Physics

Raymond E. Frey, Department Head
541-346-5826
541-346-5861 fax
120 Willamette Hall
1274 University of Oregon
Eugene, Oregon 97403-1274

Physics, the most basic of the natural sciences, is concerned with the discovery and development of the laws that describe our physical universe. This endeavor serves, also, to directly benefit humankind: integrated circuits found in computers, mobile phones, and solar cells, lasers in DVD players and computer mice, and the Internet itself were developed from fundamental physics discoveries.

Faculty

Benjamín Alemán, assistant professor (experimental condensed matter, optical physics). BS, 2004, Oregon; MA, 2010, PhD, 2011, California, Berkeley. (2013)

Dietrich Belitz, professor (condensed matter theory). Dipl Phys, 1980, Dr.rer.nat., 1982, Technical University Munich. (1987)

Gregory D. Bothun, professor (astronomy). BS, 1976, PhD, 1981, Washington (Seattle). (1990)

James E. Brau, Philip H. Knight Professor (experimental elementary particle physics). BS, 1969, United States Air Force Academy; MS, 1970, PhD, 1978, Massachusetts Institute of Technology. (1988)

Spencer Chang, assistant professor (theoretical high-energy physics). BS, 1999, Stanford; PhD, 2004, Harvard. (2010)

Timothy Cohen, assistant professor (elementary particle theory). BS, 2006, MS, 2009, PhD, 2011, Michigan, Ann Arbor. (2015)

Eric Corwin, assistant professor (biophysics, soft condensed matter). BA, 2001, Harvard; PhD, 2007, Chicago. (2010)

Paul L. Csonka, professor (elementary particle theory). PhD, 1963, Johns Hopkins. (1968)

Nilendra G. Deshpande, professor (elementary particle theory). BSc, 1959, MSc, 1960, Madras; PhD, 1965, Pennsylvania. (1975)

Miriam Deutsch, professor (optical physics). BSc, 1988, PhD, 1996, Hebrew. (2000)

Russell J. Donnelly, professor (physics of fluids, superfluidity, astrophysics). BSc, 1951, MSc, 1952, McMaster; MS, 1953, PhD, 1956, Yale. (1966)

R. Scott Fisher, lecturer (astronomy). BS, 1993, PhD, 2001, Florida. (2012)

Raymond E. Frey, professor (experimental elementary particle physics). BA, 1978, California, Irvine; MS, 1981, PhD, 1984, California, Riverside. (1989)

Stephen Gregory, associate professor (solid state physics). BSc, 1969, Manchester; MSc, 1970, Essex; PhD, 1975, Waterloo. (1992)

Roger Haydock, professor (solid state theory). BA, 1968, Princeton; MA, PhD, 1972, ScD, 1989, Cambridge. (1982)

James N. Imamura, professor (astrophysics); director, Institute of Theoretical Science. BA, 1974, California, Irvine; MA, 1978, PhD, 1981, Indiana. (1985)

Timothy Jenkins, senior instructor (physics education). BA, 1975, Linfield College; PhD, 1992, Clarkson. (1992)

Stephen D. Kevan, professor (solid state physics). BA, 1976, Wesleyan; PhD, 1980, California, Berkeley. (1985)

Graham Kribs, Alec and Kay Keith Professor in Physics (elementary particle theory). BASc, 1993, Toronto; PhD, 1998, Michigan, Ann Arbor. (2004)

Dean W. Livelybrooks, senior instructor (geophysics). BS, 1977, Massachusetts Institute of Technology; MS, 1984, PhD, 1990, Oregon. (1996)

Stephanie Majewski, assistant professor (experimental elementary particle physics). BS, 2002, Illinois, Urbana-Champaign; PhD, 2007, Stanford. (2012)

Brian W. Matthews, College of Arts and Sciences Distinguished Professor (protein crystallography). BSc, 1959, BSc, 1960, PhD, 1964, Adelaide. (1969)

Benjamin McMorran, assistant professor (experimental condensed matter, optical physics). BS, 2000, Oregon State; MS, PhD, 2009, Arizona. (2011)

Stanley J. Micklavzina, senior instructor (physics education). BS, 1982, MS, 1985, Oregon. (1985)

Jens Nöckel, associate professor (optical physics). Dipl. Phys., 1992, Hamburg; PhD, 1997, Yale. (2001)

Raghuveer Parthasarathy, associate professor (condensed matter physics, biophysics). BA, 1997, California, Berkeley; PhD, 2002, Chicago. (2006)

Michael G. Raymer, Philip H. Knight Professor (quantum optics and optical physics). BA, 1974, California, Santa Cruz; PhD, 1979, Colorado. (1988)

Stephen J. Remington, professor (protein crystallography). BS, 1971, Oregon State; PhD, 1977, Oregon. (1985)

James M. Schombert, Noble F. and Frances L. Miller Professor in Astrophysics (astronomy). BS, 1979, Maryland; MPhil, 1982, PhD, 1984, Yale. (1996)

Davison E. Soper, professor (elementary particle theory). BA, 1965, Amherst; PhD, 1971, Stanford. (1977)

Daniel Steck, associate professor (atom optics and nonlinear dynamics). BS, 1995, Dayton; PhD, 2001, Texas, Austin. (2004)

David M. Strom, professor (experimental elementary particle physics). BA, 1980, St. Olaf; PhD, 1986, Wisconsin, Madison. (1991)

Richard P. Taylor, professor (solid state physics). BS, 1985, PhD, 1988, Nottingham. CAD, 1995, Manchester School of Art; MA, 2000, New South Wales. (1999)

John J. Toner, professor (condensed matter theory). BS, 1977, Massachusetts Institute of Technology; MA, 1979, PhD, 1981, Harvard. (1995)

Eric Torrence, professor (experimental elementary particle physics). BS, 1990, Washington (Seattle); PhD, 1997, Massachusetts Institute of Technology. (2000)

Steven J. van Enk, professor (theoretical optical physics). MSc, 1988, Utrecht; PhD, 1992, Leiden. (2006)

Hailin Wang, professor (quantum optics). BS, 1982, Science and Technology (China); MS, 1986, PhD, 1990, Michigan. (1995)

Special Staff

Robert Schofield, senior research associate (nuclear biophysics). BS, 1982, Brigham Young; PhD, 1990, Oregon. (1993)

Nikolai Sinev, senior research associate (experimental high energy physics). BS, 1968, PhD, 1974, Moscow State. (1993)

Frank Vignola, senior research associate (solar energy). BA, 1967, California, Berkeley; MS, 1969, PhD, 1975, Oregon. (1977)

Emeriti

Bernd Crasemann, professor emeritus. AB, 1948, California, Los Angeles; PhD, 1953, California, Berkeley. (1953)

Marvin D. Girardeau, professor emeritus. BS, 1952, Case Institute of Technology; MS, 1954, Illinois; PhD, 1958, Syracuse. (1963)

Rudolph C. Hwa, professor emeritus. BS, 1952, MS, 1953, PhD, 1957, Illinois; PhD, 1962, Brown. (1971)

Harlan Lefevre, professor emeritus. BA, 1951, Reed; PhD, 1961, Wisconsin. (1961)

Joel W. McClure Jr., professor emeritus. BS, 1949, MS, 1951, Northwestern; PhD, 1954, Chicago. (1954)

David K. McDaniels, professor emeritus. BS, 1951, Washington State; MS, 1958, PhD, 1960, Washington (Seattle). (1963)

John T. Moseley, professor emeritus. BS, 1964, MS, 1966, PhD, 1969, Georgia Institute of Technology. (1979)

Jack C. Overley, professor emeritus. BS, 1954, Massachusetts Institute of Technology; PhD, 1960, California Institute of Technology. (1968)

Kwangjai Park, professor emeritus. BA, 1958, Harvard; PhD, 1965, California, Berkeley. (1966)

George W. Rayfield, professor emeritus. BS, 1958, Stanford; PhD, 1964, California, Berkeley. (1967)

David R. Sokoloff, professor emeritus. BA, 1966, City University of New York, Queens; PhD, 1972, Massachusetts Institute of Technology. (1978)

Robert L. Zimmerman, professor emeritus. BA, 1958, Oregon; PhD, 1963, Washington (Seattle). (1966)

The date in parentheses at the end of each entry is the first year on the University of Oregon faculty.

- **Bachelor of Arts: Applied Physics**
- **Bachelor of Arts: Teaching Physics** (p. 4)
- **Bachelor of Arts: Physics**
- **Bachelor of Science: Applied Physics**
- **Bachelor of Science: Teaching Physics**
- **Bachelor of Science: Physics**
- **Minor**

Undergraduate Studies

As it involves the development of analytical, technical, problem-solving, and science communication skills, a major in physics provides a good start for many career paths. In addition to major and minor programs, the Department of Physics offers a variety of courses for nonmajors and health science premajor students.

Preparation

Entering freshmen should have taken as much high school mathematics as possible in preparation for starting calculus in their freshman year. High school study of physics and chemistry is desirable.

Transfer Students

Because of the sequential nature of the physics curriculum, it is useful for students from two-year colleges to complete as much as possible of calculus, differential equations, several-variable calculus, chemistry, and calculus-based physics (part of an associate's degree) before transferring.

Years Completed Before Transfer	Suggested Completed Courses	UO Equivalent Courses
Two, more than two	One year of differential and integral calculus	MATH251–253
Two, more than two	One year of calculus general physics with laboratory	PHYS251–253, PHYS290
Two, more than two	General chemistry	CH221–222 or CH224H–225H
Two, more than two	One term of differential equations and two terms of multivariable calculus	MATH256, MATH281–282
More than two	Second year of physics	

Transfer students should also have completed as many as possible of the university requirements for the bachelor’s degree (see Bachelor’s Degree Requirements (http://catalog.uoregon.edu/archive/2015-2016/bachelorrequirements)).

Careers

Fifty percent of graduates with bachelor’s degrees in physics find employment in the private sector working as applied physicists, software developers, managers, or technicians, typically alongside engineers and computer scientists. About 30 percent of students who earn an undergraduate degree continue their studies in a graduate degree program, leading to a career in teaching or research or both at a university, at a government laboratory, or in industry. In addition, a degree in physics is good preparation for a career in business. Students who have demonstrated their ability with a good record in an undergraduate physics program are generally considered very favorably for admission to medical and other professional schools.

Major Requirements

The major in physics leads to a bachelor of arts (BA) or a bachelor of science degree (BS). Complete requirements are listed under **Bachelor's Degree Requirements** . The bachelor of arts degree has a second-language requirement. Knowledge of a language other than English is recommended for students planning graduate study in physics.

Required courses must be taken for letter grades and a grade point average of 2.00 (mid-C) or better must be earned in these courses. Courses beyond the minimum requirement may be taken pass/no pass (P/N). At least 20 of the upper-division credits must be completed in residence at the University of Oregon. Exceptions to these requirements must be approved by the physics director of undergraduate studies.

Undergraduate research is strongly encouraged. Laboratory courses such as Foundations of Physics Laboratory (PHYS290) and Physics Experimentation Data Analysis Laboratory (PHYS391) provide the correct foundation. Approximately 50 percent of physics undergraduates engage in substantive research during their course of study—typically beginning withResearch Project I-III (PHYS491–493).Contact the physics advisor for more information.

The sequential nature of physics courses makes it imperative to start planning a major program in physics early. Interested students should consult the advisor in the Department of Physics near the beginning of their studies. Sample programs are designed for students who are preparing for employment in industry and choose the applied physics emphasis or who are preparing for graduate studies and choose the physics emphasis. The programs assume that students are prepared to take calculus in their freshman year. Consult the physics advisor for assistance in planning a specific program adapted to a student's individual needs.

The department offers three areas of emphasis for the physics major.

- **physics—**designed for majors with a strong interest in studying physics in graduate school
- **applied physics—**designed for majors who seek a less theoretical study of physics and a more applied focus in optics, electronics, and other project areas
- **teaching physics—**designed for majors preparing to teach physical sciences in middle or high school

All physics majors have the same curriculum for the first two years.

Bachelor of Arts: Applied Physics

Physics Core Courses		
CH221–222	General Chemistry	8
orCH224H–225H	Honors General Chemistry	
MATH251–253	Calculus I-III	12
orMATH261–263	Calculus with Theory I-III	
PHYS251–253	Foundations of Physics I	12
MATH256	Introduction to Differential Equations	4
MATH281–282	Several-Variable Calculus I-II	8
PHYS290	Foundations of Physics Laboratory	3
PHYS351–353	Foundations of Physics II	12
PHYS391	Physics Experimentation Data Analysis Laboratory	4
Applied Physics Upper-Division Courses		
PHYS412–413	Mechanics, Electricity, and Magnetism	8
Applied Physics Core Courses		
Select one of the following:		8
PHYS424 &PHYS425	Classical Optics and Modern Optics	
PHYS431 &PHYS432	Analog Electronics and Digital Electronics	
Other Laboratory Courses		
Three courses [1]		12
Total Credits		**91**

1 Any combination of the four core courses listed for the Applied emphasis that have not been used to satisfy the core, and Research Project I-III (PHYS491–493) topic modules satisfy this requirement. Different topic modules (e.g., optics, instrumentation, fundamental) of Research Project I-III (PHYS491–493) may be taken.

Applied Physics Sample Program

First Year		**Credits**
CH221–222	General Chemistry	8
PHYS251–253	Foundations of Physics I	12
PHYS290	Foundations of Physics Laboratory (two or more terms)	3
MATH251–253	Calculus I-III	12
Second Year		
MATH256	Introduction to Differential Equations	4
MATH281–282	Several-Variable Calculus I-II	8
PHYS351–353	Foundations of Physics II	12
PHYS391	Physics Experimentation Data Analysis Laboratory	4
Third Year		
PHYS412–413	Mechanics, Electricity, and Magnetism	8
PHYS422	Electromagnetism	4
PHYS431	Analog Electronics	4
PHYS432	Digital Electronics	4
Fourth Year		
PHYS424	Classical Optics	4
PHYS425	Modern Optics	4
PHYS491–493	Research Project I-III	4
	Total Credits:	**95**

Bachelor of Science: Applied Physics

Physics Core Courses		
CH221–222	General Chemistry	8
orCH224H–225H	Honors General Chemistry	
MATH251–253	Calculus I-III	12
orMATH261–263	Calculus with Theory I-III	
PHYS251–253	Foundations of Physics I	12
MATH256	Introduction to Differential Equations	4
MATH281–282	Several-Variable Calculus I-II	8
PHYS290	Foundations of Physics Laboratory	3
PHYS351–353	Foundations of Physics II	12
PHYS391	Physics Experimentation Data Analysis Laboratory	4

Applied Physics Upper-Division Courses		
PHYS412–413	Mechanics, Electricity, and Magnetism	8
Applied Physics Core Courses		
Select one of the following:		8
PHYS424 &PHYS425	Classical Optics and Modern Optics	
PHYS431 &PHYS432	Analog Electronics and Digital Electronics	
Other Laboratory Courses		
Three courses [1]		12
Total Credits		**91**

1 Any combination of the four core courses listed for the Applied emphasis that have not been used to satisfy the core, and Research Project I-III (PHYS491–493) topic modules satisfy this requirement. Different topic modules (e.g., optics, instrumentation, fundamental) of Research Project I-III (PHYS491–493) may be taken.

Applied Physics Sample Program

First Year		Credits
CH221–222	General Chemistry	8
PHYS251–253	Foundations of Physics I	12
PHYS290	Foundations of Physics Laboratory (two or more terms)	3
MATH251–253	Calculus I-III	12
Second Year		
MATH256	Introduction to Differential Equations	4
MATH281–282	Several-Variable Calculus I-II	8
PHYS351–353	Foundations of Physics II	12
PHYS391	Physics Experimentation Data Analysis Laboratory	4
Third Year		
PHYS412–413	Mechanics, Electricity, and Magnetism	8
PHYS422	Electromagnetism	4
PHYS431	Analog Electronics	4
PHYS432	Digital Electronics	4
Fourth Year		
PHYS424	Classical Optics	4
PHYS425	Modern Optics	4
PHYS491–493	Research Project I-III	4
	Total Credits:	**95**

Bachelor of Arts: Teaching Physics

Physics Core Courses		
CH221–222	General Chemistry	8
orCH224H–225H	Honors General Chemistry	
MATH251–253	Calculus I-III	12
orMATH261–263	Calculus with Theory I-III	
PHYS251–253	Foundations of Physics I	12
MATH256	Introduction to Differential Equations	4
MATH281–282	Several-Variable Calculus I-II	8
PHYS290	Foundations of Physics Laboratory	3
PHYS351–353	Foundations of Physics II	12
PHYS391	Physics Experimentation Data Analysis Laboratory	4
Teaching Physics Core Courses		
ASTR321	Topics in Astrophysics	4
PHYS362	Biological Physics	4
PHYS420	Physics Demonstrations	4
PHYS431 &PHYS432	Analog Electronics and Digital Electronics	8
PHYS491–493	Research Project I-III	8
PHYS409	Supervised Tutoring [1]	6
Total Credits		**97**

1 Does not need to be taken for a letter grade.

Teaching Physics Sample Program

First Year		Credits
CH221–222	General Chemistry	8
PHYS251–253	Foundations of Physics I	12
PHYS290	Foundations of Physics Laboratory (two or more terms)	3
MATH251–253	Calculus I-III	12
Second Year		
MATH256	Introduction to Differential Equations	4
MATH281–282	Several-Variable Calculus I-II	8
PHYS351–353	Foundations of Physics II	12
PHYS391	Physics Experimentation Data Analysis Laboratory	4
Third Year		
ASTR321	Topics in Astrophysics	4
PHYS409	Supervised Tutoring	6
PHYS420	Physics Demonstrations	4
PHYS431	Analog Electronics	4
PHYS432	Digital Electronics	4
Fourth Year		
PHYS491–493	Research Project I-III	8
	Total Credits:	**93**

Bachelor of Science: Teaching Physics

Physics Core Courses		
CH221–222	General Chemistry	8
orCH224H–225H	Honors General Chemistry	
MATH251–253	Calculus I-III	12
orMATH261–263	Calculus with Theory I-III	
PHYS251–253	Foundations of Physics I	12
MATH256	Introduction to Differential Equations	4
MATH281–282	Several-Variable Calculus I-II	8
PHYS290	Foundations of Physics Laboratory	3
PHYS351–353	Foundations of Physics II	12
PHYS391	Physics Experimentation Data Analysis Laboratory	4
Teaching Physics Core Courses		
ASTR321	Topics in Astrophysics	4
PHYS362	Biological Physics	4

PHYS420	Physics Demonstrations	4
PHYS431 &PHYS432	Analog Electronics and Digital Electronics	8
PHYS491–493	Research Project I-III	8
PHYS409	Supervised Tutoring [1]	6
Total Credits		**97**

[1] Does not need to be taken for a letter grade.

Teaching Physics Sample Program

First Year		**Credits**
CH221–222	General Chemistry	8
PHYS251–253	Foundations of Physics I	12
PHYS290	Foundations of Physics Laboratory (two or more terms)	3
MATH251–253	Calculus I-III	12
Second Year		
MATH256	Introduction to Differential Equations	4
MATH281–282	Several-Variable Calculus I-II	8
PHYS351–353	Foundations of Physics II	12
PHYS391	Physics Experimentation Data Analysis Laboratory	4
Third Year		
ASTR321	Topics in Astrophysics	4
PHYS409	Supervised Tutoring	6
PHYS420	Physics Demonstrations	4
PHYS431	Analog Electronics	4
PHYS432	Digital Electronics	4
Fourth Year		
PHYS491–493	Research Project I-III	8
	Total Credits:	**93**

Bachelor of Arts: Physics

Physics Core Courses		
CH221–222	General Chemistry	8
orCH224H–225H	Honors General Chemistry	
MATH251–253	Calculus I-III	12
orMATH261–263	Calculus with Theory I-III	
PHYS251–253	Foundations of Physics I	12
MATH256	Introduction to Differential Equations	4
MATH281–282	Several-Variable Calculus I-II	8
PHYS290	Foundations of Physics Laboratory	3
PHYS351–353	Foundations of Physics II	12
PHYS391	Physics Experimentation Data Analysis Laboratory	4
Physics Upper-Division Courses		
PHYS411–413	Mechanics, Electricity, and Magnetism [1]	12
PHYS414–415	Quantum Physics	8
PHYS417	Topics in Quantum Physics	4
Upper-Division Laboratory Courses		
Three core courses [2]		6
Elective Courses		
ASTR321	Topics in Astrophysics	4
PHYS361	Modern Science and Culture	4
PHYS362	Biological Physics	4
PHYS422	Electromagnetism	4
PHYS424	Classical Optics	4
PHYS425	Modern Optics	4
Total Credits		**117**

[1] Mechanics, Electricity, and Magnetism (PHYS411) and Mechanics, Electricity, and Magnetism (PHYS412) are sometimes offered out of sequence.

[2] Any combination of Analog Electronics (PHYS431), Digital Electronics (PHYS432), or Research Project I-III (PHYS491–493)topic modules to total 6 credits. Different topic modules (e.g., optics, instrumentation, fundamental) for Research Project I-III (PHYS491–493) may be taken.

Physics Sample Program

First Year		**Credits**
CH221–222	General Chemistry	8
PHYS251–253	Foundations of Physics I	12
PHYS290	Foundations of Physics Laboratory (two or more terms)	3
MATH251–253	Calculus I-III	12
Second Year		
MATH256	Introduction to Differential Equations	4
MATH281–282	Several-Variable Calculus I-II	8
PHYS351–353	Foundations of Physics II	12
PHYS391	Physics Experimentation Data Analysis Laboratory	4
Third Year		
PHYS411–413	Mechanics, Electricity, and Magnetism	12
PHYS422	Electromagnetism	4
Select one or two of the following:		4-8
PHYS431	Analog Electronics	4
PHYS432	Digital Electronics	4
PHYS491	Research Project I	2-4
PHYS492	Research Project II	2-4
PHYS493	Research Project III	2-4
Physics or mathematics electives or both		4
Fourth Year		
PHYS414–415	Quantum Physics	8
PHYS417	Topics in Quantum Physics	4
Select one or two of the following:		4-8
PHYS431	Analog Electronics	4
PHYS432	Digital Electronics	4
PHYS491	Research Project I	2-4
PHYS492	Research Project II	2-4
PHYS493	Research Project III	2-4

Physics or mathematics electives or both		12
	Total Credits:	**115-123**

Bachelor of Science: Physics

Physics Core Courses		
CH221–222	General Chemistry	8
orCH224H–225H	Honors General Chemistry	
MATH251–253	Calculus I-III	12
orMATH261–263	Calculus with Theory I-III	
PHYS251–253	Foundations of Physics I	12
MATH256	Introduction to Differential Equations	4
MATH281–282	Several-Variable Calculus I-II	8
PHYS290	Foundations of Physics Laboratory	3
PHYS351–353	Foundations of Physics II	12
PHYS391	Physics Experimentation Data Analysis Laboratory	4
Physics Upper-Division Courses		
PHYS411–413	Mechanics, Electricity, and Magnetism [1]	12
PHYS414–415	Quantum Physics	8
PHYS417	Topics in Quantum Physics	4
Upper-Division Laboratory Courses		
Three core courses [2]		6
Elective Courses		
ASTR321	Topics in Astrophysics	4
PHYS361	Modern Science and Culture	4
PHYS362	Biological Physics	4
PHYS422	Electromagnetism	4
PHYS424	Classical Optics	4
PHYS425	Modern Optics	4
Total Credits		**117**

1. Mechanics, Electricity, and Magnetism (PHYS411) and Mechanics, Electricity, and Magnetism (PHYS412) are sometimes offered out of sequence.
2. Any combination of Analog Electronics (PHYS431), Digital Electronics (PHYS432), or Research Project I-III (PHYS491–493)topic modules to total 6 credits. Different topic modules (e.g., optics, instrumentation, fundamental) for Research Project I-III (PHYS491–493) may be taken.

Physics Sample Program

First Year		**Credits**
CH221–222	General Chemistry	8
PHYS251–253	Foundations of Physics I	12
PHYS290	Foundations of Physics Laboratory (two or more terms)	3
MATH251–253	Calculus I-III	12
Second Year		
MATH256	Introduction to Differential Equations	4
MATH281–282	Several-Variable Calculus I-II	8
PHYS351–353	Foundations of Physics II	12
PHYS391	Physics Experimentation Data Analysis Laboratory	4
Third Year		
PHYS411–413	Mechanics, Electricity, and Magnetism	12
PHYS422	Electromagnetism	4
Select one or two of the following:		4-8
PHYS431	Analog Electronics	4
PHYS432	Digital Electronics	4
PHYS491	Research Project I	2-4
PHYS492	Research Project II	2-4
PHYS493	Research Project III	2-4
Physics or mathematics electives or both		4
Fourth Year		
PHYS414–415	Quantum Physics	8
PHYS417	Topics in Quantum Physics	4
Select one or two of the following:		4-8
PHYS431	Analog Electronics	4
PHYS432	Digital Electronics	4
PHYS491	Research Project I	2-4
PHYS492	Research Project II	2-4
PHYS493	Research Project III	2-4
Physics or mathematics electives or both		12
	Total Credits:	**115-123**

Sample Programs for Transfer Students

These sample programs are for transfer students who have completed two years of college work including one year of calculus, one year of general physics with laboratories, one year of general chemistry, and as many as possible of the university requirements for the bachelor's degree. In addition to graduation requirements for the bachelor's degree, transfer students should plan to take the following courses, depending on their area of emphasis:

Applied Physics Emphasis

Third Year		**Credits**
MATH256	Introduction to Differential Equations	4
MATH281–282	Several-Variable Calculus I-II	8
PHYS351–353	Foundations of Physics II	12
PHYS391	Physics Experimentation Data Analysis Laboratory	4
Fourth Year		
PHYS412–413	Mechanics, Electricity, and Magnetism	8
PHYS422	Electromagnetism	4
PHYS424 &PHYS425	Classical Optics	8
Select one or two of the following:		4-8
PHYS431	Analog Electronics	2-4
PHYS432	Digital Electronics	2-4

PHYS491	Research Project I	2-4
PHYS492	Research Project II	2-4
PHYS493	Research Project III	2-4
	Total Credits:	**52-56**

Teaching Physics Emphasis

Third Year		**Credits**
ASTR321	Topics in Astrophysics	4
PHYS362	Biological Physics	4
PHYS409	Supervised Tutoring	6
PHYS420	Physics Demonstrations	4
PHYS431 &PHYS432	Analog Electronics	8
Fourth Year		
PHYS491–493	Research Project I-III	8
	Total Credits:	**34**

Physics Emphasis

Third Year		**Credits**
MATH256	Introduction to Differential Equations	4
MATH281–282	Several-Variable Calculus I-II	8
PHYS351–353	Foundations of Physics II	12
PHYS391	Physics Experimentation Data Analysis Laboratory	4
Fourth Year		
PHYS411–413	Mechanics, Electricity, and Magnetism	12
PHYS414–415	Quantum Physics	8
PHYS417	Topics in Quantum Physics	4
PHYS422	Electromagnetism	4
Select one or two of the following:		4-8
PHYS424	Classical Optics	4
PHYS425	Modern Optics	4
PHYS431	Analog Electronics	4
PHYS432	Digital Electronics	4
PHYS491	Research Project I	4
PHYS492	Research Project II	4
PHYS493	Research Project III	4
Mathematics or physics electives or both		8
	Total Credits:	**68-72**

Honors

To be recommended by the faculty for graduation with honors in physics, a student must complete at least 46 credits in upper-division physics courses, of which at least 40 credits must be taken for letter grades, and earn at least a 3.50 grade point average in these courses.

As an alternative, undergraduate research leading to the defense of a thesis accompanied by at least a 3.30 grade point average can lead to recommendation for graduation with honors. Contact the director of undergraduate studies for more information.

Minor Requirements

Pre-Minor Requirements		
PHYS251–253	Foundations of Physics I [1]	12
orPHYS201–203	General Physics	
Required Courses		
PHYS351–353	Foundations of Physics II	12
orPHYS411–413	Mechanics, Electricity, and Magnetism	
Select one of the following:		4
PHYS391	Physics Experimentation Data Analysis Laboratory	
400-level physics course		
Physics courses		8
Total Credits		**36**

[1] General Physics (PHYS201–203) may fulfill requirements with the physics undergraduate advisor's approval.

Additional Requirements

Course work must be completed with grades of C– or better or P. At least 12 of the upper-division credits must be completed in residence at the University of Oregon.

Engineering

Students interested in engineering may complete preparatory course work at the University of Oregon before enrolling in a professional engineering program at Oregon State University (OSU) or elsewhere. The Department of Physics coordinates a three-plus-two program that allows a student to earn a bachelor's degree in physics from Oregon and one in engineering from OSU. For more information, see Preparatory Programs in the **Academic Advising** section of this catalog.

Engineering students interested in semiconductor process engineering or polymer science may be interested in the nationally recognized master's industrial internship program. For more information, visit internship.uoregon.edu .

Preparation for Kindergarten through Secondary School Teaching Careers

The College of Education offers a fifth-year program for middle-secondary teaching licensure in physics and integrated sciences and a program for elementary teaching. Students considering a career pathway to teaching should consider following the physics teaching emphasis to prepare for the licensure programs. More information is available from the department's education advisor, Dean Livelybrooks; see also the **College of Education** section of this catalog.

- **Master of Arts**
- **Master of Science: Physics**
- **Master of Science: Applied Physics**
- **Doctor of Philosophy**

Graduate Studies

The Department of Physics offers graduate programs leading to the master of science degree in applied physics or to the master of arts (MA), master of science (MS), and doctor of philosophy (PhD) degrees in physics with a variety of opportunities for research. Current research

areas include astronomy and astrophysics, biophysics, condensed matter physics, elementary particle physics, and optical physics.

The interdisciplinary Institute of Theoretical Science houses theoretical research in some of the above areas as well as in areas of overlap between chemistry and physics.

The Center for High Energy Physics conducts research in particle physics, much of it in laboratories outside Oregon.

The Materials Science Institute and the Oregon Center for Optics provide facilities, support, and research guidance for graduate students and postdoctoral fellows in the interdisciplinary application of concepts and techniques from both physics and chemistry to understanding physical systems.

Cooperative programs of study are possible in molecular biology through the Institute of Molecular Biology.

Pine Mountain Observatory

Pine Mountain Observatory, operated by the Department of Physics for research and advanced instruction in astronomy, is located thirty miles southeast of Bend, Oregon, off Highway 20 near Millican, at an altitude of 6,300 feet above sea level. The observatory has three telescopes—fifteen inches, twenty-four inches, and thirty-two inches in diameter—the largest governed by computer. All are Cassegrain reflectors. A wide-field CCD camera is available on the thirty-two-inch telescope. The site has an astronomers' residence building and a caretaker's house. Professional astronomical research is in progress at the observatory on every partially or totally clear night of the year, and the site is staffed year round.

Admission and Financial Aid

For admission to graduate study, a bachelor's degree in physics or a related area is required with a minimum undergraduate grade point average (GPA) of 3.00 (B) in advanced physics and mathematics courses. Submission of scores on the Graduate Record Examinations (GRE), including the physics test, is required. Students from non-English-speaking countries must demonstrate proficiency in English by submitting scores from the Test of English as a Foreign Language (TOEFL). Information about the department and the Graduate Admission Application are available through the department's website.

Financial aid in the form of graduate teaching or research fellowships (GTFs) is available on a competitive basis to PhD students. GTFs require approximately sixteen hours of work a week and provide a stipend and tuition waiver. New students are typically eligible only for teaching fellowships.

The sequential nature of most physics courses makes it difficult to begin graduate study in terms other than Fall. Furthermore, financial aid is usually available only to students who begin their studies in the Fall.

To ensure equal consideration for fall term admission, the deadline for applications for financial aid is January 15. Late applications for admission may be considered until July 15.

Degree Requirements

Entering students should consult closely with their assigned advisors. Students showing a lack of preparation are advised to take the necessary undergraduate courses in order to remedy their deficiencies.

Students should consult the **Graduate School** section of this catalog for general university admission and degree requirements. Departmental requirements, outlined in a handbook for incoming students that is available in the department office and online, are summarized below.

Industrial Internships and the Applied Physics Master's Degree

The applied physics master's program leads to a professional MS degree, an alternative to the research-based PhD. It is designed to serve physics students whose primary interests lie in applied research and development rather than in basic research. An important component of this degree program is the industrial internship. These internships in local and regional industries are designed to enhance the ability of physics graduates to obtain good jobs after graduation. Qualified students can complete this program in one year.Students must apply via the Materials Science Institute for admission to the industrial internship program, which is a prerequisite for admission to the master's program in applied physics. Further information is availablein the **Research Centers and Institutes** section of this catalog.

Master of Science: Applied Physics

500- or 600-level courses [1]	24
Industrial internship	10
Additional graduate-level physics courses	11-19
Total Credits	**45-53**

[1] At least 9 credits of 600-level courses are required.

Additional Requirements

A grade of B– or better must be achieved in each course applied to the graded-credit total. The overall GPA in physics courses must be 3.00 or better.

Graduate School requirements, including time limits, must be satisfied.

Total credits required for the degree depend on the number of graded credits and internship credits the student earns. This allows flexibility in adjusting the balance between course work and the internship experience. The more graded credits a student earns, the fewer total credits are required for the degree. The minimum total required is 45 credits if the student earns 32 or more graded credits. The minimum required is 53 credits if the student earns only 24 graded credits. In general, 1credit is added to the minimum total of 45 for each graded credit less than 32 a student earns. For example, a student who earns 28 graded credits needs a minimum total of 49 credits

The internship requirement must be fulfilled through the industrial internship program. Internship credits are taken pass/no pass. A student typically earns 10 credits for every three months of full-time internship experience

Graded credits must be selected from an approved departmental list. This list includes the following:

PHYS581	Design of Experiments	4

Other 600-level physics courses qualify, but may require additional prerequisites. Some graduate-level courses in chemistry may qualify. Other courses may be added or substituted with the approval of the applied physics program advisor.

Master of Science: Physics

Typically this degree is based on course work and the master's final examination. Detailed requirements can be found in the Graduate Student Handbook on the department's website.

Candidates must either pass the combined graduate exam at the master's level ***or*** submit a written thesis ***or*** take a program of specialized courses.

A combined graduate exam covering the four core subject areas—mechanics; electricity, magnetism, and optics; modern physics and quantum mechanics; and thermal and statistical physics—is used for both the master's and doctoral qualifying examinations. For the master's exam, a separate total score is obtained by removing, in each core area, the student's problem with the lowest score. Material covered by the combined exam is primarily at the level of advanced undergraduate physics, but as much as one-third of the exam tests core graduate-level material. The examination is given each fall and spring, and master's candidates must pass the examination by spring of their second year of study.

Thesis Option

Select one of the following:		9
PHYS503	Thesis	
PHYS503 &PHYS601	Thesis and Research: [Topic]	
Total Credits		**9**

Specified-Course Option

The specified-courses option requires 40 graduate credits in physics, 36 of which must be selected from a list of courses approved by the department.

The master's degree program is typically completed in four terms, unless sufficient transfer credits are available, in which case it can be obtained in three.

Master of Arts

Typically this degree is based on course work and the master's final examination. Detailed requirements can be found in the Graduate Student Handbook on the department's website.

Candidates must either pass the combined graduate exam at the master's level ***or*** submit a written thesis ***or*** take a program of specialized courses.

A combined graduate exam covering the four core subject areas—mechanics; electricity, magnetism, and optics; modern physics and quantum mechanics; and thermal and statistical physics—is used for both the master's and doctoral qualifying examinations. For the master's exam, a separate total score is obtained by removing, in each core area, the student's problem with the lowest score. Material covered by the combined exam is primarily at the level of advanced undergraduate physics, but as much as one-third of the exam tests core graduate-level material. The examination is given each fall and spring, and master's candidates must pass the examination by spring of their second year of study.

Thesis Option

Select one of the following:		9
PHYS503	Thesis	
PHYS503 &PHYS601	Thesis and Research: [Topic]	
Total Credits		**9**

Specified-Course Option

The specified-courses option requires 40 graduate credits in physics, 36 of which must be selected from a list of courses approved by the department.

The master's degree program is typically completed in four terms, unless sufficient transfer credits are available, in which case it can be obtained in three.

In addition to all the preceding requirements, candidates for the master of arts (MA) degree must demonstrate foreign-language proficiency.

Doctor of Philosophy

The doctor of philosophy degree (PhD) in physics is based primarily on demonstrated knowledge of physics and doctoral dissertation research. PhD students must achieve qualifying scores on the master's and doctoral combined examination, and are required to pass the qualifying exam by the end of the first term in their third year of study. Students also must take and pass the core graduate sequences, unless some of these are waived by the graduate director:

Core Sequences		
PHYS611–612	Theoretical Mechanics	6
PHYS613–614	Statistical Physics	6
PHYS622–623	Electromagnetic Theory	8
PHYS631–633	Quantum Mechanics	12
Breadth Requirements		
Six breadth courses [1]		
Total Credits		**32**

[1] Breadth courses can be chosen from several areas of physics and allied areas such as mathematics, chemistry, and biology. At least two of the courses must be in a sequence.

Next, students must locate an advisor and an advisory committee, who then administer a comprehensive oral examination testing whether the student is ready to undertake dissertation research. The heart of the PhD requirements is research leading to a doctoral dissertation.

Detailed information is available in the *Graduate Student Handbook* on the department's website.

Courses

ASTR121. The Solar System. 4 Credits.
Naked-eye astronomy, development of astronomical concepts, and the solar system.

ASTR122. Birth and Death of Stars. 4 Credits.
The structure and evolution of stars.

ASTR123. Galaxies and the Expanding Universe. 4 Credits.
Galaxies and the universe.

ASTR199. Special Studies: [Topic]. 1-5 Credits.
Repeatable.

ASTR321. Topics in Astrophysics. 4 Credits.
Problem solving of the orbits, kinematics, and dynamics of astronomical systems, structure and evolution of stars and galaxies.
Pre- or coreq: MATH 252; PHYS 252 or equivalents.

Courses

PHYS101. Essentials of Physics. 4 Credits.
Fundamental physical principles. Mechanics.

PHYS102. Essentials of Physics. 4 Credits.
Fundamental physical principles. Heat, waves, and sound; electricity and magnetism.

PHYS152. Physics of Sound and Music. 4 Credits.
Introduction to the wave nature of sound; hearing; musical instruments and scales; auditorium acoustics; and the transmission, storage, and reproduction of sound.

PHYS153. Physics of Light, Color, and Vision. 4 Credits.
Light and color, their nature, how they are produced, and how they are perceived and interpreted.

PHYS155. Physics behind the Internet. 4 Credits.
How discoveries in 20th-century physics mesh to drive modern telecommunications. Topics include electron mobility in matter, the development of transistors and semiconductors, lasers, and optical fibers.

PHYS156M. Scientific Revolutions. 4 Credits.
Surveys several major revolutions in our views of the natural and technological world, focusing on scientific concepts and methodological aspects. For nonscience majors. Multilisted with GEOL 156M.

PHYS157M. Information, Quantum Mechanics and DNA. 4 Credits.
A nonscience major's introduction to the physical and chemical concepts explaining how information is stored in and transmitted by physical objects and molecules, including DNA. Multilisted with CH 157M.

PHYS161. Physics of Energy and Environment. 4 Credits.
Practical study of energy generation and environmental impact, including energy fundamentals, fossil fuel use, global warming, nuclear energy, and energy conservation.

PHYS162. Solar and Other Renewable Energies. 4 Credits.
Topics include photovoltaic cells, solar thermal power, passive solar heating, energy storage, geothermal energy, and wind energy.

PHYS163. Nanoscience and Society. 4 Credits.
Explores the science behind scale-dependent properties of matter, focusing on its applications in futuristic nanotechnologies and the social and political issues that it raises.

PHYS171. The Physics of Life. 4 Credits.
Explores how physical laws guide the structure, function, and behavior of living organisms, and examines the physical properties of biological materials. Topics span microscropic and macroscopic scales.

PHYS196. Field Studies: [Topic]. 1-2 Credits.
Repeatable.

PHYS198. Worskhop: [Topic]. 1-2 Credits.
Repeatable.

PHYS199. Special Studies: [Topic]. 1-5 Credits.
Repeatable.

PHYS201. General Physics. 4 Credits.
Introductory series. Mechanics and fluids.
Prereq: MATH 112 or equivalent.

PHYS202. General Physics. 4 Credits.
Introductory series. Thermodynamics, waves, optics.
Prereq: PHYS 201.

PHYS203. General Physics. 4 Credits.
Introductory series. Electricity, magnetism, modern physics.
Prereq: PHYS 201.

PHYS204. Introductory Physics Laboratory. 2 Credits.
Practical exploration of the principles studied in general-physics lecture. Measurement and analysis methods applied to experiments in mechanics, waves, sound, thermodynamics, electricity and magnetism, optics, and modern physics. Sequence.
Pre- or coreq: PHYS 201.

PHYS205. Introductory Physics Laboratory. 2 Credits.
Practical exploration of the principles studied in general-physics lecture. Measurement and analysis methods applied to experiments in mechanics, waves, sound, thermodynamics, electricity and magnetism, optics, and modern physics.
Pre- or coreq: PHYS 202.

PHYS206. Introductory Physics Laboratory. 2 Credits.
Practical exploration of the principles studied in general-physics lecture. Measurement and analysis methods applied to experiments in mechanics, waves, sound, thermodynamics, electricity and magnetism, optics, and modern physics.
Pre- or coreq: PHYS 203.

PHYS251. Foundations of Physics I. 4 Credits.
Newtonian mechanics; units and vectors; one-dimensional motion; Newton’s laws; work and energy; momentum and collisions. Sequence.
Coreq: MATH 251; Prereq MATH 112 or equivalent.

PHYS252. Foundations of Physics I. 4 Credits.
Vibrations and waves; oscillations; wave mechanics; dispersion; modes; introductory optics.
Prereq: PHYS 251; coreq: MATH 253 or equivalent.

PHYS253. Foundations of Physics I. 4 Credits.
Electricity and magnetism; charge and electric field; electric potential; circuits; magnetic field; inductance.
Prereq: PHYS 252; coreq: MATH 252 or equivalent.

PHYS290. Foundations of Physics Laboratory. 1 Credit.
Repeatable. Introduction to laboratory measurements, reports, instrumentation, and experimental techniques. Repeatable twice for maximum of 3 credits.
Coreq: PHYS 251, 252 or 253.

PHYS301. Physicists' View of Nature. 4 Credits.
Illustrates physics concepts through the work of prominent physicists. The classical view--mechanics, electrical science, thermal physics.
Prereq: WR 122 or equivalent.

PHYS351. Foundations of Physics II. 4 Credits.
Introduction to relativity and quantum physics with applications to atomic, solid-state, nuclear, and astro-particle systems
Prereq: MATH 253, PHYS 253; coreq: MATH 256 or 281.

PHYS352. Foundations of Physics II. 4 Credits.
Thermodynamic systems; first and second laws; kinetic theory of gases; entropy. Sequence.
Prereq: PHYS 351; coreq: MATH 281.

PHYS353. Foundations of Physics II. 4 Credits.
Thermal radiation; Maxell-Boltzmann statistics; Fermi and Bose gases; phase transitions. Sequence.
Prereq: PHYS 352; coreq: MATH 282.

PHYS354. Introduction to Quantum Mechanics. 4 Credits.
Introductory treatment of quantum mechanics with an applied focus. Topics include square well potential, Bragg reflection, and de Broglie waves.
Prereq: PHYS 351 or 352.

PHYS361. Modern Science and Culture. 4 Credits.
Examination of 19th century and early 20th century science in a cultural context.

PHYS362. Biological Physics. 4 Credits.
Physical principles governing biological systems. Topics include molecular machines, DNA and other macromolecules, signaling and information transfer, entropic forces, and physical mechanisms of self-organization.
Prereq: PHYS 351 or 353.

PHYS391. Physics Experimentation Data Analysis Laboratory. 4 Credits.
Practical aspects of physics experimentation, including data acquisition, statistical analysis, and introduction to scientific programming, and use of Fourier methods for data analysis.

PHYS399. Special Studies: [Topic]. 1-5 Credits.
Repeatable.

PHYS401. Research: [Topic]. 1-16 Credits.
Repeatable.

PHYS403. Thesis. 1-12 Credits.
Repeatable.

PHYS405. Reading and Conference: [Topic]. 1-16 Credits.
Repeatable.

PHYS406. Field Studies: [Topic]. 1-21 Credits.
Repeatable.

PHYS407. Seminar: [Topic]. 1-4 Credits.
Repeatable.

PHYS408. Workshop: [Topic]. 1-21 Credits.
Repeatable.

PHYS409. Supervised Tutoring. 1-3 Credits.
Repeatable.

PHYS410. Experimental Course: [Topic]. 1-4 Credits.
Repeatable.

PHYS411. Mechanics, Electricity, and Magnetism. 4 Credits.
Fundamental principles of Newtonian mechanics, conservation laws, small oscillations, planetary motion, systems of particles. Electromagnetic phenomena. Series. Only nonmajors may earn graduate credit.
Prereq: MATH 282.

PHYS412. Mechanics, Electricity, and Magnetism. 4 Credits.
Fundamental principles of Newtonian mechanics, conservation laws, small oscillations, planetary motion, systems of particles. Electromagnetic phenomena. Series.
Prereq: MATH 281.

PHYS413. Mechanics, Electricity, and Magnetism. 4 Credits.
Fundamental principles of Newtonian mechanics, conservation laws, small oscillations, planetary motion, systems of particles. Electromagnetic phenomena. Series.
Prereq: PHYS 412.

PHYS414. Quantum Physics. 4 Credits.
Planck's and de Broglie's postulates, the uncertainty principle, Bohr's model of the atom, the Schroedinger equation in one dimension, the harmonic oscillator, the hydrogen atom, molecules and solids, nuclei and elementary particles. Sequence.
Prereq: PHYS 413.

PHYS415. Quantum Physics. 4 Credits.
Planck's and de Broglie's postulates, the uncertainty principle, Bohr's model of the atom, the Schroedinger equation in one dimension, the harmonic oscillator, the hydrogen atom, molecules and solids, nuclei and elementary particles. Sequence.
Prereq: PHYS 414.

PHYS417. Topics in Quantum Physics. 4 Credits.
Perturbation theory, variational principle, time-dependent perturbation theory, elementary scattering theory.
Prereq: PHYS 415.

PHYS420. Physics Demonstrations. 4 Credits.
Focuses primarily on the resources, methods, and techniques for conveying an understanding of physics principles through physics demonstrations and laboratory experiments. Offered alternate years.
Prereq: PHYS 253.

PHYS422. Electromagnetism. 4 Credits.
Study of electromagnetic waves. Topics include Maxwell's equations, wave equation, plane waves, guided waves, antennas, and other related phenomena.
Prereq: PHYS 413.

PHYS424. Classical Optics. 4 Credits.
Geometrical optics, polarization, interference, Frauenhofer and Fresnel diffraction.
Prereq: PHYS 353.

PHYS425. Modern Optics. 4 Credits.
Special topics in modern applied optics such as Fourier optics, coherence theory, resonators and lasers, holography, and image processing.
Prereq: PHYS 424.

PHYS431. Analog Electronics. 4 Credits.
Passive and active discrete components and circuits. General circuit concepts and theorems. Equivalent circuits and black box models. Integrated circuit operational amplifiers.
Prereq: PHYS 203 or equivalent; knowledge of complex numbers; MATH 256.

PHYS432. Digital Electronics. 4 Credits.
Digital electronics including digital logic, measurement, signal processing and control. Introduction to computer interfacing.
Prereq: PHYS 203 or equivalent; MATH 253.

PHYS481. Design of Experiments. 4 Credits.
Applies statistics to practical data analysis, data-based decision making, model building, and the design of experiments. Emphasizes factorial designs.

PHYS491. Research Project I. 2-4 Credits.
For physics and other science majors, Physics Projects entails construction and use of apparatus, interfaces and computers to perform technically-sophisticated experiments, analyze and communicate results.
Prereq: PHYS 391 or PHYS 399.

PHYS492. Research Project II. 2-4 Credits.
For physics and other science majors, Physics Projects entails construction and use of apparatus, interfaces and computers to perform technically-sophisticated experiments, analyze and communicate results.
Prereq: PHYS 491.

PHYS493. Research Project III. 2-4 Credits.
For physics and other science majors, Physics Projects entails construction and use of apparatus, interfaces and computers to perform technically-sophisticated experiments, analyze and communicate results.
Prereq: PHYS 492.

PHYS503. Thesis. 1-16 Credits.
Repeatable.

PHYS507. Seminar: [Topic]. 1-4 Credits.
Repeatable.

PHYS508. Workshop: [Topic]. 1-21 Credits.
Repeatable.

PHYS510. Experimental Course: [Topic]. 1-4 Credits.
Repeatable.

PHYS515. Quantum Physics. 4 Credits.
Planck's and de Broglie's postulates, the uncertainty principle, Bohr's model of the atom, the Schroedinger equation in one dimension, the harmonic oscillator, the hydrogen atom, molecules and solids, nuclei and elementary particles. Sequence. Only nonmajors may earn graduate credit.
Prereq: PHYS 414/514.

PHYS517. Topics in Quantum Physics. 4 Credits.
Perturbation theory, variational principle, time-dependent perturbation theory, elementary scattering theory. Only nonmajors may earn graduate credit.
Prereq: PHYS 415/515.

PHYS581. Design of Experiments. 4 Credits.
Applies statistics to practical data analysis, data-based decision making, model building, and the design of experiments. Emphasizes factorial designs.

PHYS601. Research: [Topic]. 1-16 Credits.
Repeatable.

PHYS603. Dissertation. 1-16 Credits.
Repeatable.

PHYS604. Internship: [Topic]. 1-16 Credits.
Repeatable.
Coreq: good standing in applied physics master's degree program.

PHYS605. Reading and Conference: [Topic]. 1-16 Credits.
Repeatable.

PHYS606. Field Studies: [Topic]. 1-16 Credits.
Repeatable.

PHYS607. Seminar: [Topic]. 1-4 Credits.
Repeatable. Recent topics include Astrophysics and Gravitation, Biophysics, Condensed Matter, High Energy Physics, Physics Colloquium, Theoretical Physics.

PHYS608. Workshop: [Topic]. 1-16 Credits.
Repeatable.

PHYS609. Supervised Tutoring. 1-3 Credits.
Repeatable.

PHYS610. Experimental Course: [Topic]. 1-4 Credits.
Repeatable.

PHYS611. Theoretical Mechanics. 4 Credits.
Lagrangian and Hamiltonian mechanics, small oscillations, rigid bodies. Sequence.

PHYS612. Theoretical Mechanics. 2 Credits.
Lagrangian and Hamiltonian mechanics, small oscillations, rigid bodies. Sequence.
Prereq: PHYS 611.

PHYS613. Statistical Physics. 2 Credits.
Thermodynamics, statistical mechanics, kinetic theory, application to gases, liquids, solids, atoms, molecules, and the structure of matter. Sequence.

PHYS614. Statistical Physics. 4 Credits.
Thermodynamics, statistical mechanics, kinetic theory, application to gases, liquids, solids, atoms, molecules, and the structure of matter. Sequence.
Prereq: PHYS 613.

PHYS622. Electromagnetic Theory. 4 Credits.
Microscopic form of Maxwell's equations, derivation and solution of the wave equation, Lorentz covariant formulation, motion of charges in given fields, propagation and diffraction, radiation by given sources, coupled motion of sources and fields, the electromagnetic field in dense media.

PHYS623. Electromagnetic Theory. 4 Credits.
Microscopic form of Maxwell's equations, derivation and solution of the wave equation, Lorentz covariant formulation, motion of charges in given fields, propagation and diffraction, radiation by given sources, coupled motion of sources and fields, the electromagnetic field in dense media. Sequence.
Prereq: PHYS 622.

PHYS626. Physical Optics with Labs. 4 Credits.
Fundamentals of applied geometric and wave optics theory, reinforced through homework assignments, and explored in experiments conducted with lasers and optical components. Sequence with PHYS 627, PHYS 628.

PHYS627. Optical Materials and Devices. 4 Credits.
Principles of quantum mechanics and solid-state physics relating to material properties of optoelectronic devices with corresponding laboratories teaching how to operate and characterize these devices. Sequence with PHYS 626, PHYS 628.
Prereq: PHYS 626 with B- or better grade.

PHYS628. Laser and Nonlinear Optics with OpticStudio. 4 Credits.
Introduction to the nature of laser and nonlinear optics and the practical systems that utilize these phenomena with computational simulations using Zemax OpticStudio software. Sequence with PHYS 626, PHYS 627.
Prereq: PHYS 627 with B- or better grade.

PHYS631. Quantum Mechanics. 4 Credits.
Review of fundamentals, central force problems, matrix mechanics. Sequence.

PHYS632. Quantum Mechanics. 4 Credits.
Approximation methods, scattering. Sequence.
Prereq: PHYS 631.

PHYS633. Quantum Mechanics. 4 Credits.
Rotation symmetry, spin, identical particles. Sequence.
Prereq: PHYS 632.

PHYS634. Advanced Quantum Mechanics. 4 Credits.
Time-dependent formulation of scattering, relativistic equations and solutions, hole theory, symmetry properties, second quantization, Fock space.

PHYS661. Elementary Particle Phenomenology. 4 Credits.
Classification and quantum numbers of elementary particles; elements of group theory, Lorentz group and spin; discrete and continuous symmetries; phenomenology of weak, electromagnetic, and strong interactions; quark model of hadron structure. Sequence.
Prereq: PHYS 633.

PHYS662. Elementary Particle Phenomenology. 4 Credits.
Classification and quantum numbers of elementary particles; elements of group theory, Lorentz group and spin; discrete and continuous symmetries; phenomenology of weak, electromagnetic, and strong interactions; quark model of hadron structure. Sequence.
Prereq: PHYS 661.

PHYS665. Quantum Field Theory. 4 Credits.
Canonical quantization, path integral formulation of quantum field theory, Feynman rules for perturbation theory, quantum electrodynamics, renormalization, gauge theory of the strong and electroweak interactions. Sequence.
Prereq: PHYS 634.

PHYS666. Quantum Field Theory. 4 Credits.
Canonical quantization, path integral formulation of quantum field theory, Feynman rules for perturbation theory, quantum electrodynamics, renormalization, gauge theory of the strong and electroweak interactions. Sequence.
Prereq: PHYS 665.

PHYS671. Solid State Physics. 4 Credits.
Crystallography; thermal, electrical, optical, and magnetic properties of solids; band theory; metals, semiconductors, and insulators; defects in solids. Sequence.
Prereq: PHYS 633.

PHYS672. Solid State Physics. 4 Credits.
Crystallography; thermal, electrical, optical, and magnetic properties of solids; band theory; metals, semiconductors, and insulators; defects in solids. Sequence.
Prereq: PHYS 671.

PHYS674. Theory of Condensed Matter. 4 Credits.
Advanced topics include quantum and statistical description of many-particle systems, electronic structure, elementary excitations in solids and fluids, critical phenomena, statics and dynamics of soft condensed matter. Topics and emphasis vary.
Prereq: PHYS 673.

PHYS675. Theory of Condensed Matter. 4 Credits.
Advanced topics include quantum and statistical description of many-particle systems, electronic structure, elementary excitations in solids and fluids, critical phenomena, statics and dynamics of soft condensed matter. Topics and emphasis vary.
Prereq: PHYS 674.

PHYS677M. Semiconductor Device Physics. 4 Credits.
Introduction to the theory behind semiconductors. Elementary theory of inorganic solids; electronic structures and transport properties. Basic theory of devices including diodes, transistors, mosfets, and optoelectronic devices. Offered only in summer. Sequence with PHYS 678M, PHYS 679M. Multilisted with CH 677M.

PHYS678M. Semiconductor Processing and Characterization Technology. 4 Credits.
Introduction to the techniques required to make semiconductors and test their properties. Solid-state and surface chemistry of inorganic semiconductors as it pertains to microelectronic devices. Offered only in summer. Sequence with PHYS 677M, PHYS 679M. Multilisted with CH 678M.
Prereq: PHYS 677M.

PHYS679M. Device Processing and Characterization Laboratory. 4 Credits.
Students use theory and techniques learned to design, fabricate, and test a device that performs a specific function, with an emphasis on wafer processing and device realization. Offered only in summer. Sequence with PHYS 677M, PHYS 678M. Multilisted with CH 679M.
Prereq: PHYS 678M.

PHYS684. Quantum Optics and Laser Physics. 4 Credits.
Nonlinear optical processes and quantum statistical properties of light produced by such processes, laser theory, wave mixing processes, optical Bloch equations, field quantization, photon statistics, cooperative emissions. Sequence.
Prereq: PHYS 354 or equivalent.

PHYS685. Quantum Optics and Laser Physics. 4 Credits.
Nonlinear optical processes and quantum statistical properties of light produced by such processes, laser theory, wave mixing processes, optical Bloch equations, field quantization, photon statistics, cooperative emissions. Sequence.
Prereq: PHYS 684; coreq PHYS 631.

PHYS686. Quantum Optics and Laser Physics. 4 Credits.
Nonlinear optical processes and quantum statistical properties of light produced by such processes, laser theory, wave mixing processes, optical Bloch equations, field quantization, photon statistics, cooperative emissions. Sequence.
Prereq: PHYS 685; coreq: PHYS 632.