laws of electricity and magnetism, electromagnetic waves, optics and electrical circuits for physics majors and students in other departments. Three hours of lecture, one hour of discussion, and two hours of laboratory per week.

PHYSICS 3200 Mathematical Methods of Theoretical Physics: 3 semester hours
Prerequisites: PHYSICS 2112 and MATH 2000. Mathematical techniques specifically used in the study of mechanics, electricity, magnetism, and quantum physics are developed in the context of various physical problems. Course includes the topics of vector calculus, coordinate systems, the Laplace equation and its solutions, elementary Fourier analysis, & complex variables. Applications to electrostatics, mechanics, and fluid dynamics are emphasized. Three hours of lecture per week.

PHYSICS 3221 Mechanics: 3 semester hours
Prerequisites: PHYSICS 3200 and MATH 2000 (MATH 2000 may be taken concurrently). Advanced course covering single and many particle dynamics, rigid-body dynamics, and oscillations. Variational principles and Hamiltonian formulations of mechanics are covered. Three hours of lecture per week.

PHYSICS 3223 Electricity and Magnetism: 3 semester hours
Prerequisites: PHYSICS 3200 and MATH 2000 (MATH 2000 may be taken concurrently). Advanced course covering the rigorous development, from basic laws, of Maxwell's equations for electromagnetic fields along with applications of these equations. Topics covered are electrostatics and electrodynamics including currents, magnetic fields, motion of charged particles in fields and an introduction to electromagnetic waves. Three hours of lecture per week.

PHYSICS 3231 Introduction to Modern Physics I: 3 semester hours
Prerequisites: PHYSICS 2111, PHYSICS 2112, and MATH 2020 (may be taken concurrently) and PHYSICS 3200 strongly recommended. Photons and the wave nature of particles, wave mechanics, Schrödinger equation, with applications to atomic physics; and radiation; the physics of solids; elementary particles; special relativity; health physics. Three hours of lecture per week.

PHYSICS 3281 Directed Readings in Physics: 1-5 semester hours
Prerequisite: Consent of Instructor. An independent study of special topics in physics. A paper may be required on an approved topic. Topics must be substantially different. Hours arranged.

PHYSICS 3390 Research: 1-10 semester hours
Prerequisite: Consent of department. Independent physics research projects arranged between student and instructor. Hours arranged.

PHYSICS 4304 Introduction to Nanotechnology: 3 semester hours
Prerequisites: PHYSICS 3231. This course presents a broad overview of the field of nanotechnology with an emphasis on physical phenomena involved with three main parts: Nanoscale Fabrication and Characterization (nano-lithography, self-assembly and self-organization, scanning probe microscopes); Nanomaterials and Nanostructures (low-dimensional materials, graphene, carbon nanotubes, quantum dots, nano-composites, etc); Select Applications (nanoscale and molecular electronics, nano-magnetism, nano-photonic, bio-inspired nano-materials). The goal is to lay a foundation for a research career in the rapidly growing area of nanotechnology and to enhance student's competitiveness in the job market.

PHYSICS 4305 Bayesian Data analysis for the Sciences: 3 semester hours
Prerequisites: Consent of Instructor. This is a cross-disciplinary course in two parts. Part one covers Bayesian inference as applied to data analysis in general, with a special focus on the mathematics of model-selection in the physical and life sciences. Part two concentrates specifically on the Bayesian use of log-probability (i.e. information) measures to track order-disorder transitions in thermodynamics, and to track the evolution of subsystem correlations (via both digital and analog means) in a wide variety of complex systems. Expect weekly empirical observation exercises, and opportunities for asynchronous as well as synchronous collaboration.

PHYSICS 4306 Nanoscience Practicals: 1-3 semester hours
Studies of Nanoscience characterization, synthesis, modeling techniques designed for clients of these tools, as well as for technical users interested in a current overview. Course consists of a set of 1/3 semester modules. Check with the instructor on more specialized modules, (e.g. on materials microscopy), if interested. Each module will cover instrumentation, current applications, weaknesses, and will involve lab visits for hands-on experience, weekly web interaction and classroom hours.

PHYSICS 4310 Modern Electronics: 3 semester hours
An integrated recitation/laboratory study of modern analog and digital electronics with emphasis on integrated circuits. Topics include circuit elements, operational amplifiers, logic gates, counters, ac/dc converters, noise reduction, microprocessors, embedded microcontrollers, and digital processing. Three hours of lecture/laboratory per week.

PHYSICS 4311 Advanced Physics Laboratory I: 3 semester hours
Prerequisite: Advanced standing with at least nine completed hours of Physics at or above the 3000 level. Physics majors are introduced to the experimental techniques used in research. A student will choose and do several special problems during the semester. Six hours laboratory per week.

PHYSICS 4323 Modern Optics: 3 semester hours
Prerequisite: PHYSICS 3223. A study of modern optics including diffraction theory, polarization, light propagation in solids, quantum optics, and coherence.

PHYSICS 4331 Intro to Quantum Mechanics: 3 semester hours
Prerequisites: PHYSICS 3200 and PHYSICS 3231. Photons and the wave nature of particles; wave mechanics, Schrödinger equation, operator and matrix formulations, and Dirac notation; applications to single particle systems, atomic physics, and spectroscopy.

PHYSICS 4341 Thermal And Statistical Physics: 3 semester hours
Prerequisites: MATH 2000 and PHYSICS 3231. Introduction to statistical mechanics, classical thermodynamics, and kinetic theory.
PHYSICS 4343 Selected Topics in Physics I: 3 semester hours
Prerequisites: PHYSICS 3221, PHYSICS 3223, PHYSICS 3231, PHYSICS 4341. Topics include special phenomena for research areas such as physics of waves, biophysics, nonlinear physics, geophysical fluid dynamics and the atmospheric sciences treated by methods of advanced mechanics, electromagnetism, statistical mechanics, thermodynamics and quantum mechanics. Three hours of lecture per week.

PHYSICS 4347 Introduction to Biophysics: 4 semester hours
Prerequisites: PHYSICS 3221, BIOL 1821, and BIOL 1831; or permission of instructor. Introduction to the application of physical principles to problems in biology. The course will cover topics such as ion transport, protein folding, molecular motors, collective dynamics and self-assembly of biological systems, x-ray crystallography and NMR, a survey of medical imaging techniques, the relation between nonlinear dynamics and electrophysiology in the heart and brain, and physics-based approaches to modeling gene networks and evolutionary dynamics.

PHYSICS 4350 Computational Physics: 3 semester hours
Prerequisite: PHYSICS 3221, PHYSICS 3223, and PHYSICS 3231.
Computer analysis in physics; solutions of Eigenvalue problems; coupled differential equations; and writing of Fortran programs.

PHYSICS 4351 Elementary Solid State Physics: 3 semester hours
Prerequisites: PHYSICS 4331. Theoretical and experimental aspects of solid state physics, including one-dimensional band theory of solids; electron emission from metals and semiconductors; electrical and thermal conductivity of solids.

PHYSICS 4353 Physics of Fluids: 3 semester hours
Prerequisites: PHYSICS 3221, PHYSICS 3223, and PHYSICS 4341, or consent of instructor. Dynamical theory of gases and liquids. Course covers the mathematical development of physical fluid dynamics with contemporary applications.

PHYSICS 4358 Introduction to Global Geodynamics: 3 semester hours
Prerequisites: PHYSICS 3221 and PHYSICS 3223. This advanced course covers the development, from basic laws, of equations describing the many geodynamic processes underpinning geological modeling and geological data. Topics covered are paleomagnetism, plate tectonics, viscoelastic media, heat transfer, gravity, fluid mechanics, rheology, faulting, and geochronology.

PHYSICS 4365 Introduction to Plasma Physics: 3 semester hours
Prerequisites: PHYSICS 3223 and PHYSICS 4341. A study of the nonlinear collective interactions of ions, electrons, and neutral molecules with each other and with electric and magnetic fields. Topics include plasma confinement and stability, electrical discharges and ionization, kinetic theory of plasma transport, plasma waves and radiation, and controlled fusion. Solutions of the Boltzmann, Fokker-Planck, and Vlasov equations are discussed and methods of advanced electromagnetism and statistical physics are utilized.

PHYSICS 4370 Relativity and Cosmology: 3 semester hours
Prerequisites: PHYSICS 3221, PHYSICS 3223 and PHYSICS 3231. An introduction to Einstein's general theory of relativity. Topics will include special relativity in the formalism of Minkowski's four dimensional space-time, Principle of Equivalence, metric description of curved space, geodesic equation, Einstein Field Equation, black holes, and cosmology.

PHYSICS 4381 Directed Readings in Physics: 1-10 semester hours
Prerequisite: Consent of instructor. An independent study of special topics in physics for senior undergraduates or graduate students.

PHYSICS 5306 Advanced Nanoscience Practicals: 1-3 semester hours
Prerequisites: Graduate standing in physics or consent of instructor. Advanced studies of Nanoscience characterization, synthesis, and modeling techniques designed for clients of these tools, as well as for technical users interested in a current overview. The course consists of a set of 1/3 semester modules. Check with the instructor on more specialized modules, (e.g, on materials microscopy), if interested. Each module will cover instrumentation, current applications, and weaknesses and will involve lab visits for hands-on experience, weekly web interaction and classroom hours.

PHYSICS 5345 Nonlinear Dynamics and Stochastic Processes: 3 semester hours
Prerequisites: PHYSICS 3221 and PHYSICS 4341 and consent of instructor. Dynamical systems; theory of oscillations; introduction to bifurcation theory and chaos in dissipative systems with applications in physics and biology; introduction to stochastic processes with applications in physics, chemistry and biology; dynamics of nonlinear systems perturbed by noise; noise-induced phase transitions; linear and nonlinear time series analysis. Three classroom hours per week.

PHYSICS 5357 Fundamental Particles and Forces: 3 semester hours
Prerequisites: PHYSICS 3223, PHYSICS 3231, and PHYSICS 4331, may be taken concurrently Introduction to nuclear and particle physics. Nuclear phenomenology and models; high energy particle accelerators and detectors; phenomenology of strong, electromagnetic and weak interactions; symmetry principles; quark compositions of strongly interacting baryons and mesons; gauge theories and the standard model of particle interactions; grand unification.

PHYSICS 5370 Intermediate Relativity and Cosmology: 3 semester hours
Prerequisites: PHYSICS 3221, PHYSICS 3223, and PHYSICS 3231; or graduate standing. Topics will include special relativity in the formalism of Minkowski's four dimensional space-time, Principle of Equivalence, geodesic equation, Einstein Field Equation, black holes, and cosmology. Differential geometry from metric description to Riemann curvature tensor will be studied.

PHYSICS 5402 Introduction to Mathematical Physics: 3 semester hours
Prerequisites: Graduate standing in physics or consent of instructor. A course covering mathematical techniques as applied in advanced theoretical physics including generalized vector spaces and their dual spaces, linear operators and functionals, generalized functions, spectral decomposition of operators, tensor analysis, and complex variables. Three hours of lecture per week.

PHYSICS 5403 Principles of Mathematical Physics: 3 semester hours
Prerequisites: Graduate standing in physics or consent of instructor. Boundary value problems; Strum-Liouville theory and orthogonal functions; Green's function techniques; and introduction to group theory with emphasis on representations of Lie Algebras. Three hours of lecture per week.

PHYSICS 6300 Master's Thesis: 3 semester hours
Prerequisite: Consent of Instructor. Thesis work under the supervision of a faculty member. The course is designed for those students intending to present a thesis as part of their M.S. program. Students who do not write a thesis cannot apply PHYSICS 6300 to a degree. This course transfers to the Cooperative Ph.D. program as three research credits.

PHYSICS 6400 Special Problems: 1-5 semester hours
Must have faculty mentor and approval of Department Chairperson. A study of special topics in physics for graduate students.
**PHYSICS 6401 Special Topics: 1-4 semester hours**
Prerequisite: Consent of instructor. This course is designed to give the department an opportunity to test a new course.

**PHYSICS 6409 Theoretical Mechanics I: 3 semester hours**
Prerequisite: PHYSICS 3221. Classical mechanics, methods of Newton, Lagrange, and Hamilton applied to motion of particles and rigid bodies, elasticity, hydrodynamics.

**PHYSICS 6410 Seminar: 1-3 semester hours**
Prerequisite: Approval of Department Chair. Discussion of current topics.

**PHYSICS 6411 Electrodynamics I: 3 semester hours**
Prerequisite: PHYSICS 3223. A rigorous development of the fundamentals of electromagnetic fields and waves. Electrostatics, magnetostatics, Maxwell's equations, Green's functions, boundary value problems, multipoles, conservation laws.

**PHYSICS 6413 Statistical Mechanics: 3 semester hours**
Prerequisite: PHYSICS 4331, PHYSICS 4341. A study of statistical ensembles; Maxwell-Boltzmann, Fermi-Dirac and Einstein-Bose distribution laws, application to some physical systems.

**PHYSICS 6423 Electrodynamics II: 3 semester hours**

**PHYSICS 6461 Quantum Mechanics I: 3 semester hours**
Prerequisite: PHYSICS 4331. A study of the Schroedinger wave equation, operators and matrices, perturbation theory, collision and scattering problems.

**PHYSICS 6463 Quantum Mechanics II: 3 semester hours**
Prerequisite: PHYSICS 6461. Continuation of PHYSICS 6461. To include such topics as Pauli Spin-Operator Theory, classification of atomic states, introduction to field quantization, and Dirac Electron Theory.

**PHYSICS 6481 Physics of Solid State: 3 semester hours**
Prerequisite: PHYSICS 6461. Crystal symmetry, point and space groups, lattice vibrations, phonons, one-electron model, Hartee-Fock approximation, elementary energy band theory, transport properties, the Boltzmann equation, introduction to superconductivity, semiconductors and magnetism.

**PHYSICS 6490 Research: 1-10 semester hours**
Prerequisite: Must have a faculty mentor and approval of the department chair. Investigations of an advanced nature leading to the preparation of a thesis or dissertation.

**PHYSICS 6495 Continuous Registration: 1-6 semester hours**
Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy.