Physics

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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)

David Allcock, assistant professor (ion trapping and quantum information). MS, 2007, PhD, 2012, Oxford. (2019)

Jayanth Banavar, professsor (statistical physics). BS, 1972, MS, 1974, Bangalore University, PhD, 1978, University of Pittsburgh. (2019)

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

Bryan S. Boggs, senior lecturer (optical physics). BS, 1995, MS, 1996, PhD, 2012, Oregon. (2013)

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

Ben Farr, assistant professor (gravitational waves). BS, 2009, Rochester Institute of Technology; PhD, 2014, Northwestern. (2017)

R. Scott Fisher, senior 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)

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

Laura Jeanty, assistant professor (high-energy physics). BS, 2006, Yale; MS, 2009, PhD, 2013, Harvard. (2018)

Elsa Johnson, instructor (astronomy). BS, 1993, Oregon State University, MS, 1999, California; Irvine, PhD, 2010, Oregon. (2010)

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

Graham Kribs, professor (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, associate professor (experimental elementary particle physics). BS, 2002, Illinois, Urbana-Champaign; PhD, 2007, Stanford. (2012)

Benjamin McMorran, associate 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, Alec and Kay Keith Professor (condensed matter physics, biophysics). BA, 1997, California, Berkeley; PhD, 2002, Chicago. (2006)

Jayson Paulose, assistant professor (condensed matter theory). AB, 2007, Princeton; SM, 2009, PhD, 2013, Harvard. (2018)

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

William C. Scannell, lab instructor (physics education). BS, 2002, MS, 2004, PhD, 2010, Oregon. (2016)

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

Brian J. Smith, associate professor (quantum optics, optical physics). BA, 2000, Gustavus Adolphus College; PhD, 2007, Oregon. (2015)

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)

Tristan S. Ursell, assistant professor (condensed matter physics, biophysics). BS, 2003, Rensselaer Polytechnic Institute; MS, 2003, PhD, 2009, California Institute of Technology. (2014)

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

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

David Wineland, research professor (atomic spectroscopy, quantum information, quantum-limited metrology). BA, 1965, California, Berkeley; MA, 1966, PhD, 1970, Harvard. (2018)

Tien-Tien Yu, assistant professor (high-energy physics). AB, 2007, Chicago; PhD, 2013, Wisconsin, Madison. (2017)

Research Faculty and 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

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)

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)

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: 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	MATH 251–253-253
Two, more than two	One year of calculus general physics with laboratory	PHYS 251–253-253, PHYS 290
Two, more than two	General chemistry	CH 221–222-222 or CH 224H–225H-225H
Two, more than two	One term of differential equations and two terms of multivariable calculus	MATH 256, MATH 281–282-282
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/2021-2022/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 (PHYS 290) and Physics Experimentation Data Analysis Laboratory (PHYS 391) provide the correct foundation. Approximately 50 percent of physics undergraduates engage in substantive research during their course of study—typically beginning with Research Project I-III (PHYS 491–493). 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. 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.

Bachelor of Arts: Physics

Code	Title	Credits
Physics Core Courses		
MATH 251–253	Calculus I-III	12
or MATH 261–263	Calculus with Theory I-III	
PHYS 251–253	Foundations of Physics I	12
MATH 256	Introduction to Differential Equations	4
MATH 281–282	Several-Variable Calculus I-II	8
PHYS 290	Foundations of Physics Laboratory [1]	2
PHYS 351–353	Foundations of Physics II	12
PHYS 391	Physics Experimentation Data Analysis Laboratory	4
Interdisciplinary Science Core		
Two from the following: [2]		8
CH 221	General Chemistry I	
CH 222	General Chemistry II	
CH 224H	Advanced General Chemistry I	
CH 225H	Advanced General Chemistry II	
BI 211	General Biology I: Cells	
BI 212	General Biology II: Organisms	
BI 213	General Biology III: Populations	
CIS 210	Computer Science I	
CIS 211	Computer Science II	
CIS 212	Computer Science III	
ERTH 201	Dynamic Planet Earth	
HPHY 212	Scientific Investigation in Physiology	
Physics Upper-Division Courses		**24**
Three upper-division laboratory courses [3]		6
Total Credits		**92**

1. To be repeated, totaling 2 credits.
2. Students are strongly urged to complete this requirement in the first two years.
3. Any combination of PHYS 424–425 or PHYS 431–432 or PHYS 491–493 or PHYS 401, to total 6 credits.

Physics Sample Program

First Year		Credits
CH 221–222	General Chemistry (or any two courses from the Interdisciplinary Science Core)	8
PHYS 251–253	Foundations of Physics I	12
PHYS 290	Foundations of Physics Laboratory (two or more terms)	2
MATH 251–253	Calculus I-III	12
Second Year		
MATH 256	Introduction to Differential Equations	4
MATH 281–282	Several-Variable Calculus I-II	8
PHYS 351–353	Foundations of Physics II	12
PHYS 391	Physics Experimentation Data Analysis Laboratory	4
Third Year		
PHYS 411–413	Mechanics, Electricity, and Magnetism	12
Upper-division laboratory course from the following list: PHYS 424–425, PHYS 431–432, PHYS 491–493, or PHYS 401		2-4
Fourth Year		
PHYS 414–415	Quantum Physics	8
PHYS 417	Topics in Quantum Physics	4
Upper-division laboratory course from the following list: PHYS 424–425, PHYS 431–432, PHYS 491–493, or PHYS 401		2-4
	Total Credits:	**91-94**

Bachelor of Science: Physics

Code	Title	Credits
Physics Core Courses		
MATH 251–253	Calculus I-III	12
or MATH 261–263	Calculus with Theory I-III	
PHYS 251–253	Foundations of Physics I	12
MATH 256	Introduction to Differential Equations	4
MATH 281–282	Several-Variable Calculus I-II	8
PHYS 290	Foundations of Physics Laboratory [1]	2

PHYS 351–353	Foundations of Physics II	12
PHYS 391	Physics Experimentation Data Analysis Laboratory	4
Interdisciplinary Science Core		
Two from the following: [2]		8
CH 221	General Chemistry I	
CH 222	General Chemistry II	
CH 224H	Advanced General Chemistry I	
CH 225H	Advanced General Chemistry II	
BI 211	General Biology I: Cells	
BI 212	General Biology II: Organisms	
BI 213	General Biology III: Populations	
CIS 210	Computer Science I	
CIS 211	Computer Science II	
CIS 212	Computer Science III	
ERTH 201	Dynamic Planet Earth	
HPHY 212	Scientific Investigation in Physiology	
Physics Upper-Division Courses		**24**
Three upper-division laboratory courses [3]		6
Total Credits		**92**

1 To be repeated, totaling 2 credits.

2 Students are strongly urged to complete this requirement in the first two years.

3 Any combination of PHYS 424–425 or PHYS 431–432 or PHYS 491–493 or PHYS 401, to total 6 credits.

Physics Sample Program

First Year		Credits
CH 221–222	General Chemistry (or any two courses from the Interdisciplinary Science Core)	8
PHYS 251–253	Foundations of Physics I	12
PHYS 290	Foundations of Physics Laboratory (two or more terms)	2
MATH 251–253	Calculus I-III	12
Second Year		
MATH 256	Introduction to Differential Equations	4
MATH 281–282	Several-Variable Calculus I-II	8
PHYS 351–353	Foundations of Physics II	12
PHYS 391	Physics Experimentation Data Analysis Laboratory	4
Third Year		
PHYS 411–413	Mechanics, Electricity, and Magnetism	12
Upper-division laboratory course from the following list: PHYS 424–425, PHYS 431–432, PHYS 491–493, or PHYS 401		2-4
Fourth Year		
PHYS 414–415	Quantum Physics	8
PHYS 417	Topics in Quantum Physics	4
Upper-division laboratory course from the following list: PHYS 424–425, PHYS 431–432, PHYS 491–493, or PHYS 401		2-4
	Total Credits:	**91-94**

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:

Third Year		Credits
MATH 256	Introduction to Differential Equations	4
MATH 281–282	Several-Variable Calculus I-II	8
PHYS 351–353	Foundations of Physics II	12
PHYS 391	Physics Experimentation Data Analysis Laboratory	4
Fourth Year		
PHYS 411–413	Mechanics, Electricity, and Magnetism	12
PHYS 414–415	Quantum Physics	8
PHYS 417	Topics in Quantum Physics	4
PHYS 422	Electromagnetism	4
Select one or two of the following:		4-8
PHYS 424	Classical Optics	4
PHYS 425	Modern Optics	4
PHYS 431	Analog Electronics	4
PHYS 432	Digital Electronics	4
PHYS 491	Research Project I	4
PHYS 492	Research Project II	4
PHYS 493	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

Code	Title	Credits
Pre-Minor Requirements		
PHYS 251–253 or PHYS 201–203	Foundations of Physics I [1] or General Physics	12
Required Courses		
PHYS 351–353 or PHYS 411–413	Foundations of Physics II or Mechanics, Electricity, and Magnetism	12
Select one of the following:		4
PHYS 391	Physics Experimentation Data Analysis Laboratory	
400-level physics course		
Physics courses		8
Total Credits		**36**

[1] General Physics (PHYS 201–203) 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 another institution. 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 another institution. 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 (http://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.

Four-Year Degree Plan

- **Physics**

Bachelor of Arts in Physics

Course	Title	Credits	Milestones
First Year			
Fall			
PHYS 251	Foundations of Physics I	4	
PHYS 290	Foundations of Physics Laboratory	1	
CH 221	General Chemistry I	4	
MATH 251	Calculus I	4	
WR 121	College Composition I	4	
	Credits	**17**	
Winter			
PHYS 252	Foundations of Physics I	4	
PHYS 290	Foundations of Physics Laboratory	1	
CH 222	General Chemistry II	4	
MATH 252	Calculus II	4	
WR 122	College Composition II	4	
	Credits	**17**	
Spring			
PHYS 253	Foundations of Physics I	4	
PHYS 290	Foundations of Physics Laboratory	1	
MATH 253	Calculus III	4	
CIS 210	Computer Science I	4	
General-education course in arts and letters		4	
	Credits	**17**	
	Total Credits	**51**	

Course	Title	Credits	Milestones
Second Year			
Fall			
PHYS 351	Foundations of Physics II	4	
MATH 281	Several-Variable Calculus I	4	
PHYS 391	Physics Experimentation Data Analysis Laboratory	4	
General education course in arts and letters		4	
	Credits	**16**	
Winter			
PHYS 353	Foundations of Physics II	4	
MATH 282	Several-Variable Calculus II	4	
General-education course in social science		4	
General-education course that also satisfies a multicultural requirement		4	
	Credits	**16**	
Spring			
PHYS 353	Foundations of Physics II	4	
MATH 256	Introduction to Differential Equations	4	
General-education course in arts and letters		4	
General-education course in social science		4	
	Credits	**16**	
	Total Credits	**48**	

Course	Title	Credits	Milestones
Third Year			
Fall			
PHYS 412	Mechanics, Electricity, and Magnetism	4	
General-education course in arts and letters		4	
General-education course that also satisfies a multicultural requirement		4	
First term of first-year second-language sequence		4	
	Credits	**16**	
Winter			
PHYS 411	Mechanics, Electricity, and Magnetism	4	
PHYS 413	Mechanics, Electricity, and Magnetism	4	
General-education course in social science		4	
Second term of first-year second-language sequence		4	
	Credits	**16**	
Spring			
PHYS 422	Electromagnetism	4	
Third term of first-year second-language sequence		4	
General-education course in social science		4	
Elective course		4	
	Credits	**16**	
	Total Credits	**48**	

Course	Title	Credits	Milestones
Fourth Year			
Fall			
PHYS 414	Quantum Physics	4	
First term of second-year second-language sequence		4	
Elective courses		8	
	Credits	**16**	
Winter			
PHYS 415	Quantum Physics	4	
PHYS 431	Analog Electronics	4	
Second term of second-year second-language sequence		4	
Elective course		4	
	Credits	**16**	
Spring			
PHYS 417	Topics in Quantum Physics	4	
PHYS 432	Digital Electronics	4	
Third term of second-year second-language sequence		4	
Elective course		4	
	Credits	**16**	
	Total Credits	**48**	

Bachelor of Science in Physics

Course	Title	Credits	Milestones
First Year			
Fall			
PHYS 251	Foundations of Physics I	4	
PHYS 290	Foundations of Physics Laboratory	1	
CH 221	General Chemistry I	4	
MATH 251	Calculus I	4	
WR 121	College Composition I	4	
	Credits	**17**	
Winter			
PHYS 252	Foundations of Physics I	4	
PHYS 290	Foundations of Physics Laboratory	1	
CH 222	General Chemistry II	4	
MATH 252	Calculus II	4	
WR 122	College Composition II	4	
	Credits	**17**	
Spring			
PHYS 253	Foundations of Physics I	4	
PHYS 290	Foundations of Physics Laboratory	1	
MATH 253	Calculus III	4	
CIS 210	Computer Science I	4	
General-education course in arts and letters		4	
	Credits	**17**	
	Total Credits	**51**	

Course	Title	Credits	Milestones
Second Year			
Fall			
PHYS 351	Foundations of Physics II	4	
PHYS 391	Physics Experimentation Data Analysis Laboratory	4	
MATH 281	Several-Variable Calculus I	4	
General-education course in arts and letters		4	
	Credits	**16**	
Winter			
PHYS 352	Foundations of Physics II	4	
MATH 282	Several-Variable Calculus II	4	
General-education course in social science		4	
General-education course that also satisfies a multicultural requirement		4	
	Credits	**16**	
Spring			
PHYS 353	Foundations of Physics II	4	
MATH 256	Introduction to Differential Equations	4	
General-education course in arts and letters		4	
General-education course in social science		4	
	Credits	**16**	
	Total Credits	**48**	

Course	Title	Credits	Milestones
Third Year			
Fall			
PHYS 412	Mechanics, Electricity, and Magnetism	4	
General-education course in arts and letters		4	
General-education course in social science		4	
General-education course that also satisfies a multicultural requirement		4	
	Credits	**16**	

Winter		
PHYS 411	Mechanics, Electricity, and Magnetism	4
PHYS 413	Mechanics, Electricity, and Magnetism	4
General-education course in social science		4
Elective course		4
	Credits	**16**
Spring		
PHYS 422	Electromagnetism	4
Elective courses		12
	Credits	**16**
	Total Credits	**48**

Course	Title	Credits	Milestones
Fourth Year			
Fall			
PHYS 414	Quantum Physics	4	
Elective courses		12	
	Credits	**16**	
Winter			
PHYS 415	Quantum Physics	4	
PHYS 431	Analog Electronics	4	
Elective courses		8	
	Credits	**16**	
Spring			
PHYS 417	Topics in Quantum Physics	4	
PHYS 432	Digital Electronics	4	
Elective courses		8	
	Credits	**16**	
	Total Credits	**48**	

- **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 for Fundamental Science (IFS) enhances the experimental, theoretical, (http://physics.uoregon.edu/%7Ehet/) and astronomy research activities at the University of Oregon. (http://uoregon.edu/) IFS is one of several centers and institutes supported by the Office of the Vice President for Research and Innovation (http://research.uoregon.edu/), and maintains a close relationship with the Department of Physics (https://physics.uoregon.edu/) as well as the Department of Chemistry (https://chemistry.uoregon.edu/) and the Department of Mathematics (https://math.uoregon.edu/).

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 General Graduate Record Examinations (GRE), is required; the Physics GRE is strongly recommended. 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 employee (GE) opportunities or research fellowships is available on a competitive basis to PhD students. GEs 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.

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 department offers a traditional master's as well as an internship-based master's program in applied physics, designed to serve physics students whose primary interests lie in applied research and development rather than in basic research. The Master's Industrial Internship Program includes course work, professional development, and a nine-month paid internship that helps prepare physicists for a career in

industry or government labs. The internship salary helps offset the cost of tuition for students in this program; the traditional master's program does not include financial support.

Master of Science: Applied Physics

Code	Title	Credits
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

For a student to be in good academic standing, the cumulative GPA of the graded-credit total must be 3.00 or better.

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

The applied physics master of science (MS) degree requires the completion of 54 total credits—24 graded credits at the 500 level or higher and 30 internship research credits. The internship requirement must be fulfilled through the industrial internship program. Internship credits are taken pass/no pass. A student who is working full-time as an intern typically earns 10 credits each term.

Graded credits must be selected from an approved departmental list. The table below highlights courses commonly taken by students in the Master's Industrial Internship Program. 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.

Code	Title	Credits
PHYS 581	Design of Experiments	4
PHYS 626	Physical Optics with Labs	4
PHYS 627	Optical Materials and Devices	4
PHYS 628	Laser and Nonlinear Optics with OpticStudio	4
PHYS 677M	Semiconductor Device Physics	4
PHYS 678M	Semiconductor Processing and Characterization Technology	4
PHYS 679M	Device Processing and Characterization Laboratory	4
CH 680	Electronics and Vacuum Systems	4
CH 681	Introduction to Electron Microscopy	4
CH 682	Electron Microprobe Analysis	4
CH 683	Surface Analysis	4
CH 685	Advanced Transmission Electron Microscopy	4

Master of Science: Physics

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

Candidates must either submit a written thesis ***or*** take a program of specialized courses.

Thesis Option

Code	Title	Credits
Select one of the following:		9
PHYS 503	Thesis	
PHYS 503 & PHYS 601	Thesis and Research: [Topic]	
Total Credits		**9**

Specified-Course Option

The specified-courses option requires 40 graded graduate credits in physics with a GPA of at least 3.00 in these courses; 36 of those 40 credits 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 solely on course work. Detailed requirements can be found in the Graduate Student Handbook on the department's website.

Candidates must either submit a written thesis ***or*** take a program of specialized courses.

Thesis Option

Code	Title	Credits
Select one of the following:		9
PHYS 503	Thesis	
PHYS 503 & PHYS 601	Thesis and Research: [Topic]	
Total Credits		**9**

Specified-Course Option

The specified-courses option requires 40 graded graduate credits in physics with a GPA of at least 3.00 in these courses; 36 of those 40 credits 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 also must take and pass the core graduate sequences, listed below, achieving a B– or better grade in each course. Courses may be retaken once to achieve this minimum grade. The director of graduate studies can selectively waive these requirements in exceptional cases:

Code	Title	Credits
Core Sequences		
PHYS 611 & PHYS 612	Theoretical Mechanics and Theoretical Mechanics	6

PHYS 613 & PHYS 614	Statistical Physics and Statistical Physics	6
PHYS 622 & PHYS 623	Electromagnetic Theory and Electromagnetic Theory	8
PHYS 631 & PHYS 632 & PHYS 633	Quantum Mechanics and Quantum Mechanics and Quantum Mechanics	12
Breadth Requirements		
Six breadth courses [1]		

[1] Breadth courses can be chosen from several areas of physics and allied areas such as mathematics, chemistry, and biology.

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.

Astronomy Courses

ASTR 121. The Solar System. 4 Credits.
Naked-eye astronomy, development of astronomical concepts, and the solar system.

ASTR 122. Birth and Death of Stars. 4 Credits.
The structure and evolution of stars.

ASTR 123. Galaxies and the Expanding Universe. 4 Credits.
Galaxies and the universe.

ASTR 199. Special Studies: [Topic]. 1-5 Credits.
Repeatable.

ASTR 321. 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.

Physics Courses

PHYS 101. Essentials of Physics. 4 Credits.
Fundamental physical principles. Mechanics.

PHYS 152. 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.

PHYS 153. Physics of Light, Color, and Vision. 4 Credits.
Light and color, their nature, how they are produced, and how they are perceived and interpreted.

PHYS 155. 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.

PHYS 156M. 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 ERTH 156M.

PHYS 161. 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.

PHYS 162. Solar and Other Renewable Energies. 4 Credits.
Topics include photovoltaic cells, solar thermal power, passive solar heating, energy storage, geothermal energy, and wind energy.

PHYS 171. 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.

PHYS 181. Quantum Mechanics for Everyone. 4 Credits.
Introduction to quantum mechanics, a set of sometimes counterintuitive scientific principals describing atoms and light, along with the modern technologies it makes possible.

PHYS 196. Field Studies: [Topic]. 1-2 Credits.
Repeatable.

PHYS 198. Worskhop: [Topic]. 1-2 Credits.
Repeatable.

PHYS 199. Special Studies: [Topic]. 1-5 Credits.
Repeatable.

PHYS 201. General Physics. 4 Credits.
Introductory series. Mechanics and fluids.
Prereq: MATH 112 or equivalent.

PHYS 202. General Physics. 4 Credits.
Introductory series. Thermodynamics, waves, optics.
Prereq: PHYS 201.

PHYS 203. General Physics. 4 Credits.
Introductory series. Electricity, magnetism, modern physics.
Prereq: PHYS 201.

PHYS 204. 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.

PHYS 205. 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.

PHYS 206. 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.

PHYS 251. 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.

PHYS 252. Foundations of Physics I. 4 Credits.
Vibrations and waves; oscillations; wave mechanics; dispersion; modes; introductory optics.
Prereq: PHYS 251; coreq: MATH 252 or equivalent.

PHYS 253. Foundations of Physics I. 4 Credits.
Electricity and magnetism; charge and electric field; electric potential; circuits; magnetic field; inductance.
Prereq: PHYS 252; coreq: MATH 253 or equivalent.

PHYS 290. 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, PHYS 252 or PHYS 253.

PHYS 299. Special Studies: [Topic]. 1-5 Credits.
Repeatable.

PHYS 351. 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 MATH 281.

PHYS 352. Foundations of Physics II. 4 Credits.
Thermodynamic systems; first and second laws; kinetic theory of gases; entropy. Sequence.
Prereq: PHYS 351; coreq: MATH 281.

PHYS 353. Foundations of Physics II. 4 Credits.
Thermal radiation; Maxell-Boltzmann statistics; Fermi and Bose gases; phase transitions. Sequence.
Prereq: PHYS 352; coreq: MATH 282.

PHYS 362. 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 PHYS 353.

PHYS 369M. Science of Climbing. 2 Credits.
Introduction to the physics and scientific principles behind climbing, climbing equipment, anchors, ropes, climbing gear, static versus dynamic load, fall factor, and breaking strength. A prerequisite is students must have completed at least one Outdoor Program climbing course. Multilisted with PEO 369M.
Prereq: PEO 251.

PHYS 391. 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.

PHYS 399. Special Studies: [Topic]. 1-5 Credits.
Repeatable.

PHYS 400M. Temporary Multilisted Course. 1-5 Credits.
Repeatable.

PHYS 401. Research: [Topic]. 1-16 Credits.
Repeatable.

PHYS 403. Thesis. 1-12 Credits.
Repeatable.

PHYS 405. Reading and Conference: [Topic]. 1-16 Credits.
Repeatable.

PHYS 406. Field Studies: [Topic]. 1-21 Credits.
Repeatable.

PHYS 407. Seminar: [Topic]. 1-4 Credits.
Repeatable.

PHYS 408. Workshop: [Topic]. 1-21 Credits.
Repeatable.

PHYS 409. Supervised Tutoring. 1-3 Credits.
Repeatable.

PHYS 410. Experimental Course: [Topic]. 1-4 Credits.
Repeatable.

PHYS 411. Mechanics, Electricity, and Magnetism. 4 Credits.
Fundamental principles of Newtonian mechanics, conservation laws, small oscillations, planetary motion, systems of particles. Electromagnetic phenomena. Only nonmajors may earn graduate credit.
Prereq: MATH 282.

PHYS 412. Mechanics, Electricity, and Magnetism. 4 Credits.
Fundamental principles of Newtonian mechanics, conservation laws, small oscillations, planetary motion, systems of particles. Electromagnetic phenomena.
Prereq: MATH 281.

PHYS 413. Mechanics, Electricity, and Magnetism. 4 Credits.
Fundamental principles of Newtonian mechanics, conservation laws, small oscillations, planetary motion, systems of particles. Electromagnetic phenomena.
Prereq: PHYS 412.

PHYS 414. 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.

PHYS 415. 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.

PHYS 417. Topics in Quantum Physics. 4 Credits.
Perturbation theory, variational principle, time-dependent perturbation theory, elementary scattering theory.
Prereq: PHYS 415.

PHYS 421M. Partial Differential Equations: Fourier Analysis I. 4 Credits.
Introduction to PDEs with a view towards applications in physics. Wave and heat equations, classical Fourier series on the circle, Bessel and Legendre series. Multilisted with MATH 421M.
Prereq: MATH 253; one from MATH 256, MATH 281.

PHYS 422. 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.

PHYS 424. Classical Optics. 4 Credits.
Geometrical optics, polarization, interference, Frauenhofer and Fresnel diffraction.
Prereq: PHYS 353.

PHYS 425. 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.

PHYS 431. 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.

PHYS 432. 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.

PHYS 481. 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.

PHYS 491. 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.

PHYS 492. 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.

PHYS 493. 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.

PHYS 500M. Temporary Multilisted Course. 1-5 Credits.
Repeatable.

PHYS 503. Thesis. 1-16 Credits.
Repeatable.

PHYS 507. Seminar: [Topic]. 1-4 Credits.
Repeatable.

PHYS 508. Workshop: [Topic]. 1-21 Credits.
Repeatable.

PHYS 510. Experimental Course: [Topic]. 1-4 Credits.
Repeatable.

PHYS 521M. Partial Differential Equations: Fourier Analysis I. 4 Credits.
Introduction to PDEs with a view towards applications in physics. Wave and heat equations, classical Fourier series on the circle, Bessel and Legendre series. Multilisted with MATH 521M.

PHYS 581. 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.

PHYS 601. Research: [Topic]. 1-16 Credits.
Repeatable.

PHYS 603. Dissertation. 1-16 Credits.
Repeatable.

PHYS 604. Internship: [Topic]. 1-16 Credits.
Repeatable.
Coreq: good standing in applied physics master's degree program.

PHYS 605. Reading and Conference: [Topic]. 1-16 Credits.
Repeatable.

PHYS 606. Field Studies: [Topic]. 1-16 Credits.
Repeatable.

PHYS 607. Seminar: [Topic]. 1-4 Credits.
Repeatable. Recent topics include Astrophysics and Gravitation, Biophysics, Condensed Matter, High Energy Physics, Physics Colloquium, Theoretical Physics.

PHYS 608. Workshop: [Topic]. 1-16 Credits.
Repeatable.

PHYS 609. Supervised Tutoring. 1-3 Credits.
Repeatable.

PHYS 610. Experimental Course: [Topic]. 1-4 Credits.
Repeatable.

PHYS 611. Theoretical Mechanics. 4 Credits.
Lagrangian and Hamiltonian mechanics, small oscillations, rigid bodies. Sequence.

PHYS 612. Theoretical Mechanics. 2 Credits.
Lagrangian and Hamiltonian mechanics, small oscillations, rigid bodies. Sequence.
Prereq: PHYS 611.

PHYS 613. Statistical Physics. 2 Credits.
Thermodynamics, statistical mechanics, kinetic theory, application to gases, liquids, solids, atoms, molecules, and the structure of matter. Sequence.

PHYS 614. 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.

PHYS 622. 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.

PHYS 623. 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.

PHYS 626. 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.

PHYS 627. 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.

PHYS 628. 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.

PHYS 631. Quantum Mechanics. 4 Credits.
Review of fundamentals, central force problems, matrix mechanics. Sequence.

PHYS 632. Quantum Mechanics. 4 Credits.
Approximation methods, scattering. Sequence.
Prereq: PHYS 631.

PHYS 633. Quantum Mechanics. 4 Credits.
Rotation symmetry, spin, identical particles. Sequence.
Prereq: PHYS 632.

PHYS 661. Particle Physics I. 4 Credits.
Theory, phenomenology, and experimental basis of the standard model of particle physics: fundamentals; symmetries; quantum electrodynamics; R; quarks and leptons; chirality; flavor symmetry; mesons; baryons; form factors; deep inelastic scattering. Sequence.

PHYS 662. Particle Physics II. 4 Credits.
Theory, phenomenology, and experimental basis of the standard model of particle physics: quantum chromodynamics; parton distribution functions; hadron-hadron collisions; particle interactions in matter; collider detectors; experimental methodologies to analyze data; statistical thresholds and significance. Sequence with PHYS 661, PHYS 663.
Prereq: PHYS 661.

PHYS 663. Particle Physics III. 4 Credits.
Theory, phenomenology, and experimental basis of the standard model of particle physics: electroweak symmetry breaking; CKM mixing; Higgs couplings; early universe cosmology; Friedmann expansion; entropy; freeze-out; impact of neutrinos on cosmology; dark matter evidence and candidates. Sequence with PHYS 661, PHYS 662.
Prereq: PHYS 662.

PHYS 664. 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 with PHYS 665, PHYS 666.

PHYS 665. Quantum Field Theory II. 4 Credits.
The purpose of this course is to apply the methodology established in QFT I to theories of charged fermions coupled to a photon. Then we will begin to explore QFT beyond leading order. Sequence with PHYSS 664, PHYS 666.
Prereq: PHYS 664.

PHYS 666. Quantum Field Theory III. 4 Credits.
The purpose of this course is to understand QFT at loop level, and to extend the formalism to non-Abelian gauge bosons. In addition, we will cover a variety of special topics. This course is designed to be the last quarter of a full year sequence. Sequence with PHYS 664, PHYS 665.
Prereq: PHYS 665.

PHYS 671. 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.

PHYS 672. 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.

PHYS 674. 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.

PHYS 675. 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.

PHYS 677M. 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.

PHYS 678M. 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. Multilisted with CH 678M. Sequence with PHYS 677M, PHYS 679M.
Prereq: PHYS 677M.

PHYS 679M. 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: CH 678M.

PHYS 684. 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.

PHYS 685. 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.

PHYS 686. 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.