Department of Physics

Department Head: Jan J. Sojka
Location: Science Engineering Research 250A
Phone: (435) 797-2848
FAX: (435) 797-2492
E-mail: physics@cc.usu.edu
WWW: http://www.physics.usu.edu/

Assistant Department Head:
Charles G. Torre, Science Engineering Research 232,
(435) 797-3426, charles.torre@usu.edu

Academic Advisor:
Karalee Ransom, Science Engineering Research 250D,
(435) 797-4021, karalee.ransom@usu.edu

Degrees offered: Bachelor of Science (BS), Bachelor of Arts (BA), Master of Science (MS), and Doctor of Philosophy (PhD) in Physics; BS in Physics Teaching; BS in Composite Teaching—Physical Science (Physics)

Undergraduate emphases: *BS*—Professional Emphasis or Applied Emphasis

Graduate specializations: Electromagnetic Theory, Industrial Physics (MS only), Space Science, Surface Physics, Theoretical Physics, Upper Atmospheric Physics (MS only)

Undergraduate Programs

Objectives

The Physics Department embraces undergraduate students from all quarters of the University—in introductory courses required for majors by various departments, in courses for more general audiences that are part of the University Studies Program, and in upper-level courses designed primarily to fulfill bachelor's degree requirements in Physics. These courses, and the degree programs offered, are strongly impacted by the department's central goals:

1. to communicate the beauty and utility of the fundamental principles of the physical universe and the power of describing nature in quantitative terms,
2. to create new knowledge,
3. to foster critical and creative thinking,
4. to enhance the ability of citizens to participate in a technological democracy,
5. to assist in the preparation of elementary and secondary school teachers,
6. to provide opportunities for students to sharpen their communication and interpersonal skills, and
7. to develop new tools and texts to improve physics pedagogy.

The degree programs of the department are constructed to be rigorous, yet flexible, and are intended to help students prepare for careers in academia, government and industrial laboratories, medicine, law, teaching, and business. Required course and laboratory work in these programs carefully balances theory and experiment. Because the department believes one must participate in discovery to understand science, undergraduates are encouraged to engage in departmental research early in their studies, and a formal research experience is integral to most departmental programs. The department's Microgravity Research Team (MRT) activities provide excellent opportunities for students of all backgrounds to participate in space-related research.

Requirements

Departmental Admission and Graduation Requirements

New freshmen admitted to USU in good standing qualify for admission to the degree programs in Physics. Admission in good standing for students transferring from another institution requires a minimum transfer GPA of 2.2, while students transferring from another USU major are required to have a minimum total GPA of 2.0. Students wishing to complete the Teaching Major in Physics must apply for admission to the Secondary Education program as well. Requirements for admission to the **Secondary Teacher Education Program (STEP)** include a minimum GPA of 2.75 in either PHYS 2110 and 2120, or PHYS 2210 and 2220; and at least 60 total credits completed with a minimum GPA of 2.75. A Composite Teaching Major in Physical Science is available through either the Physics or the Chemistry and Biochemistry departments. Students applying for admission to the STEP with the Composite major must satisfy the latter requirements, plus a minimum GPA of 2.75 in CHEM 1210, 1215, 1220, and 1225.

Students may use no more than one course with the *P-D-F* option to satisfy a major or minor requirement in Physics. All other courses used to satisfy major or minor requirements must be completed with at least a *C-* grade, and the total GPA in all required Physics courses must be at least 2.3. The Teaching Major and Teaching Minor in Physics and the Composite Teaching Major in Physical Science require a 2.75 minimum GPA in Physics courses and a minimum 2.75 overall GPA for graduation.

College of Science Requirements

The College of Science requires a year of mathematics (8 credits) and a year sequence in science (6-8 credits) for all of its majors. For Physics majors, the College of Science requirements are:

MATH 1210 (QL) Calculus I, (F,Sp,Su) 4
MATH 1220 (QL) Calclulus II (F,Sp,Su) 4

Choose *one* of the following pairs of courses:
BIOL 1610 Biology I (F) (4 cr) **and**
BIOL 1620 (BLS) Biology II (Sp) (4 cr) 8
Or
CHEM 1210 Principles of Chemistry I (F,Sp) (4 cr) **and**
CHEM 1220 (BPS) Principles of Chemistry II (F,Sp,Su) (4 cr) 8
Or
GEO 1110 (BPS) The Dynamic Earth: Physical Geology (F,Sp) (4 cr) **and**
GEO 3200 (DSC) The Earth Through Time (Sp) (4 cr) 8

Bachelor's Degrees and Core Requirements

The Physics Department awards the following degrees: BS in Physics, BA in Physics, BS in Physics with a Professional Emphasis, BS in Physics with an Applied Emphasis, BS in Mathematics and Physics Dual Major Option, BS in Physics Teaching, and BS in Composite Teaching—Physical Science.

Except for the two Teaching Majors, all degrees require a common core (42 credits):

A. College of Science Requirements (16 credits)

B. Required Physics Courses (23 credits)

PHYS 2210 (QI) General Physics—Science and Engineering I (4 cr) **and**
PHYS 2220 (BPS/QI) General Physics—Science and Engineering II (4 cr) 8
Or
PHYS 2110 The Physics of Living Systems I (4 cr) **and**
PHYS 2120 (BPS) The Physics of Living Systems II (4 cr) 8
(PHYS 2210 and 2220 are preferred.)

PHYS 2500 Introduction to Computer Methods in Physics 2
PHYS 2710 Introductory Modern Physics 3
PHYS 3550 Intermediate Classical Mechanics 3
PHYS 3600 Intermediate Electromagnetism 3
PHYS 3870 (CI) Intermediate Laboratory I 2
PHYS 4900 (CI) Research in Physics 2

C. Required Mathematics Courses (7 credits)

MATH 2210 (QI) Multivariable Calculus (F,Sp,Su) 3
MATH 2250 (QI) Linear Algebra and Differential Equations (F,Sp,Su) 4

The specific requirements beyond this core for the various bachelor's degrees are:

1. Bachelor of Science Degree in Physics (11 credits)
PHYS 3710 Intermediate Modern Physics 3
PHYS 3700 Thermal Physics (3 cr) **or**
PHYS 4650 Optics I (3 cr) 3
Courses in Physics at the 3500 level and above (*not* to include PHYS courses designed as University Studies depth courses) 5

2. Bachelor of Arts Degree in Physics (28 credits)
PHIL 4310 (DHA) Philosophy of Science (Sp) 3
PHIL 4320 (DHA) History of Scientific Thought 3
Courses in Physics at the 3500 level and above (*not* to include PHYS courses designed as University Studies depth courses) 6
Two years training (or equivalent) in a foreign language 16

3. Bachelor of Science Degree in Physics with a Professional Emphasis (25 credits)
PHYS 3700 Thermal Physics 3
PHYS 3710 Intermediate Modern Physics 3
PHYS 3750 Foundations of Wave Phenomena 3
PHYS 3880 (CI) Intermediate Laboratory II 2
PHYS 4600 Advanced Electromagnetism 3
PHYS 4650 Optics I 3
PHYS 4700 Quantum Mechanics I 3
PHYS 4710 Quantum Mechanics II 3
PHYS 4900 (CI) Research in Physics 2

4. Bachelor of Science Degree in Physics with an Applied Emphasis (20 credits)
PHYS 3700 Thermal Physics 3
PHYS 3880 (CI) Intermediate Laboratory II 2
PHYS 4650 Optics I 3
Courses in other technical departments at the 3000 level or above (*not* to include courses designated as University Studies depth courses). Selected courses must have a coherent theme and must be approved by the Physics Department 12

5. Mathematics and Physics Dual Major Option
By fulfilling *all degree requirements* for *any two separate majors*, it is possible for a student to receive a diploma having two majors listed. Because most physics majors are required to complete a minimum of 14 credits in mathematics courses, many students elect to complete the requirements for a BS degree in mathematics, as well as the requirements for their physics degree.

Suggested Four-year Course of Study for Bachelor of Science Degree in Physics

The suggested schedule shown below should be used in conjunction with the major requirement sheet. Students should consult with their advisor to develop an individualized plan of study which is applicable to their interests and degree track.

Prior to enrolling in MATH 1220 (Calculus II), students must have completed MATH 1210 (Calculus I) with a grade of *C-* or better, ***or*** must have received an AP score of *at least 4* on the Calculus AB exam **or** *at least 3* on the Calculus BC exam.

Freshman Year (30 credits)

Fall Semester (15 credits)
PHYS 2210 (QI) General Physics—Science and Engineering I 4
MATH 1220 (QL) Calculus II 4
College of Science sequence requirement 4
University Studies Breadth course 3

Spring Semester (15 credits)
PHYS 2220 (BPS/QI) General Physics—Science and Engineering II 4
MATH 2210 (QI) Multivariable Calculus 3
College of Science sequence requirement 4
University Studies Breadth course 3
Elective course 1

Sophomore Year (30 credits)

Fall Semester (15 credits)
PHYS 2500 Introduction to Computer Methods in Physics 2
PHYS 2710 Introductory Modern Physics 3
MATH 2250 (QI) Linear Algebra and Differential Equations 4
ENGL 1010 (CL1) Introduction to Writing: Academic Prose 3
University Studies Breadth course 3

Spring Semester (15 credits)
PHYS 3710 Intermediate Modern Physics 3
University Studies Breadth courses 6
Elective courses 6

Junior Year (30 credits)

Fall Semester (14 credits)
PHYS 3550 Intermediate Classical Mechanics 3
PHYS 3600 Intermediate Electromagnetism 3
PHYS 3870 (CI) Intermediate Laboratory I 2
ENGL 2010 (CL2) Intermediate Writing: Research Writing in a Persuasive Mode 3
University Studies Depth course 3

Spring Semester (16 credits)
PHYS 3880 (CI) Intermediate Laboratory II (as elective credit) 2
PHYS elective course (if not taken sophomore spring) 3
University Studies Breadth course 3
University Studies Depth course 3
Elective courses 5

Senior Year (30 credits)
Fall Semester (15 credits)
PHYS 4650 Optics I (required if PHYS 3700 was not taken, or may be used as a physics elective) 3
Elective courses 12

Spring Semester (15 credits)
PHYS 3700 Thermal Physics (3 cr) **or**
Physics elective course at 3500-level or higher (3 cr) 3
PHYS 4900 (CI) Research in Physics 2
Elective courses 10

Suggested Four-year Course of Study for Bachelor of Arts Degree in Physics

The suggested schedule shown below should be used in conjunction with the major requirement sheet. Students should consult with their advisor to develop an individualized plan of study that is applicable to their interests and degree track.

Prior to enrolling in MATH 1220 (Calculus II), students must have completed MATH 1210 (Calculus I) with a grade of *C-* or better, ***or*** must have received an AP score of *at least 4* on the Calculus AB exam **or** *at least 3* on the Calculus BC exam.

Freshman Year (30 credits)
Fall Semester (15 credits)
PHYS 2210 (QI) General Physics—Science and Engineering I 4
MATH 1220 (QL) Calculus II 4
College of Science sequence requirement 4
University Studies Breadth course 3

Spring Semester (15 credits)
PHYS 2220 (BPS/QI) General Physics—Science and Engineering II 4
MATH 2210 (QI) Multivariable Calculus 3
College of Science sequence requirement 4
University Studies Breadth course 3
Elective course 1

Sophomore Year (30 credits)
Fall Semester (15 credits)
PHYS 2500 Introduction to Computer Methods in Physics 2
PHYS 2710 Introductory Modern Physics 3
MATH 2250 (QI) Linear Algebra and Differential Equations 4
ENGL 1010 (CL1) Introduction to Writing: Academic Prose 3
University Studies Breadth course 3

Spring Semester (15 credits)
PHIL 4310 (DHA) Philosophy of Science 3
University Studies Breadth courses 6
Elective courses 6

Junior Year (30 credits)
Fall Semester (15 credits)
PHYS 3550 Intermediate Classical Mechanics 3
PHYS 3870 (CI) Intermediate Laboratory I 2
ENGL 2010 (CL2) Intermediate Writing: Research Writing in a Persuasive Mode 3
University Studies Breadth course 3
Required language courses 4

Spring Semester (15 credits)
PHYS 3600 Intermediate Electromagnetism 3
PHYS 3710 Intermediate Modern Physics (3 cr) **or**
Elective course at 3500-level or higher (3 cr) 3
University Studies Depth Social Sciences (DSS) course 3
Required language courses 4
Elective course(s) 2

Senior Year (30 credits)
Fall Semester (15 credits)
PHYS elective course at 3500-level or higher 3
Required language courses 4
Elective courses 8

Spring Semester (15 credits)
PHYS 4900 (CI) Research in Physics 2
PHIL 4320 (DHA) History of Scientific Thought 3
Required language courses 4
Elective courses 6

Suggested Four-year Course of Study for Bachelor of Science Degree in Physics with Professional Emphasis

The suggested schedule shown below should be used in conjunction with the major requirement sheet. Students should consult with their advisor to develop an individualized plan of study that is applicable to their interests and degree track.

Prior to enrolling in MATH 1220 (Calculus II), students must have completed MATH 1210 (Calculus I) with a grade of *C-* or better, ***or*** must have received an AP score of *at least 4* on the Calculus AB exam **or** *at least 3* on the Calculus BC exam.

Freshman Year (30 credits)
Fall Semester (15 credits)
PHYS 2210 (QI) General Physics—Science and Engineering I 4
MATH 1220 (QL) Calculus II 4
College of Science sequence requirement 4
University Studies Breadth course 3

Spring Semester (15 credits)
PHYS 2220 (BPS/QI) General Physics—Science and Engineering II 4
MATH 2210 (QI) Multivariable Calculus 3
College of Science sequence requirement 4
University Studies Breadth course 3
Elective course 1

Sophomore Year (30 credits)
Fall Semester (15 credits)
PHYS 2500 Introduction to Computer Methods in Physics 2
PHYS 2710 Introductory Modern Physics 3
MATH 2250 (QI) Linear Algebra and Differential Equations 4
ENGL 1010 (CL1) Introduction to Writing: Academic Prose 3
University Studies Breadth course 3

Spring Semester (15 credits)
PHYS 3710 Intermediate Modern Physics 3
PHYS 3750 Foundations of Wave Phenomena 3
University Studies Breadth courses 6
Elective course(s) 3

Junior Year (30 credits)
Fall Semester (15 credits)
PHYS 3550 Intermediate Classical Mechanics 3
PHYS 3600 Intermediate Electromagnetism 3
PHYS 3870 (CI) Intermediate Laboratory I 2
ENGL 2010 (CL2) Intermediate Writing: Research Writing in a Persuasive Mode 3
University Studies Depth course 3
Elective course 1

Spring Semester (15 credits)
PHYS 3700 Thermal Physics 3
PHYS 3880 (CI) Intermediate Laboratory II 2
University Studies Breadth course 3
University Studies Depth course 3
Elective course(s) 4

Senior Year (30 credits)
Fall Semester (15 credits)
PHYS 4650 Optics I 3
PHYS 4700 Quantum Mechanics I 3
PHYS 4900 (CI) Research in Physics 2
Elective courses 7

Spring Semester (15 credits)
PHYS 4600 Advanced Electromagnetism 3
PHYS 4710 Quantum Mechanics II 3
PHYS 4900 (CI) Research in Physics 2
Elective courses 7

Suggested Four-year Course of Study for Bachelor of Science Degree in Physics with Applied Emphasis

The suggested schedule shown below should be used in conjunction with the major requirement sheet. Students should consult with their advisor to develop an individualized plan of study that is applicable to their interests and degree track.

Prior to enrolling in MATH 1220 (Calculus II), students must have completed MATH 1210 (Calculus I) with a grade of *C-* or better, ***or*** must have received an AP score of *at least 4* on the Calculus AB exam **or** *at least 3* on the Calculus BC exam.

Freshman Year (30 credits)
Fall Semester (15 credits)
PHYS 2210 (QI) General Physics—Science and Engineering I 4
MATH 1220 (QL) Calculus II 4
University Studies Breadth courses 6
Elective course 1

Spring Semester (15 credits)
PHYS 2220 (BPS/QI) General Physics—Science and Engineering II 4
MATH 2210 (QI) Multivariable Calculus 3
ENGL 1010 (CL1) Introduction to Writing: Academic Prose 3
University Studies Breadth course 3
Elective course(s) 2

Sophomore Year (30 credits)
Fall Semester (14 credits)
PHYS 2500 Introduction to Computer Methods in Physics 2
PHYS 2710 Introductory Modern Physics 3
MATH 2250 (QI) Linear Algebra and Differential Equations 4
College of Science sequence requirement 4
Elective course 1

Spring Semester (16 credits)
ENGL 2010 (CL2) Intermediate Writing: Research Writing in a Persuasive Mode 3
College of Science sequence requirement 4
University Studies Breadth courses 6
Elective course(s) 3

Junior Year (30 credits)
Fall Semester (15 credits)
PHYS 3870 (CI) Intermediate Laboratory I 2
PHYS 3550 Intermediate Classical Mechanics 3
University Studies Breadth course 3
Elective technical course at 3000-level or higher 3
Elective course(s) 4

Spring Semester (15 credits)
PHYS 3600 Intermediate Electromagnetism 3
PHYS 3880 (CI) Intermediate Laboratory II 2
Elective technical course at 3000-level or higher 3
University Studies Depth course 3
Elective course(s) 4

Senior Year (30 credits)
Fall Semester (15 credits)
PHYS 4650 Optics I 3
Elective technical course 3
University Studies Depth course 3
Elective courses 6

Spring Semester (15 credits)
PHYS 3700 Thermal Physics 3
PHYS 4900 (CI) Research in Physics 2
Elective technical course 3
Elective courses 7

Minor in Physics

Majors in other departments may obtain a minor in physics by successfully completing the following courses:
PHYS 2210 (QI) General Physics–Science and Engineering I (4 cr) **and**
PHYS 2220 (BPS/QI) General Physics—Science and Engineering II (4 cr) 8
Or
PHYS 2110 The Physics of Living Systems I (4 cr) **and**
PHYS 2120 (BPS) The Physics of Living Systems II (4 cr) 8
(PHYS 2210 and 2220 are preferred.)

To obtain a physics minor, students must also select 10 additional credits from PHYS 2500, 2710, and/or PHYS courses at the 3000 level and above (*not* to include PHYS courses designated as USU Depth courses). Note that MATH 1100 or 1210 is a prerequisite for PHYS 2110, MATH 1210 is a prerequisite for PHYS 2210, and MATH 1220 is a prerequisite for PHYS 2710.

Bachelor of Science in Physics Teaching with a Teaching Minor

In addition to the College of Science requirements, courses required for the Bachelor of Science in Physics Teaching with a Teaching Minor include the following:

MATH 1210 (QL) Calculus I (F,Sp,Su) 4
MATH 1220 (QL) Calculus II (F,Sp,Su) 4
MATH 2250 (QI) Linear Algebra and Differential Equations (F,Sp,Su) 4
STAT 3000 (QI) Statistics for Scientists (F,Sp,Su) 3

PHYS 2210 (QI) General Physics—Science and Engineering I (4 cr) **and**
PHYS 2220 (BPS/QI) General Physics—Science and Engineering II (4 cr) 8
Or (PHYS 2210, 2220 preferred; **or** PHYS 2110, 2120)
PHYS 2110 The Physics of Living Systems I (4 cr) **and**
PHYS 2120 (BPS) The Physics of Living Systems II (4 cr) 8

PHYS 1040 (BPS) Introductory Astronomy 3
PHYS 2500 Introduction to Computer Methods in Physics 2
PHYS 2710 Introductory Modern Physics 3
PHYS 3710 Intermediate Modern Physics 3
PHYS 3870 (CI) Intermediate Laboratory I 2
In addition, student must select 5 credits in Physics above the 3000 level (including USU Depth courses); SCI 4300; and 8 credits in science, with 4 credits minimum in each of the two areas not covered by the College of Science science sequence requirement.

Students seeking this degree must complete the requirements for the Secondary Teacher Education Program (STEP). Admission to the STEP with this major requires a minimum GPA of 2.75 in either PHYS 2110 and 2120 **or** PHYS 2210 and 2220, in addition to Department of Secondary Education requirements.

Note: Beginning in 2006, all USU teacher education candidates will be required to take and pass the content exam approved by the Utah State Office of Education in their major content area prior to student teaching.

Suggested Four-year Course of Study for Bachelor of Science Degree in Physics Teaching with a Teaching Minor

The suggested schedule shown below should be used in conjunction with the major requirement sheet. Students should consult with their advisor to develop an individualized plan of study that is applicable to their interests and degree track.

Prior to enrolling in MATH 1220 (Calculus II), students must have completed MATH 1210 (Calculus I) with a grade of *C-* or better, ***or*** must have received an AP score of *at least 4* on the Calculus AB exam **or** *at least 3* on the Calculus BC exam.

Freshman Year (30 credits)

Fall Semester (15 credits)
PHYS 2210 (QI) General Physics—Science and Engineering I 4
MATH 1220 (QL) Calculus II 4
General Science sequence requirement 4
University Studies Breadth course 3

Spring Semester (15 credits)
PHYS 2220 (BPS/QI) General Physics—Science and Engineering II 4
MATH 2250 (QI) Linear Algebra and Differential Equations 4
General Science sequence requirement 4
University Studies Breadth course 3

Sophomore Year (33 credits)

Fall Semester (17 credits)
PHYS 1040 (BPS) Introductory Astronomy 3
PHYS 2500 Introduction to Computer Methods in Physics 2
PHYS 2710 Introductory Modern Physics 3
ENGL 1010 (CL1) Introduction to Writing: Academic Prose 3
STAT 3000 (QI) Statistics for Scientists 3
University Studies Breadth course 3

Spring Semester (16 credits)
PHYS 3710 Intermediate Modern Physics 3
General Science requirement 4
University Studies Breadth courses 6
University Studies Depth course 3
Apply for STEP (Secondary Teacher Education Program)

Junior Year (31 credits)

Fall Semester (15 credits)
PHYS 3870 (CI) Intermediate Laboratory I 2
PHYS elective course at 3000-level or higher 3
ENGL 2010 (CL2) Intermediate Writing: Research Writing in a Persuasive Mode 3
General Science requirement 4
University Studies Breadth course 3

Spring Semester (16 credits)
PHYS elective course at 3000-level or higher 2
University Studies Breadth course 3
STEP Level 1 courses 11

Senior Year (29 credits)

Fall Semester (17 credits)
SCI 4300 Science in Society 2
University Studies Depth course 3
STEP Level 2 courses 12

Spring Semester (12 credits)
STEP Level 3 Student Teaching 12

Bachelor of Science Degree in Composite Teaching—Physical Science (91-92 credits)

Courses required for the Bachelor of Science in Composite Teaching—Physical Science include the following:
MATH 1210 (QL) Calculus I (F,Sp,Su) 4
MATH 1220 (QL) Calculus II (F,Sp,Su) 4
STAT 3000 (QI) Statistics for Scientists (F,Sp,Su) 3

PHYS 2210 (QI) General Physics—Science and Engineering I (4 cr) **and**
PHYS 2220 (BPS/QI) General Physics—Science and Engineering II (4 cr) 8
Or
PHYS 2110 The Physics of Living Systems I (4 cr) **and**
PHYS 2120 (BPS) The Physics of Living Systems II (4 cr) 8
(PHYS 2210 and 2220 are preferred.)

PHYS 1040 (BPS) Introductory Astronomy 3
PHYS 1080 (BPS) Intelligent Life in the Universe (sometimes listed as USU 1360, IPS: Intelligent Life in the Universe) (3 cr) **or**
PHYS 3030 (QI) The Universe (3 cr) 3
Courses in Physics from PHYS 2500, 2710, and/or PHYS courses at the 3000 level and above (including USU Depth courses) 5
CHEM 1210 Principles of Chemistry I (F,Sp) 4
CHEM 1215 Chemical Principles Laboratory I (F,Sp) 1
CHEM 1220 (BPS) Principles of Chemistry II (F,Sp,Su) 4
CHEM 1225 Chemical Principles Laboratory II (F,Sp) 1
CHEM 2300 Principles of Organic Chemistry (F) (3 cr) **or**
CHEM 2310 Organic Chemistry I (F) (4 cr) ..... 3 or 4
CHEM 2315 Organic Chemistry Laboratory I (F) 1
BIOL 1010 (BLS) Biology and the Citizen (F,Sp,Su) 3
GEO 1110 (BPS) The Dynamic Earth: Physical Geology (F,Sp) 4
CLIM 2000 (BPS) The Atmosphere and Weather (F,Sp) 3
SCI 4300 Science in Society (F,Sp) 2

Students seeking this degree must complete the requirements for the Secondary Teacher Education Program (STEP). Admission to the STEP with this major requires a minimum GPA of 2.75 in either PHYS 2110 and 2120 **or** PHYS 2210 and 2220, in addition to Department of Secondary Education requirements.

Students who may wish to teach Integrated Science at the middle or junior high school level should talk to their advisor about completing the courses necessary for an Integrated Science endorsement.

Note: Beginning in 2006, all USU teacher education candidates will be required to take and pass the content exam approved by the Utah State Office of Education in their major content area prior to student teaching.

Suggested Four-year Course of Study for Bachelor of Science Degree in Composite Teaching—Physical Science

The suggested schedule shown below should be used in conjunction with the major requirement sheet. Students should consult with their advisor to develop an individualized plan of study that is applicable to their interests and degree track.

Prior to enrolling in MATH 1220 (Calculus II), students must have completed MATH 1210 (Calculus I) with a grade of *C-* or better, ***or*** must have received an AP score of *at least 4* on the Calculus AB exam **or** *at least 3* on the Calculus BC exam.

Freshman Year (31 credits)

Fall Semester (15 credits)
PHYS 2210 (QI) General Physics—Science and Engineering I....4
MATH 1220 (QL) Calculus II....4
PHYS 1080/USU 1360 (BPS) Intelligent Life in the Universe....3
University Studies Breadth course....3
Elective course....1

Spring Semester (16 credits)
PHYS 2220 (BPS/QI) General Physics—Science and Engineering II....4
STAT 3000 (QI) Statistics for Scientists....3
BIOL 1010 (BLS) Biology and the Citizen....3
ENGL 1010 (CL1) Introduction to Writing: Academic Prose....3
University Studies Breadth course....3

Sophomore Year (32 credits)

Fall Semester (18 credits)
PHYS 1040 (BPS) Introductory Astronomy....3
GEO 1110 (BPS) The Dynamic Earth: Physical Geology....4
CHEM 1210 Principles of Chemistry I....4
CHEM 1215 Chemical Principles Laboratory I....1
CLIM 2000 (BPS) The Atmosphere and Weather....3
University Studies Breadth course....3

Spring Semester (14 credits)
CHEM 1220 (BPS) Principles of Chemistry II....4
CHEM 1225 Chemical Principles Laboratory II....1
ENGL 1010 (CL1) Introduction to Writing: Academic Prose....3
PHYS elective course at 2500-level or higher....3
University Studies Breadth course....3
Apply for STEP (Secondary Teacher Education Program)

Junior Year (31-33 credits)

Fall Semester (15-17 credits)
CHEM 2300 Principles of Organic Chemistry (3 cr) **or**
CHEM 2310 Organic Chemistry I (4 cr)....3 or 4
CHEM 2315 Organic Chemistry Laboratory I....1
ENGL 2010 (CL2) Intermediate Writing: Research Writing in a Persuasive Mode....3
University Studies Breadth course....3
University Studies Depth course....3
PHYS elective course at 2500-level or higher....2-3

Spring Semester (16 credits)
SCI 4300 Science in Society....2
University Studies Depth course....3
STEP Level I courses....11

Senior Year (24 credits)

Fall Semester (12 credits)
STEP Level 2 courses....12

Spring Semester (12 credits)
STEP Level 3 Student Teaching....12

Teaching Minor in Physics

Students who complete the Secondary Teacher Education Program (STEP) are eligible to obtain a Teaching Minor in Physics by successfully completing the following courses:
PHYS 1040 (BPS) Introductory Astronomy....3

PHYS 2210 (QI) General Physics—Science and Engineering I (4 cr) **and**
PHYS 2220 (BPS/QI) General Physics—Science and Engineering II (4 cr)....8
Or
PHYS 2110 The Physics of Living Systems I (4 cr) **and**
PHYS 2120 (BPS) The Physics of Living Systems II (4 cr)....8
(PHYS 2210 and 2220 are preferred.)

Courses in Physics chosen from PHYS 2500, 2710, and/or courses above the 3000 level (including USU Depth courses)....6

SCI 4300 Science in Society (F,Sp) (2 cr) **or**
Science course (not including Physics) not required by the major, if SCI 4300 is required by the student's major (2-3 cr)....2 or 3

Note: MATH 1100 or 1210 is a prerequisite for PHYS 2110, MATH 1210 is a prerequisite for PHYS 2210, and MATH 1220 is a prerequisite for PHYS 2710.

In addition, the Teaching Minor in Physics requires completion of the Secondary Teacher Education Program (STEP). Admission to the STEP with this major requires a minimum GPA of 2.75 in either PHYS 2110 and 2120, **or** PHYS 2210 and 2220, in addition to Department of Secondary Education requirements.

Secondary Teacher Education Program (STEP) (35 credits)

Level 1 (11 credits)
SCED 3100 Motivation and Classroom Management (F,Sp)....3
SCED 3210 (CI/DSS) Educational and Multicultural Foundations (F,Sp)....3
SCED 3300 Clinical Experience I (40 hours minimum) (F,Sp)....1
SCED 3400 Teaching Science I (F,Sp)....3
INST 3500 Technology Tools for Secondary Teachers (F,Sp,Su)....1

Level 2 (12 credits)
SCED 4200 (CI) Reading, Writing, and Technology (F,Sp) 3
SCED 4210 Cognition and Evaluation of Student Learning (F,Sp) 3
SCED 4300 Clinical Experience II (40 hours minimum) (F,Sp) 1
SCED 4400 Teaching Science II (F,Sp) 3
SPED 4000 Education of Exceptional Individuals (may be taken at any time) (F,Sp,Su) 2

Level 3 (12 credits)
SCED 5500 Student Teaching Seminar (2 weeks) (F,Sp) 2
SCED 5630 Student Teaching in Secondary Schools (13 weeks, full-time) (F,Sp) 10

Undergraduate Research Opportunities

The Physics Department at Utah State University has a long record of successfully involving its undergraduate students in research and extracurricular scholarly activities. Learning what science is requires more than just doing homework and taking exams; it requires getting involved in the pursuit of knowledge that is not yet in any textbook. Undergraduates can take PHYS 4900 (Research in Physics) for academic credit. However, many students participate in research activities without credit, because they enjoy being immersed in the act of discovery. Having a meaningful research experience and working closely with faculty are useful for applying for employment, admission to graduate schools, and applying for competitive scholarships. For more information, contact David Peak at david.peak@usu.edu, or visit the following website:
http://www.physics.usu.edu/research/undergrad.html

Departmental Honors

Students who would like to experience greater academic depth within their major are encouraged to enroll in departmental honors. Through original, independent work, Honors students enjoy the benefits of close supervision and mentoring, as they work one-on-one with faculty in select upper-division departmental courses. Honors students also complete a senior project, which provides another opportunity to collaborate with faculty on a problem that is significant, both personally and in the student's discipline. Participating in departmental honors enhances students' chances for obtaining fellowships and admission to graduate school. Minimum GPA requirements for participation in departmental honors vary by department, but usually fall within the range of 3.30-3.50. Students may enter the Honors Program at almost any stage in their academic career, including at the junior (and sometimes senior) level. The campus-wide Honors Program, which is open to all qualified students regardless of major, offers a rich array of cultural and social activities, special classes, and the benefit of Honors early registration. Interested students should contact the Honors Program, Main 15, (435) 797-2715, honors@cc.usu.edu. Additional information can be found online at: **http://www.usu.edu/honors/**

Learning Objectives

The Physics Department has the following learning objectives. While many of these objectives are applicable to all six departmental programs, some apply only to specific programs. To see which program(s) includes each learning objective, see the footnotes which follow.

1. Capable communication, written and oral[1,2,3,4,5,6]
2. Skepticism[1,2,3,4,5,6]
3. Ability in critical thinking and problem solving[1,2,3,4,5,6]
4. Knowledge of physics subjects to an advanced undergraduate level[1,2,3,4,5,6]
5. Wide knowledge of physics subjects to an advanced undergraduate level[2,3]
6. Knowledge of focused applied areas of study to the undergraduate level[4]
7. Experience in experimental physics[1,2,3,4,5,6]
8. Experience in physics research[1,2,3,4,5,6]
9. Knowledge of computer methods in physics[1,2,3,4,5,6]
10. Knowledge of broadening subjects[1,2,3,4,5,6]
11. Knowledge of mathematics to undergraduate calculus level[1,2,3,4,5,6]
12. Knowledge of mathematics to undergraduate differential equations level[1,2,3,4,5]
13. Knowledge of statistics to undergraduate level[5,6]
14. Knowledge of philosophy of science to the undergraduate level[1]
15. Knowledge of a foreign language to the undergraduate level[1]

Programs:
The footnotes following each of the preceding learning objectives indicate which program(s) include that objective. The six undergraduate programs are as follows:

[1]BA degree in physics
[2]BS degree in physics
[3]BS degree in physics with professional emphasis
[4]BS degree in physics with applied emphasis
[5]BS degree in physics teaching
[6]BS degree in composite teaching

Assessment

The Physics Department supports an ongoing program of assessment based upon input from students, alumni, colleagues, professional organizations, etc. For details, see:
http://www.physics.usu.edu/assessment/assessment.htm

Financial Support

The Physics Department has several small scholarship funds available for physics majors with excellent academic records. In addition, there are a number of Microgravity Research Team (MRT) scholarships for students interested in designing and constructing experiments to be flown in space and in participating in other MRT activities. Inquiries should be made with the Physics advisor in SER 250.

Additional Information

Information concerning degree programs, recommended schedules of courses, career opportunities, and opportunities to participate in the Microgravity Research Team (MRT) activities and in other areas of undergraduate research may be obtained by consulting the Physics advisor in SER 250. Also see the department's website at: **http://www.physics.usu.edu/**

Major requirement sheets, which provide details of undergraduate programs in physics, can be obtained from the department, or online at: **http://www.usu.edu/majorsheets/**

Graduate Programs

Admission Requirements

In addition to the general requirements for admission established by the School of Graduate Studies (see pages 101-102), the department admission committee bases its decisions for offering admission on the following criteria: review of applicants' undergraduate records, letters of recommendation, performance in graduate courses (if any), performance in research (if any), and scores on the General portion of the Graduate Record Examination. Students whose native language is not English are strongly encouraged to submit to the School of Graduate Studies results of the Test of Spoken English (TSE). Regardless, nonnative English speakers must submit a score for the Test of English as a Foreign Language (TOEFL). If a satisfactory score on the TSE is not provided, such students will be required to take a test given by the Intensive English Language Institute (IELI) at USU. The purpose of this test is to guide the selection of remedial language courses, if needed, to help with physics coursework comprehension. (See also *Financial Assistance*, pages 462-463.)

Placement

Prior to registering for graduate courses for the first time, each student will consult with the Graduate Student Tracking Committee and the departmental advisor. Based on these discussions, the student will be advised to register for courses in either the Physics Department standard curriculum or advanced curriculum. Continuing advisement concerning courses will be provided by the Graduate Student Tracking Committee, the departmental advisor, and the student's graduate supervisory committee.

Qualification Requirements

Each student enrolled in the PhD program will be evaluated for qualification for PhD work. Consideration of qualification will occur no later than the end of the second semester after the student has been admitted for study in the PhD program and has taken a first graduate course in physics. Evaluation will be based on whatever relevant information the student wishes to have presented on his or her behalf (coursework, research, TA performance, subject GRE, etc.), but must include a faculty evaluation of coursework in physics for courses taken at USU. Normally, the student should present the results of at least four physics courses. Students admitted to the PhD program with considerable coursework from another institution, who have not taken at least four courses in physics at USU, must present a qualification seminar to the Department of Physics on research he or she has done during the preceding year at USU. Based on the various pieces of information presented on behalf of the student, the department will judge whether or not the student is qualified to continue in the PhD program. If not, a student already having an MS in physics from USU will be asked to leave. A student without an MS in physics from USU will be invited to finish his or her MS degree. Upon completion, the student can reapply to the PhD program, but acceptance will be contingent on the evaluation of the student's graduate work to that point.

Degree Programs

Master of Science

In addition to the above general requirements, students completing a Plan A MS degree must complete four of the nine required PhD courses listed below (see Doctor of Philosophy). Plan B MS students must complete five of the nine courses, and Plan C MS students must complete six of the nine courses. Each student is required to pass PHYS 5800 (Physics Colloquium) for four consecutive semesters, beginning with the first semester after matriculation. The student must also submit and orally defend either a thesis (Plan A) or a research report (Plan B) at the discretion of the student's supervisory committee. Plan A and Plan B MS candidates must present a colloquium to the department on the research topic during the time the thesis or research report is being written. The department also accepts Plan C, which has no research component. For Plan C, the student must complete 33 credits of graduate-level classwork, the composition of which shall include the required courses listed above. In addition, the student must present a seminar and a paper to his or her supervisory committee on a topic related to educational or managerial aspects of physics graduate education, which is chosen by his or her supervisory committee.

Master of Science (Upper Atmospheric Physics Specialization)

The department offers a specialization in Upper Atmospheric Physics for MS students. This degree is a Plan A MS. In consultation with his or her advisor, the student selects a minimum of 18 credits of classwork from the following courses:

PHYS 4600 Advanced Electromagnetism 3
PHYS 6240 Space Environment and Engineering 3
PHYS 6310 Solar-terrestrial Physics I 3
PHYS 6320 Solar-terrestrial Physics II 3
PHYS 6330 Plasma Physics I 3
PHYS 6340 Plasma Physics II 3
PHYS 7210 Spacecraft Instrumentation (Sp) 3
PHYS 7500 Advanced Topics in Physics (Topic) 3

Three to six additional credits may be chosen from courses in electrical engineering, computer science, mathematics, and biometeorology. The student may gain from 6 to 12 credits by research, to be written up as a thesis that must be defended orally. In addition, the student must present a colloquium on the topic of his or her research.

Doctor of Philosophy

In addition to the general requirements, a total of nine courses (27 credits) are required for all PhD students. The required courses are:

PHYS 5340 Methods of Theoretical Physics I 3
PHYS 5350 Methods of Theoretical Physics II 3
PHYS 6010 Classical Mechanics I 3
PHYS 6110 Electrodynamics I 3
PHYS 6210 Quantum Mechanics I 3
PHYS 6410 Statistical Mechanics I 3
One State of Matter course 3
Two courses in Advanced Topics 6

The State of Matter requirement can be fulfilled by taking any one of PHYS 6330 (Plasma Physics I), 6530 (Solid State Physics I), or 6930 (Quantum Field Theory I). These courses must be completed no more than one year after PhD qualification. Each student is required to pass PHYS 5800 (Physics Colloquium) for four consecutive semesters, beginning with the first semester after matriculation. The student must also take an oral candidacy examination, consisting of a presentation made by the student, then followed by questions from departmental faculty. The presentation and questions will be based upon a research topic set by the student's supervisory committee. The candidacy oral examination will normally occur no later than the fifth semester after the student begins graduate coursework. The student will have at least two months to prepare for the examination.

The student must also complete a research dissertation and give an oral defense of the dissertation. Furthermore, the PhD candidate is expected to give two colloquia to the department. The first of these will normally be given at the time of submission of the research proposal, with the other given at the time the dissertation is completed.

Research

Space Science

The Physics Department is active in the field of atmospheric and space science, in close association with the interdisciplinary Center for Atmospheric and Space Sciences and the Space Dynamics Laboratory. Atmospheric and space science involves many areas of physics, in addition to such disciplines as engineering, chemistry, and meteorology. At USU, these groups enjoy a strong cooperative relationship and, as a result, the atmospheric and space science program has flourished for many years. Once the departmental requirements have been met, students may select courses from the offerings of the associated departments suited for their particular interests and needs while they gain research experience on challenging problems in atmospheric and space science. Opportunities are available for students in both experimental and theoretical projects. These include participation in instrument development and data analysis related to rocket, satellite, and space shuttle projects and projects in experimental design and data analysis related to incoherent-scatter and coherent radars, ground-based magnetometer, and ground-based optical instruments including a LIDAR system. Opportunities also exist in theoretical modeling of physical processes occurring in both the neutral atmosphere and in the plasma in the solar-terrestrial environment.

Plasma Theory and Confinement

Research in the field of magnetic confinement fusion at Utah State University includes the theoretical development and experimental realization of minimum-energy confinement configurations possessing substantial electric fields. These configurations hold promise as neutron and energy sources and are being developed as a collaborative effort between Dr. Farrell Edwards and Dr. Eric Held. In addition, Dr. Held is involved in developing improved hybrid fluid/kinetic models for terrestrial and astrophysical plasmas. This work provides theoretical support for next-step fusion experiments such as the International Thermonuclear Experimental Reactor (ITER).

Surface Physics

The surface physics group has an active experimental research program studying the structure, growth, dynamics, electronic properties, and optical properties of surfaces, interfaces, and adsorbed layers. The group has expertise in the interactions of electrons, ions, and photons with materials. Experimental techniques used within the group include atomic force microscopy (AFM), Auger electron spectroscopy (AES), infrared spectroscopy, ion scattering spectroscopy, ion implantation, low-energy electron diffraction (LEED), photoemission spectroscopy, scanning electron microscopy (SEM), scanning tunneling microscopy (STM), secondary ion mass spectroscopy (SIMS), thermal deflection spectroscopy, ultrafast femtosecond laser spectroscopy, vapor pressure adsorption isotherms, and x-ray diffraction. This interdisciplinary research brings together the fields of solid-state physics, surface physics and chemistry, optics, physical chemistry, and electrochemistry through active collaborations between Physics, Chemistry and Biochemistry, Mechanical and Aerospace Engineering, and other departments. It includes both basic and applied research.

Physics of Quantum Devices

The rapid advance of technology has made quantum physics an indispensable foundation of the nanoscale devices. The Physics Department is positioned to explore this new field with two complementary research themes. The first theme is to study the growth of novel electronic/photonic materials involving group III-V elements using a commericial, state-of-the-art molecular beam epitaxy machine. Also, novel semiconductor quantum nanostructures are studied using an *in-situ* scanning tunneling microscope directly attached to the machine. The second theme is to use the most advanced surface science techniques to fabricate nanoscale structures on semiconductor surfaces. The interdisciplinary nature of this field provides a stimulating research environment for faculty and students with backgrounds in physics, electrical engineering, material sciences, and chemistry.

Theoretical Physics

The department maintains an active research program in theoretical physics via its Field Theory Group. The principal focus of this group is on unified field theories, gravitational theory, classical and quantum field theory, and geometric methods in mathematical physics. Current research projects include: conformal and scale invariant gravity theories and unified field theories, Weyl-geometric quantization, exact solutions in Gauss-Bonnet extended gravity, classical and quantum dynamics of the gravitational field, symmetries and conservation laws in relativistic field theories, Lagrangian and Hamiltonian formulation of field theory, and application of geometrical methods in physics.

Physics Education

The USU Physics Department is engaged in the study of how to improve the teaching and learning of physics. The program currently emphasizes introductory and general education courses and involves development of hands-on, inquiry-based curricula for lecture and laboratory, development of associated laboratory and multimedia equipment and modules, preparation of new texts and workbooks, sponsorship of undergraduate research, and outreach to the pre-college community.

Complex Materials and Dynamics

Current work at USU in the interdisciplinary area of complex systems includes theoretical and experimental studies of the physical properties of granular materials, liquid flow in fractured media, and development of new data analysis techniques for uncovering evidence for determinism and computation in biological systems.

Financial Assistance

Financial assistance in the form of teaching assistantships and fellowships is awarded by the department. Research assistantships are available from research groups or individuals. Some support for teaching laboratory sections or grading papers is available. To be eligible for a teaching assistantship (TA), a student must successfully

complete a graduate TA workshop. Nonnative English-speaking students must pass a test of spoken English (or submit a satisfactory TSE score) administered by the Intensive English Language Institute before being admitted to the TA workshop. The MS specialization in Upper Atmospheric Physics is a Western Regional Graduate Program (see page 100).

Career Opportunities

Master's degree holders in physics are generally employed by industrial or government laboratories as either physicists or engineers. Some are hired as teachers by high schools and by two-year colleges. Holders of the PhD in physics will generally be hired as research and development physicists by industrial or government laboratories and as professors in universities (though this may require additional postdoctoral research experience).

Additional Information

Regularly updated information about Physics Department activities and programs may be obtained via the Web at:
http://www.physics.usu.edu/

Physics Faculty

Professors
J. R. Dennison, surface physics
W. Farrell Edwards, electromagnetic and plasma theory
Bela G. Fejer, space plasma physics
David Peak, nonlinear dynamics, complex materials
Robert W. Schunk, space plasma physics
Jan J. Sojka, atmospheric and space physics
Michael J. Taylor, atmospheric and space physics
Charles G. Torre, mathematical and gravitational physics
Vincent B. Wickwar, atmospheric and space physics

Research Professors
F. Tom Berkey, atmospheric and space physics
Kent L. Miller, atmospheric physics
Thomas D. Wilkerson, atmospheric and space physics

Adjunct Professors
Stephen E. Bialkowski, nonlinear optics and laser spectroscopy
Yeaton H. Clifton, mathematical physics
Raymond DeVito, medical physics
Leonard F. Hall, structure forming systems
Allen Q. Howard, electromagnetic theory
R. Gilbert Moore, space physics
David Rees, atmospheric physics
Ray W. Russell, astronomy
Neal D. Shinn, surface interface physics
John R. Tucker, device physics and superconductivity

Professors Emeritus
Wilford N. Hansen, reflection spectroscopy, surface physics
Eastman N. Hatch, nuclear physics
Don L. Lind, space physics
V. Gordon Lind, medium energy nuclear physics
William R. Pendleton, Jr., atomic and molecular physics
W. John Raitt, space plasma physics
John K. Wood, spectroscopy

Associate Professors
Eric D. Held, plasma physics
D. Mark Riffe, surface physics
Tsung-Cheng Shen, surface physics, nanotechnology
James T. Wheeler, mathematical physics, field theory

Research Associate Professors
Abdallah R. Barakat, space plasma physics
Howard G. Demars, space physics
Timothy E. Doyle, random and disordered systems
J. Steven Hansen, image processing
Ajay Singh, plasma physics
Lie Zhu, space physics

Adjunct Associate Professors
K. S. Balasubramanian, solar physics
I. Lee Davis, condensed matter physics
Hugo deGaris, artificial intelligence
James S. Dyer, space contamination and outgassing
Jill A. Marshall, physics education
David J. Vieira, nuclear physics
Vladimir Zavyalov, condensed matter physics

Associate Professor Emeritus
Robert E. McAdams, nuclear physics

Assistant Professor
Haeyeon Yang, surface physics, nanotechnology

Adjunct Assistant Professor
Jeremy R. King, astrophysics

Lecturer
Tonya B. Triplett, physics education

Course Descriptions

Physics (PHYS), click here