

Department of Physics and Astronomy

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Overview

Physics is that branch of science concerned with the study of natural phenomena at the fundamental level. Physicists study the smallest particles of matter (quarks and leptons), nuclei, and atoms; the fundamental forces; the properties of solids, liquids, gases, and plasmas; the behavior of matter on the grand scale in stars and galaxies; and even the origin and fate of the universe. Other disciplines such as chemistry, biology, medicine, and engineering often build upon the foundations laid by physics.

The Department of Physics and Astronomy offers introductory and advanced courses for students of various interests, from those in the humanities and social sciences, to those in biological sciences, and to those in physics, engineering, and other sciences. The Department offers majors in Physics and Applied Physics, with interdisciplinary concentrations and tracks that include astrophysics, engineering physics, science education, and courses taught by faculty in Biological Sciences, Chemistry, Engineering, and Medicine.

Furthermore, the faculty is vigorous, innovative, and engaged in a wide variety of research, education, and public service activities. The Department encourages student-faculty interaction and student involvement in undergraduate research. Faculty conduct active research in forefront research areas, providing students access to research opportunities in specialized areas like cosmology, particle physics, plasmas and fusion, condensed matter physics, biophysics, and medical physics.

Undergraduate Program

The goal of the undergraduate majors in Physics and Applied Physics is to develop expert problem solvers with a broad understanding of physical principles. The programs are flexible and prepare students for careers in industrial research, applications programming, education, law, or business, as well as for graduate study in astronomy, biomedical physics, engineering, or physics.

Students choose a major in either pure Physics or Applied Physics. The major in Physics includes a standard track for graduate study in physics, a Specialization in Astrophysics, and Concentrations in Computational Physics, the Philosophy of Physics, and Physics Education. The major in Applied Physics allows students to combine physics courses with courses from overlapping disciplines, such as materials science, electrical engineering, geosciences, biomedical imaging, or other fields. Annual mandatory meetings with faculty advisors assist students in selecting the right program for their aptitudes and interests.

Different sequences of lower-division physics courses are distinguished by their intended audience, their mathematical prerequisites, and the extent to which they offer preparation for more advanced courses. These aspects of the introductory courses are summarized as follows:

Physics 3: *Intended audience:* Premedical students, Biological Sciences majors. *Prerequisites:* concurrent enrollment in MATH 2A. *Preparation for advanced courses:* PHYSICS 7D with permission.

Physics 7: *Intended audience:* Physical Sciences and Engineering majors. *Prerequisite:* concurrent enrollment in MATH 2B. *Preparation for advanced courses:* PHYSICS 51A or PHYSICS 61A.

Physics 12-21: *Intended audience:* Nonscience majors. *Prerequisites:* none. *Preparation for advanced courses:* none.

Admission to the Physics or Applied Physics Majors

Students may be admitted to the Physics or Applied Physics majors upon entering the University as freshmen, via change of major, or as transfer students from other colleges and universities. Information about change of major policies is available in the Physical Sciences Student Affairs Office and at the UCI Change of Major Criteria website (<http://www.changeofmajor.uci.edu>). For transfer student admission, preference will be given to junior-level applicants with the highest grades overall and who have satisfactorily completed the following required courses: one year of approved calculus and one year of calculus-based physics with laboratory for engineering and physics majors. Completion of multivariable calculus, linear algebra, and differential equations is recommended.

Requirements for the B.S. in Physics (with Concentrations and a Specialization)

All students must meet the University Requirements (<http://catalogue.uci.edu/informationforadmittedstudents/requirementsforabachelorsdegree>).

School Requirements: None.

Departmental Requirements

MATH 2A

or MATH 5A

Single-Variable Calculus

Calculus for Life Sciences

MATH 2B	Single-Variable Calculus
MATH 2D- 2E	Multivariable Calculus and Multivariable Calculus
MATH 3A	Introduction to Linear Algebra
MATH 3D	Elementary Differential Equations
PHYSICS 7C- 7D- 7E	Classical Physics and Classical Physics and Classical Physics
PHYSICS 7LC- 7LD	Classical Physics Laboratory and Classical Physics Laboratory
PHYSICS 50	Introductory Mathematical Physics
PHYSICS 52A- 52B- 52C	Fundamentals of Experimental Physics and Fundamentals of Experimental Physics and Fundamentals of Experimental Physics
PHYSICS 53	Introduction to Programming and Numerical Analysis (or another programming course)
PHYSICS 60	Thermal Physics
PHYSICS 61A	Modern Physics for Majors ¹
PHYSICS 61B or PHYSICS 61C	Modern Physics for Majors Introduction to Astrophysics
PHYSICS 111A- 111B	Classical Mechanics and Classical Mechanics
PHYSICS 112A- 112B	Electromagnetic Theory and Electromagnetic Theory
PHYSICS 113A	Quantum Physics
PHYSICS 115A	Statistical Physics
PHYSICS 121W	Advanced Laboratory
PHYSICS 125A	Mathematical Physics
PHYSICS 194	Research Communication for Physics Majors

And select five additional coherently related four-unit courses. (This requirement is normally satisfied by concentrations, specializations, and tracks, as listed below.)

¹ For students transferring into the major after taking PHYSICS 51A-PHYSICS 51B, PHYSICS 51A-PHYSICS 51B will be accepted in place of PHYSICS 61A-PHYSICS 61B.

Upper-Division Writing Requirement: Physics majors are required to satisfy the upper-division writing requirement by completing PHYSICS 194 with a grade of C or better, followed by PHYSICS 121W with a grade of C or better.

Sample Program — Physics Core Curriculum

Freshman		
Fall	Winter	Spring
MATH 2B	MATH 2D	MATH 2E
PHYSICS 7C- 7LC (PHYSICS 99)	PHYSICS 7D- 7LD	PHYSICS 7E
Sophomore		
Fall	Winter	Spring
MATH 3A	MATH 3D	PHYSICS 60
PHYSICS 52A	PHYSICS 52B PHYSICS 61A	PHYSICS 52C PHYSICS 61B or 61C
Junior		
Fall	Winter	Spring
PHYSICS 111A	PHYSICS 111B	PHYSICS 53
PHYSICS 50	PHYSICS 112A	PHYSICS 112B PHYSICS 113A

Senior

Fall	Winter
PHYSICS 115A	PHYSICS 121W
PHYSICS 194	PHYSICS 125A

For a student planning graduate study in physics, additional courses in advanced physics are strongly recommended.

Concentration in Computational Physics

The **Computational Physics concentration** provides training for positions in software development in a wide variety of high-technology fields. For example, consider medical imaging software for magnetic resonance imaging. To write a first-rate program, one must understand the apparatus and analysis techniques (physics), use appropriate numerical techniques (numerical analysis), and employ a convenient object-oriented interface (computer science). The concentration develops this unique set of skills: physical and mathematical insight through the Physics curriculum, knowledge of modern computer programming techniques, and knowledge of numerical analysis.

Requirements:

Three courses in computer science:

I&C SCI 31	Introduction to Programming
I&C SCI 32	Programming with Software Libraries
I&C SCI 33	Intermediate Programming

Two courses in numerical analysis plus the accompanying laboratories:

MATH 105A- 105B	Numerical Analysis and Numerical Analysis
MATH 105LA- 105LB	Numerical Analysis Laboratory and Numerical Analysis Laboratory

One advanced computational course and accompanying laboratory:

MATH 107- 107L	Numerical Differential Equations and Numerical Differential Equations Laboratory
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Sample Program — Computational Physics Concentration**Junior**

Fall	Winter	Spring
I&C SCI 31	I&C SCI 32	I&C SCI 33

Senior

Fall	Winter	Spring
MATH 105A- 105LA	MATH 105B- 105LB	MATH 107- 107L

Concentration in Philosophy of Physics

The **Philosophy of Physics concentration** is concerned with the study of the conceptual history of physics, the method of inquiry that has led to our best physical theories, and the structure and interpretation of the theories themselves. Students take courses in deductive and inductive logic, the philosophy and history of physics, and quantum mechanics. The emphasis on careful argument makes this concentration useful for anyone who wishes to pursue a graduate degree in philosophy or law, or for other careers that employ both verbal and quantitative analysis.

Requirements:

Select one from the following:

LPS 40	The Nature of Scientific Inquiry
LPS 60	The Making of Modern Science
SOC SCI H1G	Honors: Critical Issues on the Social Sciences
LPS H125	What Is Time?
LPS H80	Scientific Realism and Instrumentalism
or another approved Campuswide Honors course	

Select one of the following:

LPS 30	Introduction to Symbolic Logic
LPS 104	Introduction to Logic
LPS 105A- 105B- 105C	Elementary Set Theory and Metalogic and Undecidability and Incompleteness
MATH 150	Introduction to Mathematical Logic

Complete:

LPS 31 Introduction to Inductive Logic

Select one from the following:

LPS 104 Introduction to Logic

LPS 105A- 105B- 105C Elementary Set Theory and Metalogic and Undecidability and Incompleteness

LPS 140 Topics in Philosophy of Science

MATH 150 Introduction to Mathematical Logic

HISTORY 135D Maps from Prehistory to the Present (when the topic is physics; or another approved elective)

Complete:

PHYSICS 113B Quantum Physics

Select three from the following:

LPS 141A Topics in Philosophy of Physics

LPS 141B Geometry and Spacetime

LPS 141C Philosophy of Quantum Mechanics

LPS 141D Probability and Determinism

or other approved Philosophy of Physics course

Concentration in Physics Education

The **Physics Education concentration** is for students who plan a career in secondary education. An Education course, four general science courses, a research methods course, and two quarters of classroom experience complete the requirements for the concentration. Students are encouraged to take PHYSICS 191 (outreach).

Requirements:

EDUC 55 Knowing and Learning in Mathematics and Science

PHY SCI 5 California Teach 1: Introduction to Science and Mathematics Teaching

PHY SCI 105 California Teach 2: Middle School Science and Mathematics Teaching

PHYSICS 193 Research Methods

Select four courses from the following:

BIO SCI 1A Life Sciences

BIO SCI 93 From DNA to Organisms

BIO SCI 94 From Organisms to Ecosystems

CHEM 1A- 1B- 1C General Chemistry and General Chemistry and General Chemistry

EARTHSS 1 Introduction to Earth System Science

EARTHSS 7 Physical Geology

PHYSICS 20A- 20B Introduction to Astronomy and Cosmology: Humanity's Place in the Universe

NOTE: With this concentration, a Secondary Teaching Certification (p.) option is available.

Secondary Teaching Certification Option: With *additional* course work and field experience offered through the UCI Cal Teach program, students who complete the concentration in Physics Education can also earn a California Preliminary Single Subject Teaching Credential. Completing the bachelor's degree, concentration, and teacher certification in four years is possible with careful, early planning. Additional courses required for teacher certification are:

LPS 60 The Making of Modern Science

EDUC 109 Reading and Writing in Secondary Mathematics and Science Classrooms

EDUC 143AW Classroom Interactions I

EDUC 143BW Classroom Interactions II

EDUC 148 Complex Pedagogical Design ¹

EDUC 158	Student Teaching Mathematics and Science in Middle/High School (two quarters)
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¹ Successful completion of EDUC 143AW-EDUC 143BW and EDUC 148 will be accepted in lieu of PHYSICS 125A and PHYSICS 194 for Cal Teach students.

For additional information about teacher certification requirements and enrollment procedures, see Preparation for Teaching Science and Mathematics (<http://catalogue.uci.edu/schoolofphysicalsciences/#undergraduateprogramstext>). Interested students are strongly encouraged to contact the Cal Teach Resource and Advising Center or the Physical Sciences Student Affairs Office.

Sample Program — Concentration in Physics Education with Secondary Teaching Certification Option

Freshman		
Fall	Winter	Spring
MATH 2B	MATH 2D	MATH 2E
PHYSICS 7C- 7LC	PHYSICS 7D- 7LD	PHYSICS 7E
General Education (PHYSICS 99)	General Education PHY SCI 5	General Education General Education
Sophomore		
Fall	Winter	Spring
MATH 3A	MATH 3D	PHYSICS 60
PHYSICS 52A	PHYSICS 61A	PHYSICS 61B
PHY SCI 105	PHYSICS 52B	PHYSICS 52C
	PHYSICS 193	LPS 60
Junior		
Fall	Winter	Spring
PHYSICS 50	PHYSICS 111B	PHYSICS 53
PHYSICS 111A	PHYSICS 112A	PHYSICS 112B
General Science	General Science	PHYSICS 113A
General Science	EDUC 143AW	EDUC 148
EDUC 55		
Senior		
Fall	Winter	Spring
PHYSICS 115A	General Education	PHYSICS 121W
General Science	EDUC 109	General Education
EDUC 143BW	EDUC 158	EDUC 158

Specialization in Astrophysics

The **Astrophysics specialization** is primarily taken by two types of students, those planning on going on to graduate school in astronomy or astrophysics and those planning to work in aeronautics or astrophysics-related industries or government research laboratories after receiving their bachelor's degree. It also is an excellent focus for students who anticipate careers in science journalism, teaching, science administration, or public relations. The course work includes:

A. Complete:

PHYSICS 61C	Introduction to Astrophysics
PHYSICS 139	Observational Astrophysics

B. Select three courses from the following:

PHYSICS 137	Introduction to Cosmology
PHYSICS 138	Extragalactic Astrophysics
PHYSICS 144	Stellar Astrophysics
PHYSICS 145	High-Energy Astrophysics

C. Two or more upper-division Physics courses. Of the Physics electives, students bound for graduate school are strongly advised to include:

PHYSICS 113B	Quantum Physics
PHYSICS 125B	Mathematical Physics

Other recommended electives include:

PHYSICS 116	Relativity and Black Holes
PHYSICS 134A	Physical and Geometrical Optics
PHYSICS 135	Plasma Physics
PHYSICS 136	Introduction to Particle Physics

Sample Program — Astrophysics Specialization

Junior		
Fall	Winter	Spring
PHYSICS 116	PHYSICS 137	PHYSICS 144 or 145
Senior		
Fall	Winter	Spring
PHYSICS 113B	PHYSICS 138	PHYSICS 135
PHYSICS 139		PHYSICS 125B
		PHYSICS 144 or 145

Requirements for the B.S. in Applied Physics (with Concentrations)

All students must meet the University Requirements (<http://catalogue.uci.edu/informationforadmittedstudents/requirementsforabachelorsdegree>).

School Requirements: None**Departmental Requirements**

A. Complete the following:

MATH 2A or MATH 5A	Single-Variable Calculus Calculus for Life Sciences
MATH 2B	Single-Variable Calculus
MATH 2D- 2E	Multivariable Calculus and Multivariable Calculus
MATH 3A	Introduction to Linear Algebra
MATH 3D	Elementary Differential Equations
PHYSICS 50	Introductory Mathematical Physics
PHYSICS 61A or PHYSICS 51A	Modern Physics for Majors Modern Physics
PHYSICS 111A	Classical Mechanics
PHYSICS 112A	Electromagnetic Theory
PHYSICS 113A	Quantum Physics
PHYSICS 115A	Statistical Physics

B. Complete one of the following series:

PHYSICS 7C- 7LC- 7D- 7LD- 7E	Classical Physics and Classical Physics Laboratory and Classical Physics and Classical Physics Laboratory and Classical Physics
or	
PHYSICS 3A- 3B- 3LB- 3C- 3LC	Basic Physics I and Basic Physics II and Basic Physics Laboratory and Basic Physics III and Basic Physics Laboratory

C. Complete one of the following:

PHYSICS 53	Introduction to Programming and Numerical Analysis
I&C SCI 45C	Programming in C/C++ as a Second Language
MATH 9	Introduction to Programming for Numerical Analysis
EECS 10	Computational Methods in Electrical and Computer Engineering
EECS 12	Introduction to Programming

D. Complete one of the following:

PHYSICS 60	Thermal Physics
CHEM 1C	General Chemistry
CHEM H2C	Honors General Chemistry
CHEM M3C	Majors Quantitative Analytical Chemistry
ENGRMAE 91	Introduction to Thermodynamics

E. Complete six units of lower-division laboratory using any combination of the following courses:

PHYSICS 52A- 52B- 52C	Fundamentals of Experimental Physics and Fundamentals of Experimental Physics and Fundamentals of Experimental Physics
CHEM 1LC- 1LD	General Chemistry Laboratory and General Chemistry Laboratory
CHEM H2LA- H2LB	Honors General Chemistry Laboratory and Honors General Chemistry Laboratory
CHEM M2LA- M2LB	Majors General Chemistry Laboratory and Majors General Chemistry Laboratory
CHEM 51LB- 51LC	Organic Chemistry Laboratory and Organic Chemistry Laboratory
CHEM H52LA- H52LB	Honors Organic Chemistry Laboratory and Honors Organic Chemistry Laboratory
CHEM M52LA- M52LB	Majors Organic Chemistry Laboratory and Majors Organic Chemistry Laboratory
ENGR 7A- 7B	Introduction to Engineering I and Introduction to Engineering II
EECS 70LA- 70LB	Network Analysis I Laboratory and Network Analysis II Laboratory

F. Complete eight units of upper-division laboratory using any combination of the following courses:

PHYSICS 106W	Laboratory Skills and Scientific Writing
PHYSICS 120	Electronics for Scientists
PHYSICS 121W	Advanced Laboratory
PHYSICS 139	Observational Astrophysics
PHYSICS 193	Research Methods
PHYSICS 196C	Thesis in Physics III
or one approved upper-division laboratory course outside of Physics	

G. Complete two units of writing communication from the following courses:

PHYSICS 194	Research Communication for Physics Majors ¹
PHY SCI 139W	Technical Writing and Communication Skills
EDUC 143BW	Classroom Interactions II

or alternate upper-division writing course with department approval

H. Complete 32 additional units of coherently-related electives in accord with the following rules:

- Up to eight units may be lower-division electives in physics such as PHYSICS 20, PHYSICS 61B, or PHYSICS H90
- Any upper-division physics courses PHYSICS 100-150
- Any graduate level physics courses PHYSICS 200-299 with approval of the Department Undergraduate Advisor
- Any combination of physics and non-physics courses pre-approved as a formal Concentration or Specialization
- Any other combination of physics and non-physics courses approved by the Physics Department Undergraduate Committee.

¹ PHYSICS 194 does not satisfy the University's upper-division writing requirement. It is a prerequisite course for PHYSICS 121W, which does satisfy the upper-division writing requirement.

NOTE: Students may not double major in Physics and Applied Physics.

Concentration in Biomedical Physics

The **Biomedical Physics Concentration** in Applied Physics is designed for the student who anticipates a career in physics applied to biology and medicine, such as health physics or radiological physics, or who intends to work in a scholarly field which deals with the physical aspects of biology or medicine, such as molecular biology or physiology. Completion of requirements for the Physics major is required, as are nine quarters of basic courses in biology and chemistry. Students who wish to follow the Biomedical Physics Concentration are advised to seek guidance early in their college careers. The requirements are such that coordination of a program in the second year is essential.

A. Complete the following:

BIO SCI 97	Genetics
BIO SCI 98	Biochemistry
BIO SCI 99	Molecular Biology

B. Select one of the following:

CHEM 1A- 1B- 1C	General Chemistry and General Chemistry and General Chemistry
or	
CHEM H2A- H2B- H2C	Honors General Chemistry and Honors General Chemistry and Honors General Chemistry
C. Select one of the following:	
CHEM 1LC- 1LD	General Chemistry Laboratory and General Chemistry Laboratory
or	
CHEM H2LA- H2LB	Honors General Chemistry Laboratory and Honors General Chemistry Laboratory
or	
CHEM M2LA- M2LB	Majors General Chemistry Laboratory and Majors General Chemistry Laboratory
D. Select one of the following:	
CHEM 51A- 51B	Organic Chemistry and Organic Chemistry
or	
CHEM H52A- H52B	Honors Organic Chemistry and Honors Organic Chemistry

Sample Program - Biomedical Physics Concentration in Applied Physics

Freshman		
Fall	Winter	Spring
CHEM 1A	CHEM 1B	CHEM 1C- 1LC
Sophomore		
Fall	Winter	Spring
CHEM 1LD CHEM 51A	CHEM 51B	N/A
Junior		
Fall	Winter	Spring
BIO SCI 97	BIO SCI 98	BIO SCI 99

Concentration in Engineering Physics

The **Engineering Physics Concentration** in Applied Physics is designed to provide appropriate education to students who anticipate a career in industrial or technological research. It combines the fundamental knowledge of physical processes obtained from physics courses with the technical knowledge obtained from engineering courses.

Students in the Engineering Physics Concentration must complete 32 units of coherently related electives, with at least 24 of these units from courses in the Henry Samueli School of Engineering. Students may propose any sequence for approval by the Department Undergraduate Advisor. Pre-approved courses include:

EECS 70A	Network Analysis I
EECS 70B- 70LB	Network Analysis II and Network Analysis II Laboratory
EECS 170A- 170LA	Electronics I and Electronics I Laboratory
EECS 170B- 170LB	Electronics II and Electronics II Laboratory
EECS 170C- 170LC	Electronics III and Electronics III Laboratory
EECS 174	Semiconductor Devices
EECS 188	Optical Electronics
ENGRMAE 120	Heat and Mass Transfer
ENGRMAE 130A	Introduction to Fluid Mechanics

ENGRMAE 147

Vibrations

Sample Program - Engineering Physics Concentration in Applied Physics

Junior		
Fall	Winter	Spring
N/A	EECS 70A	EECS 70B- 70LB
Senior		
Fall	Winter	Spring
EECS 170A- 170LA	EECS 170B- 170LB EECS 188	PHYSICS 106W EECS 170C- 170LC

Additional Information**Honors Program in Physics**

The Honors Program in Physics provides an opportunity for selected students majoring in Physics or Applied Physics to pursue advanced work in one of the research areas of the Department. Admission to the program is based on an application normally submitted by the sixth week of the spring quarter of the junior year. Applicants must have an overall grade point average of at least 3.4 and a grade point average in physics courses of 3.5 or better. (Exceptions to these procedures and standards may be granted in unusual circumstances.) In selecting students for the program, the Department considers evidence of ability and interest in research.

Students admitted to the program participate in a year-long course, PHYSICS H196A-PHYSICS H196B-PHYSICS H196C, which includes two quarters of research and a final quarter in which a written thesis is submitted. If this work and the student's final GPA are deemed of honors quality by the program advisor, the student then graduates with Departmental Honors in Physics.

Planning a Program of Study

Physics 3 is a one-year course suitable for premedical students, students majoring in Biological Sciences, and nonscience majors. It surveys most of the important branches of physics. Laboratory work accompanies the course. Nonscience majors with some mathematical skill may wish to consider Physics 3 as an alternative to PHYSICS 12 through PHYSICS 21.

A student who decides to major in Physics after completing Physics 3 should meet with the Department Undergraduate Advisor for placement information.

Physics 7 is an intensive three-quarter course for students in Physical Sciences and Engineering who are interested in a more quantitative approach to introductory physics. Two units of laboratory work accompany the course.

Physics courses numbered between 12 and 21 are general education courses intended for nonscience majors. The content and format of PHYSICS 21 may vary from year to year.

The introduction to mathematical methods (MATH 2E, MATH 3A, MATH 3D, and PHYSICS 50), microscopic physics (PHYSICS 61A-PHYSICS 61B), and experimental physics (PHYSICS 52A-PHYSICS 52B-PHYSICS 52C) are normally taken in the sophomore year.

Courses numbered 100 and above are for Physics majors and other qualified students. Courses numbered between 111 and 115 emphasize the mathematical and theoretical structures that have unified our understanding of nature. It should be noted that multi-quarter courses such as 111A-B must be taken and passed in sequential order. Any student who is so inclined may take more than the minimum one quarter of advanced laboratory work. Courses numbered between 133 and 149 introduce active subdisciplines in current research. Independent research (PHYSICS 195, PHYSICS 196) is strongly encouraged. In PHYSICS 194, students learn the basics of writing about science, proper use of references and background material, presentation of research proposals, and more.

Transfer students are specifically advised to seek individual consultation with the Department Undergraduate Advisor before deciding on a program of courses.

All Physics and Applied Physics majors must complete the core courses listed with the sample programs. By the end of the junior year, each student is encouraged to select a concentration or track.

Note that alternatives to Physics major requirements can be approved upon petition to the Department and the Office of the Associate Dean. Furthermore, exceptionally prepared students are allowed to enroll in graduate-level courses; to do so requires the approval of the Department Undergraduate Advisor.

Sample Program — Physics Graduate School Track**Junior****Fall**PHYSICS 115A or
116

Senior		
Fall	Winter	Spring
PHYSICS 113B	PHYSICS 113C	PHYSICS 135
PHYSICS 115A or 116	Physics Elective	PHYSICS 125B
Physics Elective		Physics Elective

Students preparing for graduate school in atmospheric science or physical oceanography should complete the minor in Earth and Atmospheric Sciences.

Graduate Program

The Department offers an M.S. and a Ph.D. in Physics. These degrees are awarded in recognition of demonstrated knowledge of the basic facts and theories of physics and of a demonstrated capacity for independent research. Active programs of research are underway in particle physics, nanophysics, biophysics, medical physics, condensed matter physics, low-temperature physics, plasma physics, gravitational physics, astrophysics, and cosmology.

In general, graduate study in the physics Ph.D. program is expected to be a full-time activity. Other proposed arrangements should be approved by the Graduate Committee. The normative time for completion of the Ph.D. is six years of full-time study, and the maximum time permitted is seven years. Students may pursue the M.S. on either a full-time or part-time basis.

Complementing the formal courses, the Department offers regular colloquia and informal seminars. Graduate students are members of an intellectual community and are expected to participate fully in departmental activities. Attendance at colloquia is considered an essential part of graduate study. In addition, there are regular weekly research seminars in condensed matter, particle, and plasma physics, and astrophysics.

Sources of support available to graduate students include teaching assistantships, research assistantships, and fellowships. Students planning to pursue graduate work in Physics should visit the Physics Department website (<http://www.physics.uci.edu>).

Students admitted into the graduate program in Physics and Astronomy may elect to pursue the M.S. or Ph.D. with a concentration in Chemical and Materials Physics, as described in a later section.

Master of Science in Physics

Requirements for the M.S.

All courses must be passed with a grade of B or better.

A. Three quarters of residence.

B. Seven quarter courses including:

PHYSICS 211	Classical Mechanics
PHYSICS 212A	Mathematical Physics
PHYSICS 213A	Electromagnetic Theory
PHYSICS 213B	Electromagnetic Theory
or PHYSICS 240C	Radiative Processes in Astrophysics
PHYSICS 214A	Statistical Physics
PHYSICS 215A- 215B	Quantum Mechanics and Quantum Mechanics

C. Two courses numbered between 200 and 259

D. Two other courses approved by the graduate advisor

E. Select Option A or Option B below:

Option A. Research project and written thesis (three quarters)	
PHYSICS 295	Experimental Research
or PHYSICS 296	Theoretical Research
Option B. Comprehensive written examination	
PHYSICS 215B	Quantum Mechanics

The requirements for the M.S. with a concentration in Chemical and Materials Physics differ from these.

Doctor of Philosophy in Physics

The principal requirements for the Ph.D. are a minimum of six quarters of residence, passage of a written and an oral examination, and successful completion and defense of a dissertation reporting results of original research. In addition, the Ph.D. candidate must complete certain graduate course requirements. There is no foreign language requirement.

Course Requirements

Students are required to exhibit mastery of the basic sequences—Classical Mechanics, Electromagnetic Theory, Quantum Mechanics, Mathematical Physics, and Statistical Physics.

All courses must be passed with a grade of B or better.

Students who do not have a prior Master's degree (or other equivalent degree) in Physics from UCI or another institution must take a minimum of 11 quarter courses including:

PHYSICS 211	Classical Mechanics
PHYSICS 212A	Mathematical Physics
PHYSICS 213A	Electromagnetic Theory
PHYSICS 213B or PHYSICS 240C	Electromagnetic Theory Radiative Processes in Astrophysics
PHYSICS 214A	Statistical Physics
PHYSICS 215A- 215B	Quantum Mechanics and Quantum Mechanics

and select at least two other courses numbered between 200 and 259;

and select two other courses approved by the graduate advisor.

or

Students who have obtained a prior Master's degree (or other equivalent degree) in Physics from UCI or another institution:

Take a minimum of 4 quarter courses including: two courses numbered between 200 and 259 and two other courses approved by the graduate advisor. These students are strongly encouraged to take the qualifying exam in the Fall quarter of entrance.

Students are strongly encouraged to take PHYSICS 211, PHYSICS 212A, PHYSICS 213A, PHYSICS 214A, PHYSICS 215A-PHYSICS 215B, and either PHYSICS 213B or PHYSICS 240C in their first year of study. It is expected that students, having selected a research specialty, will ordinarily take the core courses in that subject in their second year of study. Students pursuing research in elementary particle physics ordinarily complete PHYSICS 234A-PHYSICS 234B-PHYSICS 234C and PHYSICS 235A-PHYSICS 235B during their second year. Students pursuing research in plasma physics ordinarily complete PHYSICS 239A during their first year and PHYSICS 239B-PHYSICS 239C-PHYSICS 239D their second year; PHYSICS 249 is also recommended. Students pursuing research in condensed-matter physics ordinarily take PHYSICS 238A-PHYSICS 238B-PHYSICS 238C during their second year; PHYSICS 133 should be taken in the first year by those students who have not had an equivalent course. Students pursuing research in astrophysics/cosmology ordinarily complete PHYSICS 240A during spring of their first year; PHYSICS 240B, PHYSICS 240C in their second year; and one or more of PHYSICS 241B, PHYSICS 241C, PHYSICS 241D in their second or subsequent years. Students interested in medical imaging should take PHYSICS 233A-PHYSICS 233B-PHYSICS 233C in the second year. Students pursuing research in biological physics should take PHYSICS 230A-PHYSICS 230B in the second year. Students who have earned grades of B or better in equivalent graduate-level courses prior to entering UCI may be exempted from required courses by the graduate advisor. Equivalency will be determined by the instructor of each course for which an exemption is sought.

NOTE: The requirements for the Ph.D. with a concentration in Chemical and Materials Physics (ChAMP) differ from these and are outlined in a later section.

Comprehensive Examination

Progress toward the degree is assessed by a written comprehensive examination covering a broad range of fundamentals of physics at the graduate and advanced undergraduate levels. It is offered twice a year, and a student is allowed a maximum of three attempts. The first attempt must occur before the end of the fall quarter of the student's second year, and the examination must be passed by the end of spring quarter of the student's second year.

Advancement to Ph.D. Candidacy

For advancement to Ph.D. candidacy, a student must pass an oral advancement examination. It is typically taken within one year of successful completion of the comprehensive examination. To satisfy normative progress toward the degree, it must be taken by the end of the student's third year. The candidacy committee that administers this examination will contain one or two faculty members from outside the Department. This oral examination will cover material principally related to the broad and general features of the student's dissertation area.

Teaching Program

Experience in teaching is an integral part of the graduate program, and all Ph.D. students are required to participate in the teaching program for at least one quarter during their graduate careers. All new teaching assistants are required to enroll in PHYSICS 269 and must pass in order to be allowed to

TA in future quarters. Students are required to enroll in PHYSICS 399 while serving as a TA. Lab TAs are required to enroll in PHYSICS 395 as well as PHYSICS 399.

Students who are not citizens from countries where English is either the primary or dominant language as approved by the UCI Graduate Council must pass either the Test of Spoken English (TSE) or the UCI SPEAK (Speaking Proficiency English Assessment Kit) examination. One of these tests must be passed before such a student can qualify for a teaching assistantship in order to fulfill the Department's teaching requirement. The Department expects one of these tests to be passed by the end of the student's second year at UCI.

Dissertation

A dissertation summarizing the results of original research performed by the student under the supervision of a doctoral committee, appointed by the Department Chair on behalf of the Dean of the Graduate Division and the Graduate Council, will be required for the Ph.D. A criterion for the acceptability of a dissertation by the Department is that it be suitable for publication in a scientific journal. The dissertation must not have been submitted to any other institution prior to its submission to the UCI Physics and Astronomy Department.

Defense of Dissertation. Upon completion of the dissertation, the student will take an oral examination, open to the public, before the doctoral committee.

Concentration in Chemical and Materials Physics

This is an interdisciplinary program between condensed matter physics and physical chemistry, which is designed to eliminate the barrier between these two disciplines. Students with a B.S. in Physics, Chemistry, or Materials Science and Engineering, are encouraged to apply to the program. The goal of the concentration in Chemical and Materials Physics (ChaMP) is to provide students with a broad interdisciplinary education in the applied physical sciences that emphasizes modern laboratory and computational skills. The program accepts students for both the M.S. and the Ph.D. Upon admission to the program, students are assigned two faculty advisors, one from the Department of Physics and Astronomy, and one from the Department of Chemistry, to provide guidance on curriculum and career planning.

Requirements

The curriculum for the M.S. program includes a summer session to assimilate students with different undergraduate backgrounds; formal shop, laboratory, and computational courses; a sequence on current topics to bridge the gap between fundamental principles and applied technology; and a course to develop communication skills. The required courses include thirteen core courses and three electives (subject to advisor approval) as follows:

Core

CHEM 231A or PHYSICS 215A	Fundamentals of Quantum Mechanics Quantum Mechanics
CHEM 231B or PHYSICS 215B	Applications of Quantum Mechanics Quantum Mechanics
CHEM 231C	Molecular Spectroscopy
CHEM 232A- 232B	Thermodynamics and Introduction to Statistical Mechanics and Advanced Topics in Statistical Mechanics
PHYSICS 206	Laboratory Skills
PHYSICS 207	Chemistry for Physicists
PHYSICS 228	Electromagnetism
PHYSICS 229A	Computational Methods
PHYSICS 266	Current Topics in Chemical and Materials Physics
PHYSICS 273 or CHEM 273	Technical Communication Skills Technical Communication Skills
Select one course from each of the following two groups:	
PHYSICS 133 or PHYSICS 238A	Introduction to Condensed Matter Physics Condensed Matter Physics
PHYSICS 211 or PHYSICS 222	Classical Mechanics Continuum Mechanics

Electives

CHEM 213	Chemical Kinetics
CHEM 225	Polymer Chemistry: Synthesis and Characterization of Polymers
CHEM 232C	Non-Equilibrium Statistical Mechanics
CHEM 233	Nuclear and Radiochemistry
CHEM 243	Advanced Instrumental Analysis
CHEM 248	Electrochemistry

CHEM 249	Analytical Spectroscopy
EECS 285B	Lasers and Photonics
ENGRMSE 259	Transmission Electron Microscopy
PHYSICS 134A	Physical and Geometrical Optics
PHYSICS 233A	Principles of Imaging
PHYSICS 233B	Techniques in Medical Imaging I: X-ray, Nuclear, and NMR Imaging
PHYSICS 238A	Condensed Matter Physics
PHYSICS 238B	Condensed Matter Physics
PHYSICS 238C	Condensed Matter Physics

In addition to the required courses, M.S. students complete a master's thesis. Students are required to advance to candidacy for the master's degree at least one quarter prior to filing the master's thesis. There is no examination associated with this advancement, but the thesis committee needs to be selected and appropriate forms need to be filed. The M.S. program prepares students to compete for high-tech jobs or to begin research toward a Ph.D.

Successful completion of the M.S. requirements qualifies students for the Ph.D. program. Progress toward the Ph.D. is assessed by a written comprehensive examination administered in the summer after completion of the first year of study. This examination covers comprehensive knowledge acquired in course work, and the content of the examination depends upon the student's specific area of interest.

Participants in the Ph.D. program take an examination for formal advancement to candidacy. It is typically taken within one year of successful completion of the comprehensive examination. To satisfy normative progress toward the degree, it must be taken by the end of the student's third year. The examination is comprised of two parts: (a) a written report on a topic to be determined in consultation with the research advisor and (b) an oral report on research accomplished and plans for completion of the Ph.D. dissertation.

Faculty

Kevorg N. Abazajian, Ph.D. University of California, San Diego, *Associate Professor of Physics and Astronomy*

Jun F. Allard, Ph.D. University of British Columbia, *Assistant Professor of Mathematics; Physics and Astronomy* (mathematical and computational biology)

Ioan Andricioaei, Ph.D. Boston University, *Professor of Chemistry; Physics and Astronomy* (chemical biology, physical chemistry and chemical physics, theoretical and computational)

Aaron J. Barth, Ph.D. University of California, Berkeley, *Professor of Physics and Astronomy*

Steven W. Barwick, Ph.D. University of California, Berkeley, *Professor of Physics and Astronomy*

Gregory A. Benford, Ph.D. University of California, San Diego, *Professor Emeritus of Physics and Astronomy*

James S. Bullock, Ph.D. University of California, Santa Cruz, *Gary McCue Administrative Term Chair in Cosmology and Professor of Physics and Astronomy*

David A. Buote, Ph.D. Massachusetts Institute of Technology, *Professor of Physics and Astronomy*

Kieron Burke, Ph.D. University of California, Santa Barbara, *Professor of Chemistry; Physics and Astronomy* (physical chemistry and chemical physics, polymer, materials, nanoscience, theoretical and computational)

David W. Casper, Ph.D. University of Michigan, *Associate Professor of Physics and Astronomy*

Gary A. Chanan, Ph.D. University of California, Berkeley, *Professor Emeritus of Physics and Astronomy*

Liu Chen, Ph.D. University of California, Berkeley, *Research Professor and Professor Emeritus of Physics and Astronomy*

Mu-Chun Chen, Ph.D. University of Colorado Boulder, *Associate Professor of Physics and Astronomy*

Alexander L. Chernyshev, Ph.D. Russian Academy of Sciences, *Professor of Physics and Astronomy*

Philip Collins, Ph.D. University of California, Berkeley, *Professor of Physics and Astronomy*

Michael Cooper, Ph.D. University of California, Berkeley, *Assistant Professor of Physics and Astronomy*

Asantha R. Cooray, Ph.D. University of Chicago, *Professor of Physics and Astronomy*

Michael B. Dennin, Ph.D. University of California, Santa Barbara, *Professor of Physics and Astronomy*

Franklin Dollar, Ph.D. University of Michigan, *Assistant Professor of Physics and Astronomy* (applied physics)

Igor E. Dzyaloshinskii, Ph.D. Moscow State University, *Professor Emeritus of Physics and Astronomy*

Jonathan L. Feng, Ph.D. Stanford University, *Professor of Physics and Astronomy*

Zachary Fisk, Ph.D. University of California, San Diego, *UCI Distinguished Professor Emeritus of Physics and Astronomy*

Enrico Gratton, Ph.D. University of Rome, *Professor of Biomedical Engineering; Developmental and Cell Biology; Physics and Astronomy* (design of new fluorescence instruments, protein dynamics, single molecule, fluorescence microscopy, photon migration in tissues)

Steven P. Gross, Ph.D. University of Texas at Austin, *Professor of Developmental and Cell Biology; Biomedical Engineering; Physics and Astronomy* (force generation by molecular motors in living cells)

Arnold Guerra, Ph.D. University of California, Irvine, *Lecturer of Physics and Astronomy*

Gultekin Gulsen, Ph.D. Bogazici University, *Associate Professor of Radiological Sciences; Biomedical Engineering; Electrical Engineering and Computer Science; Physics and Astronomy* (in vivo molecular imaging, diffuse optical tomography, fluorescence tomography, photo-magnetic imaging, multi-modality imaging)

Herbert W. Hamber, Ph.D. University of California, Santa Barbara, *Professor of Physics and Astronomy*

William W. Heidbrink, Ph.D. Princeton University, *Professor of Physics and Astronomy*

Wilson Ho, Ph.D. University of Pennsylvania, *Donald Bren Professor and Professor of Physics and Astronomy; Chemistry* (physical chemistry and chemical physics, polymer, materials, nanoscience)

Herbert J. Hopster, Ph.D. Aachen University, *Professor Emeritus of Physics and Astronomy*

Manoj Kaplinghat, Ph.D. Ohio State University, *Professor of Physics and Astronomy*

Anne A. Kirkby, Ph.D. California Institute of Technology, *Lecturer of Physics and Astronomy*

David P. Kirkby, Ph.D. California Institute of Technology, *Professor of Physics and Astronomy* (observational cosmology, data science, embedded systems)

Ilya N. Krivorotov, Ph.D. University of Minnesota, *Associate Professor of Physics and Astronomy*

Andrew J. Lankford, Ph.D. Yale University, *Professor of Physics and Astronomy*

Jon M. Lawrence, Ph.D. University of Rochester, *Professor Emeritus of Physics and Astronomy*

Zhihong Lin, Ph.D. Princeton University, *Professor of Physics and Astronomy*

Mark A. Mandelkern, Ph.D. University of California, Berkeley, *Research Professor and Professor Emeritus of Physics and Astronomy*

Alexei A. Maradudin, Ph.D. University of Bristol, *Professor Emeritus of Physics and Astronomy*

Roger D. McWilliams, Ph.D. Princeton University, *Associate Dean of the School of Physical Sciences and Professor of Physics and Astronomy*

William R. Molzon, Ph.D. University of Chicago, *Professor of Physics and Astronomy*

Shaul Mukamel, Ph.D. Tel Aviv University, *UCI Distinguished Professor of Chemistry; Physics and Astronomy* (physical chemistry and chemical physics, polymer, materials, nanoscience, theoretical and computational)

Simona Murgia, Ph.D. Michigan State University, *Assistant Professor of Physics and Astronomy*

Riley D. Newman, Ph.D. University of California, Berkeley, *Professor Emeritus of Physics and Astronomy; Logic and Philosophy of Science; Physics and Astronomy*

Xiaoqing Pan, Ph.D. Saarlandes University, *Henry Samueli Endowed Chair and Professor of Chemical Engineering and Materials Science; Physics and Astronomy* (transmission electron microscopy and materials science)

Siddharth Ashok Parameswaran, Ph.D. Princeton University, *Assistant Professor of Physics and Astronomy*

William H. Parker, Ph.D. University of Pennsylvania, *Professor Emeritus of Physics and Astronomy*

Arvind Rajaraman, Ph.D. Stanford University, *Professor of Physics and Astronomy*

Thorsten Ritz, Ph.D. University of Ulm, *Professor of Physics and Astronomy*

James E. Rutledge, Ph.D. University of Illinois at Chicago Circle, *Professor Emeritus of Physics and Astronomy*

Nathan Rynn, Ph.D. Stanford University, *Professor Emeritus of Physics and Astronomy*

Jonas Schultz, Ph.D. Columbia University, *Professor Emeritus of Physics and Astronomy; Logic and Philosophy of Science*

Yuri Shirman, Ph.D. University of California, Santa Cruz, *Professor of Physics and Astronomy*

Dennis J. Silverman, Ph.D. Stanford University, *Professor Emeritus of Physics and Astronomy*

Albert Siryaporn, Ph.D. University of Pennsylvania, *Assistant Professor of Physics and Astronomy; Molecular Biology and Biochemistry*

Zuzanna S. Siwy, Ph.D. Silesian University of Technology, *Professor of Physics and Astronomy; Biomedical Engineering; Chemistry (biosensing, nanotechnology, condensed matter physics)*

Tammy Ann Smecker-Hane, Ph.D. Johns Hopkins University, *Associate Professor of Physics and Astronomy*

Henry W. Sobel, Ph.D. Case Western Reserve University, *Professor of Physics and Astronomy*

Min-Ying Su, Ph.D. University of California, Irvine, *Professor of Radiological Sciences; Physics and Astronomy*

Peter Taborek, Ph.D. California Institute of Technology, *Department Chair and Professor of Physics and Astronomy*

Agnes Taffard, Ph.D. University of Liverpool, *Associate Professor of Physics and Astronomy*

Timothy Tait, Ph.D. Michigan State University, *UCI Chancellor's Fellow and Professor of Physics and Astronomy*

Fumiko Tajima, Ph.D. University of Tokyo, *Lecturer of Physics and Astronomy*

Toshiki Tajima, Ph.D. University of California, Irvine, *UCI Endowed Chair and Adjunct Professor of Physics and Astronomy*

Virginia L. Trimble, Ph.D. California Institute of Technology, *Professor of Physics and Astronomy*

Laura Tucker, B.A. California Polytechnic State University, *Lecturer of Physics and Astronomy*

Mark Vagins, Ph.D. Yale University, *Adjunct Professor of Physics and Astronomy*

Gerard Vanhoven, Ph.D. Stanford University, *Professor Emeritus of Physics and Astronomy*

Richard F. Wallis, Ph.D. Catholic University of America, *Professor Emeritus of Physics and Astronomy*

Frank J. Wessel, Ph.D. University of California, Irvine, *Project Scientist of Physics and Astronomy*

Steven R. White, Ph.D. Cornell University, *Professor of Physics and Astronomy*

Daniel Whiteson, Ph.D. University of California, Berkeley, *Associate Professor of Physics and Astronomy; Logic and Philosophy of Science*

Ruqian Wu, Ph.D. Institute of Physics, Chinese Academy of Science, *Professor of Physics and Astronomy*

Jing Xia, Ph.D. Stanford University, *Assistant Professor of Physics and Astronomy*

Gaurang B. Yodh, Ph.D. University of Chicago, *Professor Emeritus of Physics and Astronomy*

Clare C. Yu, Ph.D. Princeton University, *Professor of Physics and Astronomy*

Courses

PHYSICS 2. Introduction to Mathematical Methods for Physics. 4 Units.

Provides the applied mathematics and problem solving/presentation skills necessary for success in an introductory physics sequence. Focuses on practical exercises in problem solving. Covers kinematics in one and two dimensions in detail. Additional topics include vectors, differentiation, and integration.

Corequisite: MATH 2A or MATH 5A, or a score of 4 or higher on the AP Calculus AB exam, or a score of 3 or higher on the AP Calculus BC exam.

Prerequisite: Passing score on the UCI Physics Placement Exam.

Restriction: PHYSICS 2 may not be taken for credit if taken after PHYSICS 7C.

PHYSICS 3A. Basic Physics I. 4 Units.

Vectors; motion, force, and energy.

Corequisite: MATH 2A or MATH 5A, or a score of 4 or higher on the AP Calculus AB exam, or a score of 3 or higher on the AP Calculus BC exam.

Restriction: PHYSICS 3A may not be taken for credit if taken after PHYSICS 7C.

(II and VA).

PHYSICS 3B. Basic Physics II. 4 Units.

Fluids; heat; electricity and magnetism.

Prerequisite: PHYSICS 3A or AP Physics C: Mechanics. AP Physics C: Mechanics with a minimum score of 5

(II and V).

PHYSICS 3C. Basic Physics III. 4 Units.

Waves and sound; optics; quantum ideas; atomic and nuclear physics; relativity.

Corequisite: MATH 2B or MATH 5B, or a score of 4 or higher on the AP Calculus BC exam.

Prerequisite: PHYSICS 3A or AP Physics C: Mechanics. AP Physics C: Mechanics with a minimum score of 5

(II and Va).

PHYSICS 3LB. Basic Physics Laboratory. 1.5 Unit.

Practical applications of electronics and classical physics to biology. Goals include skill to use oscilloscope and other basic instrumentation. Materials fee.

PHYSICS 3LC. Basic Physics Laboratory. 1.5 Unit.

Practical applications of physics to medical imaging. Topics include optics, radioactivity, and acoustics. Materials fee.

PHYSICS 7C. Classical Physics. 4 Units.

Topics include force, energy, momentum, rotation, and gravity.

Corequisite: PHYSICS 7LC and MATH 2B or AP CALCULUS BC, min score = 4.

Prerequisite or corequisite: PHYSICS 2 or (MATH 2D and (CHEM 1C or CHEM H2C or CHEM M3C)) or AP Physics C: Mechanics or AP Physics C: Electricity and Magnetism or PHYSICS 7LC. PHYSICS 2 with a grade of C or better. AP Physics C: Mechanics with a minimum score of 4. AP Physics C: Electricity and Magnetism with a minimum score of 4. UCI Physics Placement Exam is also accepted.

Restriction: Physics Majors have first consideration for enrollment.

(II and VA).

PHYSICS 7D. Classical Physics. 4 Units.

Electricity and magnetism.

Corequisite: PHYSICS 7LD and MATH 2D

Prerequisite: PHYSICS 7C and (MATH 2B or AP Calculus BC). AP Calculus BC with a minimum score of 4

Restriction: Physics Majors have first consideration for enrollment.

(II and Va).

PHYSICS 7E. Classical Physics. 4 Units.

Fluids; oscillations; waves; and optics.

Prerequisite: PHYSICS 7C and MATH 2B

Restriction: Physics Majors have first consideration for enrollment.

(II and VA).

PHYSICS 7LC. Classical Physics Laboratory. 1 Unit.

Experiments related to lecture topics in Physics 7C. Materials fee.

Corequisite: PHYSICS 7C

Overlaps with PHYSICS 7LA, PHYSICS 7LB.

Restriction: Physics Majors have first consideration for enrollment.

PHYSICS 7LD. Classical Physics Laboratory. 1 Unit.

Electricity and magnetism.

Corequisite: PHYSICS 7D

Restriction: Physics Majors have first consideration for enrollment.

PHYSICS 12. Science Fiction and Science Fact. 4 Units.

An introduction to fundamental physics principles, the scientific process, and the mathematical language of science, used to analyze topics drawn from superheroes, science fiction works, and current science news to distinguish science fiction and science fact.

Overlaps with PHYSICS 21.

(II and VA).

PHYSICS 14. Energy and the Environment. 4 Units.

The physics of society's energy production and consumption, and of their influences on the environment. Topics include fossil and renewable energy resources; nuclear power; prospects for a hydrogen economy; efficient and environmentally benign transportation; efficient home and commercial energy usage.

(II, Va)

PHYSICS 15. Physics of Music. 4 Units.

Introduces basic physical principles underlying generation and properties of music, including basic properties of sound waves, musical scales and temperament, musical instruments, and acoustics of music halls. No mathematics background required, but high school algebra is recommended.

(II)

PHYSICS 17. Physics of Athletics. 4 Units.

Introduces basic physical principles behind motion. Examples are drawn from a range of athletic endeavors (such as ice skating, baseball, diving, and dance). No mathematics background required, but high school algebra is recommended.

(II)

PHYSICS 18. How Things Work. 4 Units.

Survey of the physical basis of modern technology, with an emphasis on electronics and materials. Topics include power generation and distribution, communication (radio, TV, telephone, computers, tape recorders, CD players), imaging (optics, x-rays, MRI), and modern materials (alloys, semiconductors, superconductors).

(II)

PHYSICS 20A. Introduction to Astronomy. 4 Units.

History of astronomy. Underlying physics. Objects in the solar system and how they are studied. Properties of stars: their formation, structure, and evolution. Pulsars and black holes. Galaxies and quasars.

(II and VA).

PHYSICS 20B. Cosmology: Humanity's Place in the Universe. 4 Units.

An overview of the origin, evolution, and ultimate fate of the Universe. Galaxies and dark matter. The Big Bang and dark energy. Ancient world models.

(II and VA).

PHYSICS 20D. Space Science. 4 Units.

Space exploration. Human missions to the moon, Mars, and beyond. Space stations, observatories, and deep-space probes. Robots and drones on distant worlds. Propulsion mechanisms, rockets, space flight, and the dangers of solar radiation.

(II and VA).

PHYSICS 20E. Life in the Universe. 4 Units.

An overview of the scientific quest to discover life elsewhere in the universe. Topics include the origin of life on Earth, Mars, extra-solar planets, interstellar travel, and extra-terrestrial intelligence.

(II, Va)**PHYSICS 21. Special Topics in Physics. 4 Units.**

Topics addressed vary each quarter. Past topics have included physics and music, Newton, planetary science. Lectures on areas of special interest in physics used to introduce students to scientific method, fundamental laws of science, qualitative and quantitative analysis of data.

Repeatability: Unlimited as topics vary.

Overlaps with PHYSICS 12, PHYSICS XI12.

(II)**PHYSICS 50. Introductory Mathematical Physics. 4 Units.**

Introduction to math methods for upper-division physics. Taylor and Fourier series; complex algebra; ordinary differential equations; matrices, tensors and vector spaces; eigensystems; orthogonal coordinates; vector calculus and fields. Symbolic computation with Mathematica is incorporated throughout.

Corequisite: MATH 2E

Prerequisite: MATH 3A

Overlaps with PHYSICS 100.

Restriction: Physics Majors have first consideration for enrollment.

PHYSICS 51A. Modern Physics. 4 Units.

Wave-particle duality; quantum mechanics; special relativity; statistical mechanics.

Prerequisite: (PHYSICS 7E or PHYSICS 3C) and MATH 2D

Overlaps with PHYSICS 61A.

Restriction: No Physics Majors.

PHYSICS 51B. Modern Physics. 4 Units.

Atoms; molecules; solids; nuclei; elementary particles.

Prerequisite: PHYSICS 51A or PHYSICS 61A

Overlaps with PHYSICS 61B.

Restriction: No Physics Majors.

PHYSICS 52A. Fundamentals of Experimental Physics. 2 Units.

Optics: lenses, mirrors, polarization, lasers, optical fibers, interference, spectra. Materials fee.

Corequisite: PHYSICS 7E or PHYSICS 3C.

Restriction: Physics Majors have first consideration for enrollment.

PHYSICS 52B. Fundamentals of Experimental Physics. 2 Units.

Circuits: oscilloscope, meters, DC and AC circuits. Materials fee.

Prerequisite: PHYSICS 7D or PHYSICS 3B

Restriction: Physics Majors have first consideration for enrollment.

PHYSICS 52C. Fundamentals of Experimental Physics. 2 Units.

Data analysis: random and systematic errors, curve fitting; nuclear counting; quantum experiments. Error analysis: random and systematic errors, curve fitting, nuclear counting, and quantum experiments. Materials fee.

Prerequisite: PHYSICS 51A or PHYSICS 61A

Restriction: Physics Majors have first consideration for enrollment.

PHYSICS 53. Introduction to Programming and Numerical Analysis. 4 Units.

Introduction to structured programming; in-depth training in python. Elementary numerical methods applied to physics problems.

Prerequisite: MATH 3A and MATH 3D

Restriction: Physics Majors have first consideration for enrollment.

PHYSICS 60. Thermal Physics. 4 Units.

Introduction to thermodynamics and systems of many particles. Topics include first and second laws of thermodynamics, ideal gas laws, kinetic theory, heat engines and refrigerators, thermodynamic potentials, phase transitions, dilute solutions, chemical equilibrium, and basic statistical distributions.

Prerequisite: (PHYSICS 7E or PHYSICS 3C) and MATH 2D

Restriction: Physics Majors only.

PHYSICS 61A. Modern Physics for Majors. 4 Units.

Wave-particle duality; Schrödinger equation; angular momentum.

Prerequisite: (PHYSICS 7E or PHYSICS 3C) and MATH 2D

Overlaps with PHYSICS 51A.

Restriction: Physics Majors only.

PHYSICS 61B. Modern Physics for Majors. 4 Units.

Atomic transitions; molecules; solids; nuclei; elementary particles; cosmological models.

Prerequisite: PHYSICS 61A or PHYSICS 51A

Overlaps with PHYSICS 51B.

Restriction: Physics Majors only.

PHYSICS 61C. Introduction to Astrophysics. 4 Units.

Introduction to fundamental topics in astrophysics, including stellar structure and evolution; stellar remnants; detection and characterization of exoplanets; physics of interstellar gas and star-forming regions.

Prerequisite: PHYSICS 61A or PHYSICS 51A

PHYSICS H80. Impact of World War I on Science. 4 Units.

Introduction to science in 1914 and WWI. Participants in groups of two or three will pick a preferred science; find out what happened to it during and after the war; write reports and present what they learned.

Restriction: Campuswide Honors Program students only.

(II)**PHYSICS H90. The Idiom and Practice of Science. 4 Units.**

A series of fundamental and applied scientific problems of social relevance. Possible topics include Newton's Law, calculus, earthquake physics, and radiation.

Restriction: Campuswide Honors Program students only.

(II, Va)**PHYSICS 99. Current Topics in Physics. 1 Unit.**

Designed to introduce undergraduate students to current topics in physics. Focus is discussion of selected readings on current research issues.

Repeatability: Unlimited as topics vary.

PHYSICS 100. Computational Methods. 4 Units.

Mathematical and numerical analysis using Mathematica and C programming, as applied to problems in physical science.

Overlaps with PHYSICS 50.

Concurrent with PHYSICS 229A.

PHYSICS 106W. Laboratory Skills and Scientific Writing. 4 Units.

Introduces practical laboratory techniques, including lock-in, boxcar, coincidence counting, noise-filtering, properties of common transducers, computer interfacing to instruments, basic mechanical design, shop skills. Students design their own experiments, take measurements, analyze data, and write up results in scientific manuscript style.

Prerequisite: PHYSICS 52B

Restriction: Formerly PHYS 106. PHYS 106W may not be taken for credit if taken after PHYS 106.

Concurrent with PHYSICS 206 and CHEM 206.

(Ib)

PHYSICS 111A. Classical Mechanics. 4 Units.

One-dimensional motion and oscillations; three-dimensional motion, non-inertial coordinates, conservation laws, and Lagrangian and Hamiltonian dynamics; rigid body motion and relativity.

Corequisite: PHYSICS 50

Prerequisite: (PHYSICS 7E or PHYSICS 3C)

PHYSICS 111B. Classical Mechanics. 4 Units.

One-dimensional motion and oscillations; three-dimensional motion, non-inertial coordinates, conservation laws, and Lagrangian and Hamiltonian dynamics; rigid body motion and relativity.

Prerequisite: PHYSICS 111A

PHYSICS 112A. Electromagnetic Theory. 4 Units.

Electric, magnetic, and gravitational fields and potentials; electrodynamics; mechanical and electromagnetic waves and radiation.

Prerequisite: (PHYSICS 7D or PHYSICS 3B) and PHYSICS 50

PHYSICS 112B. Electromagnetic Theory. 4 Units.

Electric, magnetic, and gravitational fields and potentials; electrodynamics; mechanical and electromagnetic waves and radiation.

Prerequisite: PHYSICS 7E and PHYSICS 112A

PHYSICS 113A. Quantum Physics. 4 Units.

Inadequacy of classical physics; time independent and time dependent Schrodinger equation; systems in one, two, and three dimensions; matrices; Hermitian operators; symmetries; angular momentum; perturbation theory; scattering theory; applications to atomic structure; emphasis on phenomenology.

Prerequisite: (PHYSICS 51A or PHYSICS 61A) and PHYSICS 50

PHYSICS 113B. Quantum Physics. 4 Units.

Inadequacy of classical physics; time independent and time dependent Schrodinger equation; systems in one, two, and three dimensions; matrices; Hermitian operators; symmetries; angular momentum; perturbation theory; scattering theory; applications to atomic structure; emphasis on phenomenology.

Prerequisite: PHYSICS 111B and PHYSICS 112B and PHYSICS 113A

PHYSICS 113C. Quantum Physics. 4 Units.

Inadequacy of classical physics; time independent and time dependent Schrodinger equation; systems in one, two, and three dimensions; matrices; Hermitian operators; symmetries; angular momentum; perturbation theory; scattering theory; applications to atomic structure; emphasis on phenomenology.

Prerequisite: PHYSICS 111B and PHYSICS 112B and PHYSICS 113B

PHYSICS 115A. Statistical Physics. 4 Units.

Microscopic theory of temperature, heat, and entropy; kinetic theory; multicomponent systems; quantum statistics.

Prerequisite: PHYSICS 50 and (PHYSICS 60 or CHEM 1C or ENGRMAE 91)

PHYSICS 116. Relativity and Black Holes. 4 Units.

Introduces students to both special and general relativity; includes the formalism of four-vectors, equivalence principle, curved space-time, and modern issues with black holes.

Corequisite: PHYSICS 111A

Prerequisite: PHYSICS 50

PHYSICS 120. Electronics for Scientists. 4 Units.

Applications of modern semiconductor devices to physical instrumentation. Characteristics of semiconductor devices, integrated circuits, analog and digital circuits. Materials fee.

Prerequisite: PHYSICS 52B

Concurrent with PHYSICS 220.

PHYSICS 121W. Advanced Laboratory. 4 Units.

Experiments in atomic, condensed matter, nuclear, particle, and plasma physics. Introduction to instrumentation and a first experience in the research laboratory.

Prerequisite: (PHYSICS 51B or PHYSICS 61B or PHYSICS 61C) and (PHYSICS 52C or PHYSICS 193) and (PHYSICS 194 or EDUC 143BW)

Repeatability: May be taken for credit 3 times.

Restriction: Physics Majors only.

(Ib)**PHYSICS 125A. Mathematical Physics. 4 Units.**

Complex variables; Legendre and Bessel functions; complete sets of orthogonal functions; partial differential equations; integral equations; calculus of variations; coordinate transformations; special functions and series.

Prerequisite: PHYSICS 50 and MATH 3D

PHYSICS 125B. Mathematical Physics. 4 Units.

Complex variables; Legendre and Bessel functions; complete sets of orthogonal functions; partial differential equations; integral equations; calculus of variations; coordinate transformations; special functions and series.

Prerequisite: PHYSICS 125A and PHYSICS 113A

PHYSICS 133. Introduction to Condensed Matter Physics. 4 Units.

Phenomena of solids and their interpretation in terms of quantum theory.

Prerequisite: PHYSICS 113B and PHYSICS 115A

PHYSICS 134A. Physical and Geometrical Optics. 4 Units.

Focuses on the practical aspects of optics and optical engineering, starting at the fundamentals. Topics include geometrical optics, ray tracing, polarization optics, interferometers, and diffractive optics.

Corequisite: PHYSICS 112B

Prerequisite: PHYSICS 112A

Concurrent with CBEMS 242A and CHEM 242A.

PHYSICS 135. Plasma Physics. 4 Units.

Basic concepts, orbits, kinetic and fluid equations, Coulomb collisions, fluctuations, scattering, radiation.

Prerequisite: PHYSICS 112B

Concurrent with PHYSICS 239A.

PHYSICS 136. Introduction to Particle Physics. 4 Units.

Experimental techniques and theoretical concepts of high-energy phenomena: accelerators and detectors; classification of particles and interactions; particle properties; symmetries and mass multiplets; production and decay mechanisms.

Prerequisite: PHYSICS 113B

PHYSICS 137. Introduction to Cosmology. 4 Units.

Solution of the differential equations governing the expansion of the Universe. Observational determinations of the parameters governing the expansion. Big Bang inflation, primordial nucleosynthesis, and cosmic microwave background. Dark matter, dark energy, and large-scale structure of the Universe.

Prerequisite: PHYSICS 111A

PHYSICS 138. Extragalactic Astrophysics. 4 Units.

Introduction to the solar neighborhood, Milky Way, and other galaxies. Interstellar medium. Star formation. Stellar populations. Evolution of spiral, elliptical, and irregular galaxies. Supermassive black holes, quasars, and active galaxies. Galaxies as probes of the expansion rate of the Universe.

Prerequisite: PHYSICS 111A

PHYSICS 139. Observational Astrophysics. 4 Units.

Telescopes and astronomical observations, imaging with CCD detectors and image processing techniques. Photometry and spectroscopy of stars, galaxies, and quasars. Advanced imaging techniques such as deconvolution, adaptive optics, and interferometry.

Prerequisite: PHYSICS 52A and PHYSICS 52B and PHYSICS 52C and PHYSICS 53

PHYSICS 144. Stellar Astrophysics. 4 Units.

Stars: their structure and evolution; physical state of the interior; the Hertzsprung- Russell diagram, stellar classification, and physical principles responsible for the classification; star formation; nuclear burning; giant and dwarf stars; neutron stars and black holes.

Prerequisite: (PHYSICS 51A or PHYSICS 61A) and PHYSICS 111A and PHYSICS 112A

PHYSICS 145. High-Energy Astrophysics. 4 Units.

Production of radiation by high-energy particles, white dwarfs, neutron stars, and black holes. Evolution of galactic nuclei, radio galaxies, quasars, and pulsars. Cosmic rays and the cosmic background radiation.

Prerequisite: (PHYSICS 51A or PHYSICS 61A) and PHYSICS 111A and PHYSICS 112A

PHYSICS 146A. Biophysics of Molecules and Molecular Machines. 4 Units.

Physical concepts and experimental and computational techniques used to study the structure and function of biological molecules and molecular machines with examples from enzyme action, protein folding, molecular motors, photobiology, chemotaxis, and vision.

Prerequisite: PHYSICS 115A

Concurrent with PHYSICS 230A.

PHYSICS 146B. Biophysics of Molecules and Molecular Machines. 4 Units.

Physical concepts and experimental and computational techniques used to study the structure and function of biological molecules and molecular machines with examples from enzyme action, protein folding, molecular motors, photobiology, chemotaxis, and vision.

Prerequisite: PHYSICS 115A

Concurrent with PHYSICS 230B.

PHYSICS 147A. Principles of Imaging. 4 Units.

Linear systems, probability and random processes, image processing, projection imaging, tomographic imaging.

Prerequisite: PHYSICS 50

Concurrent with PHYSICS 233A and EECS 202A.

PHYSICS 147B. Techniques in Medical Imaging I: X-ray, Nuclear, and NMR Imaging. 4 Units.

Ionizing radiation, planar and tomographic radiographic and nuclear imaging, magnetism, NMR, MRI imaging.

Prerequisite: PHYSICS 147A

Concurrent with PHYSICS 233B and EECS 202B.

PHYSICS 147C. Techniques in Medical Imaging II: Ultrasound, Electrophysiological, Optical. 4 Units.

Sound and ultrasound, ultrasonic imaging, physiological electromagnetism, EEG, MEG, ECG, MCG, optical properties of tissues, fluorescence and bioluminescence, MR impedance imaging, MR spectroscopy, electron spin resonance and ESR imaging.

Prerequisite: PHYSICS 147B

Concurrent with PHYSICS 233C and EECS 202C.

PHYSICS 150. Special Topics in Physics and Astronomy. 4 Units.

Current topics in physics. Includes topics from nano-science, biological sciences, astrophysics, and the common use of estimation across subdisciplines within physics.

Repeatability: Unlimited as topics vary.

PHYSICS 191. Field Experience in Physics Education. 1-4 Units.

Students develop and perform physics assemblies at neighboring public schools.

Prerequisite: PHYSICS 7C and PHYSICS 7D and PHYSICS 7E

Grading Option: Pass/no pass only.

Repeatability: May be taken for credit for 8 units.

PHYSICS 192. Tutoring in Physics. 1-2 Units.

Formalizes the already existing free tutoring for the lower-division physics courses that is provided by the Society of Physics Students (SPS). Includes instructions on tutoring techniques.

Prerequisite: PHYSICS 7E

Grading Option: Pass/no pass only.

Repeatability: May be taken for credit for 12 units.

Restriction: Society of Physics Students (SPS) tutoring program students only.

PHYSICS 193. Research Methods. 4 Units.

Explores tools of inquiry for developing and implementing science research projects. Students undertake independent projects requiring data collection, analysis, and modeling, and the organization and presentation of results. Additional topics include ethical issues and role of scientific literature.

Prerequisite: BIO SCI 14 or PHY SCI 5

Same as BIO SCI 108, CHEM 193.

PHYSICS 194. Research Communication for Physics Majors. 2 Units.

Students learn the fundamentals of communicating about research. Topics include preparing abstracts, proposals, and literature reviews. Provides preparation for presentation of independent research projects in PHYSICS 121 and PHYSICS 196.

Prerequisite: PHYSICS 61B or PHYSICS 61C. Satisfactory completion of the Lower-Division Writing requirement.

Restriction: Physics Majors only.

PHYSICS 195. Undergraduate Research. 4 Units.

Independent research under the guidance of a Physics faculty member.

Grading Option: Pass/no pass only.

Repeatability: May be repeated for credit unlimited times.

Restriction: Juniors only. Physics Majors only.

PHYSICS 196A. Thesis in Physics I. 2 Units.

Independent research for seniors conducted under the guidance of a faculty member. Students' research results are discussed in oral presentations, and a written proposal, progress report, and thesis are submitted.

Corequisite: PHYSICS 194

Overlaps with PHYSICS H196A.

Restriction: Physics Majors only.

PHYSICS 196B. Thesis in Physics II. 4 Units.

Independent research for seniors conducted under the guidance of a faculty member. Students' research results are discussed in oral presentations, and a written proposal, progress report, and thesis are submitted.

Prerequisite: PHYSICS 196A

Overlaps with PHYSICS H196B.

Restriction: Physics Majors only.

PHYSICS 196C. Thesis in Physics III. 4 Units.

Independent research for seniors conducted under the guidance of a faculty member. Students' research results are discussed in oral presentations, and a written proposal, progress report, and thesis are submitted.

Prerequisite: PHYSICS 196B

Overlaps with PHYSICS H196C, PHYSICS 197.

Restriction: Physics Majors only.

PHYSICS H196A. Honors Thesis in Physics I. 2 Units.

Independent research for seniors conducted under the guidance of a faculty member. Students' research results are discussed in oral presentations, and a written proposal, progress report, and thesis are submitted.

Corequisite: PHYSICS 194

Overlaps with PHYSICS 196A.

Restriction: Physics Majors only. Campuswide Honors Program students only. Honors Program in Physics students only.

PHYSICS H196B. Honors Thesis in Physics II. 4 Units.

Independent research for seniors conducted under the guidance of a faculty member. Students' research results are discussed in oral presentations, and a written proposal, progress report, and thesis are submitted.

Prerequisite: PHYSICS H196A

Overlaps with PHYSICS 196B.

Restriction: Physics Majors only. Campuswide Honors Program students only. Honors Program in Physics students only.

PHYSICS H196C. Honors Thesis in Physics III. 4 Units.

Independent research for seniors conducted under the guidance of a faculty member. Students' research results are discussed in oral presentations, and a written proposal, progress report, and thesis are submitted.

Prerequisite: PHYSICS H196B

Overlaps with PHYSICS 196C.

Restriction: Physics Majors only. Campuswide Honors Program students only. Honors Program in Physics students only.

PHYSICS 199. Readings on Special Topics. 1-4 Units.

Readings in selected areas of Physics. Topics addressed vary each quarter.

Grading Option: Pass/no pass only.

Repeatability: May be repeated for credit unlimited times.

PHYSICS 206. Laboratory Skills. 4-6 Units.

Introduces students to a variety of practical laboratory techniques, including lock-in, boxcar, coincidence counting, noise filtering, PID control, properties of common transducers, computer interfacing to instruments, vacuum technology, laboratory safety, basic mechanical design, and shop skills. Materials fee.

Same as CHEM 206.

Concurrent with PHYSICS 106.

PHYSICS 207. Chemistry for Physicists. 4 Units.

Introduction to fundamental concepts in molecular structure and reactivity: theory of bonding, valence and molecular orbitals; structure and reactivity in inorganic chemistry; elements in molecular group theory; nomenclature in organic chemistry; and survey of macromolecules.

Same as CHEM 207.

PHYSICS 208. Mathematics for Chemists. 4 Units.

Applications of mathematics to physical and chemical problems. Calculus of special functions, complex variables and vectors; linear vector spaces and eigenvalue problems. Differential equations.

Same as CHEM 208.

PHYSICS 211. Classical Mechanics. 4 Units.

Variational principles, Lagrange's equations; applications to two body problems, small oscillation theory, and other phenomena. Hamilton's equations. Hamilton-Jacobi theory. Canonical transformations.

Restriction: Graduate students only.

PHYSICS 212A. Mathematical Physics. 4 Units.

Complex variables and integration; ordinary and partial differential equations; the eigenvalue problem.

Restriction: Graduate students only.

PHYSICS 213A. Electromagnetic Theory. 4 Units.

Electrostatics; magnetostatics; relativity; classical electron theory; fields in vacuum and matter; retardation; radiation and absorption; dispersion; propagation of light; diffraction; geometric optics; theories of the electric and magnetic properties of materials; scattering.

PHYSICS 213B. Electromagnetic Theory. 4 Units.

Electrostatics; magnetostatics; relativity; classical electron theory; fields in vacuum and matter; retardation; radiation and absorption; dispersion; propagation of light; diffraction; geometric optics; theories of the electric and magnetic properties of materials; scattering.

Prerequisite: PHYSICS 213A

PHYSICS 214A. Statistical Physics. 4 Units.

Maxwell-Boltzmann, Bose-Einstein, Fermi-Dirac statistics; ideal and imperfect gases; thermodynamic properties of solids; transport theory.

Restriction: Graduate students only.

PHYSICS 214B. Statistical Physics. 4 Units.

Phase transitions; critical phenomena; cooperative phenomena; fluctuations.

Prerequisite: PHYSICS 214A

Restriction: Graduate students only.

PHYSICS 214C. Many Body Theory. 4 Units.

Application of field theory methods, perturbative and non-perturbative, to many particle systems; second quantization, Feynman diagrams, linear response theory, and functional integral methods applied to the ground state and at finite temperature.

Prerequisite: PHYSICS 214A and PHYSICS 215A and PHYSICS 215B

Restriction: Graduate students only.

PHYSICS 215A. Quantum Mechanics. 4 Units.

Foundations; Dirac notation; basic operators and their eigenstates; perturbation theory; spin.

Restriction: Graduate students only.

PHYSICS 215B. Quantum Mechanics. 4 Units.

Atomic physics; scattering theory, formal collision theory; semi-classical radiation theory; many body systems.

Prerequisite: PHYSICS 215A

Restriction: Graduate students only.

PHYSICS 220. Electronics for Scientists. 4 Units.

Applications of modern semiconductor devices to physical instrumentation. Characteristics of semiconductor devices, integrated circuits, analog and digital circuits.

Restriction: Graduate students only.

Concurrent with PHYSICS 120.

PHYSICS 222. Continuum Mechanics. 4 Units.

Introduction to the continuum limit and stress and strain tensors. Hydrodynamics of perfect fluids; two-dimensional problems, motion of incompressible viscous fluids, Navier Stokes equations. Basic elasticity theory. Description of viscoelastic materials. Introduction to nonlinear behavior instabilities.

PHYSICS 228. Electromagnetism. 4 Units.

Maxwell's equations, electrodynamics, electromagnetic waves and radiation, wave propagation in media, interference and quantum optics, coherent and incoherent radiation, with practical applications in interferometry, lasers, waveguides, and optical instrumentation.

Same as CHEM 228.

PHYSICS 229A. Computational Methods. 4 Units.

Mathematical and numerical analysis using Mathematica and C programming, as applied to problems in physical science.

Same as CHEM 229A.

Concurrent with PHYSICS 100.

PHYSICS 230A. Biophysics of Molecules and Molecular Machines. 4 Units.

Physical concepts and experimental and computational techniques used to study the structure and function of biological molecules and molecular machines with examples from enzyme action, protein folding, molecular motors, photobiology, chemotaxis, and vision.

Concurrent with PHYSICS 146A.

PHYSICS 230B. Biophysics of Molecules and Molecular Machines. 4 Units.

Physical concepts and experimental and computational techniques used to study the structure and function of biological molecules and molecular machines with examples from enzyme action, protein folding, molecular motors, photobiology, chemotaxis, and vision.

Concurrent with PHYSICS 146B.

PHYSICS 233A. Principles of Imaging. 4 Units.

Linear systems, probability and random processes, image processing, projecting imaging, tomographic imaging.

Same as EECS 202A.

Restriction: Graduate students only.

Concurrent with PHYSICS 147A.

PHYSICS 233B. Techniques in Medical Imaging I: X-ray, Nuclear, and NMR Imaging. 4 Units.

Ionizing radiation, planar and tomographic radiographic and nuclear imaging, magnetism, NMR, MRI imaging.

Prerequisite: EECS 202A

Same as EECS 202B.

Restriction: Graduate students only.

Concurrent with PHYSICS 147B.

PHYSICS 233C. Techniques in Medical Imaging II: Ultrasound, Electrophysiological, Optical. 4 Units.

Sound and ultrasound, ultrasonic imaging, physiological electromagnetism, EEG, MEG, ECG, MCG, optical properties of tissues, fluorescence and bioluminescence, MR impedance imaging, MR spectroscopy, electron spin resonance and ESR imaging.

Prerequisite: EECS 202B

Same as EECS 202C.

Restriction: Graduate students only.

Concurrent with PHYSICS 147C.

PHYSICS 234A. Elementary Particle Physics. 4 Units.

Overview of Standard Model theory and phenomenology. Electromagnetic, strong and weak forces, quark model, interactions with matter, particle detectors and accelerators.

Prerequisite: PHYSICS 215B

PHYSICS 234B. Advanced Elementary Particle Physics. 4 Units.

$SU(3)\times SU(2)\times U(1)$ model of strong, weak, and electromagnetic interactions. K-meson system and CP violation, neutrino masses and mixing, grand-unified theories, supersymmetry, introduction to cosmology and its connection to particle physics.

Prerequisite: PHYSICS 234A and PHYSICS 235A

PHYSICS 234C. Advanced Elementary Particle Physics. 4 Units.

$SU(3)\times SU(2)\times U(1)$ model of strong, weak, and electromagnetic interactions. K-meson system and CP violation, neutrino masses and mixing, grand-unified theories, supersymmetry, introduction to cosmology and its connection to particle physics.

Prerequisite: PHYSICS 234A and PHYSICS 235A

PHYSICS 235A. Quantum Field Theory. 4 Units.

Canonical quantization, scalar field theory, Feynman diagrams, tree-level quantum electrodynamics.

Prerequisite: PHYSICS 215B

Restriction: Graduate students only.

PHYSICS 235B. Advanced Quantum Field Theory. 4 Units.

Pathintegral techniques, loop diagrams, regularization and renormalization, anomalies.

Prerequisite: PHYSICS 235A

Restriction: Graduate students only.

PHYSICS 238A. Condensed Matter Physics. 4 Units.

Bonding in solids; crystal symmetry and group theory, elastic properties of crystals; lattice vibrations, interaction of radiation with matter; cohesion of solids; the electron gas; electron energy bands in solids; ferromagnetism; transport theory; semiconductors and superconductors; many-body perturbation theory.

Prerequisite: PHYSICS 133 and (PHYSICS 214A or CHEM 232A) and (PHYSICS 215B or CHEM 231B)

PHYSICS 238B. Condensed Matter Physics. 4 Units.

Bonding in solids; crystal symmetry and group theory, elastic properties of crystals; lattice vibrations, interaction of radiation with matter; cohesion of solids; the electron gas; electron energy bands in solids; ferromagnetism; transport theory; semiconductors and superconductors; many-body perturbation theory.

Prerequisite: PHYSICS 238A

PHYSICS 238C. Condensed Matter Physics. 4 Units.

Bonding in solids; crystal symmetry and group theory, elastic properties of crystals; lattice vibrations, interaction of radiation with matter; cohesion of solids; the electron gas; electron energy bands in solids; ferromagnetism; transport theory; semiconductors and superconductors; many-body perturbation theory.

Prerequisite: PHYSICS 238B

PHYSICS 239A. Plasma Physics. 4 Units.

Basic concepts, orbits, kinetic and fluid equations, Coulomb collisions, fluctuations, scattering, radiation.

Restriction: Graduate students only.

Concurrent with PHYSICS 135.

PHYSICS 239B. Plasma Physics. 4 Units.

Magnetic confinement, MHD equilibrium and stability, collisional transport.

Prerequisite: PHYSICS 239A

Restriction: Graduate students only.

PHYSICS 239C. Plasma Physics. 4 Units.

Linear waves and instabilities, uniform un-magnetized and magnetized plasmas, non-uniform plasmas.

Prerequisite: PHYSICS 239B

Restriction: Graduate students only.

PHYSICS 239D. Plasma Physics. 4 Units.

Nonlinear plasma physics, quasilinear theory, large-amplitude coherent waves, resonance broadening, strong turbulence.

Prerequisite: PHYSICS 239C

Restriction: Graduate students only.

PHYSICS 240A. Galactic Astrophysics. 4 Units.

The morphology, kinematics, and evolution of our Milky Way and other galaxies. Topics include stellar formation and stellar evolution, end states of stars (supernovae, neutron stars), the distribution of stars, interstellar gas and mass in galaxies. The Local Group.

PHYSICS 240B. Cosmology. 4 Units.

An introduction to modern cosmology set within the context of general relativity. Topics include the expansion history of the Universe, inflation, the cosmic microwave background, density fluctuations, structure formation, dark matter, dark energy, and gravitational lensing.

PHYSICS 240C. Radiative Processes in Astrophysics. 4 Units.

Exploration of radiation mechanisms (electron scattering, synchrotron emission, collisional excitation, and more) and radiative transfer through matter including absorption and emission. Includes such observational astrophysics topics as spectroscopic study of atoms and nuclei, X-rays, and cosmic rays.

PHYSICS 241B. Stellar Astrophysics. 4 Units.

Physics of stellar interiors and equations of stellar structure. Stellar atmospheres and absorption processes. Introduction to stellar winds. Thermonuclear reactions, nucleosynthesis, and solar neutrinos. Binary stars and mass accretion. White dwarfs, supernovae, neutron stars, and black holes.

Prerequisite: PHYSICS 211 and PHYSICS 240A

PHYSICS 241C. Extragalactic Astrophysics. 4 Units.

The physics and phenomenology of galaxies; star formation, interstellar medium, and intergalactic medium. Galaxy structure and dynamics. Galaxy evolution, stellar populations, and scaling relations; the relationship between galaxy properties and environment. Galaxy clusters and active galactic nuclei.

Prerequisite: PHYSICS 211 and PHYSICS 240A

PHYSICS 241D. Early Universe Physics. 4 Units.

Includes a thorough quantum treatment of the generation of perturbations during inflation and various topics related to kinetic theory in an expanding Universe. Other topics include the astrophysics and cosmology of weakly interacting particles.

Prerequisite: PHYSICS 234A and (PHYSICS 240B or PHYSICS 255)

PHYSICS 246. Special Topics in Astrophysics. 4 Units.

Outlines and emphasizes a subarea of astrophysics that is undergoing rapid development.

Repeatability: May be repeated for credit unlimited times.

Restriction: Graduate students only.

PHYSICS 247. Special Topics in Particle Physics. 4 Units.

Current topics in particle non-accelerator-based research fields.

Repeatability: May be repeated for credit unlimited times.

Restriction: Graduate students only.

PHYSICS 248. Special Topics in Condensed Matter Physics. 4 Units.

Outlines and emphasizes a subarea of condensed matter physics that is undergoing rapid development.

Repeatability: Unlimited as topics vary.

Restriction: Graduate students only.

PHYSICS 249. Special Topics in Plasma Physics. 4 Units.

Outlines and emphasizes a subarea of plasma physics that is undergoing rapid development.

Prerequisite: PHYSICS 239A and PHYSICS 239B

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.

PHYSICS 255. General Relativity. 4 Units.

An introduction to Einstein's theory of gravitation. Tensor analysis, Einstein's field equations, astronomical tests of Einstein's theory, gravitational waves.

PHYSICS 260A. Seminar in Condensed Matter Physics. 1 Unit.

Seminar designed to acquaint students with recent advances in solid state physics. Lecturers from the Department of Physics and Astronomy (both faculty and graduate students), other UCI departments, and other institutions.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.

Restriction: Graduate students only.

PHYSICS 260B. Seminar in Condensed Matter Physics. 1 Unit.

Seminar designed to acquaint students with recent advances in solid state physics. Lecturers from the Department of Physics and Astronomy (both faculty and graduate students), other UCI departments, and other institutions.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.

Restriction: Graduate students only.

PHYSICS 260C. Seminar in Condensed Matter Physics. 1 Unit.

Seminar designed to acquaint students with recent advances in solid state physics. Lecturers from the Department of Physics and Astronomy (both faculty and graduate students), other UCI departments, and other institutions.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.

Restriction: Graduate students only.

PHYSICS 261A. Seminar in Plasma Physics. 1 Unit.

Advanced topics in plasma physics: wave propagation, nonlinear effects, kinetic theory and turbulence, stability problems, transport coefficients, containment, and diagnostics. Applications to controlled fusion and astrophysics.

Grading Option: Satisfactory/unsatisfactory only.

Restriction: Graduate students only.

PHYSICS 261B. Seminar in Plasma Physics. 1 Unit.

Advanced topics in plasma physics: wave propagation, nonlinear effects, kinetic theory and turbulence, stability problems, transport coefficients, containment, and diagnostics. Applications to controlled fusion and astrophysics.

Grading Option: Satisfactory/unsatisfactory only.

Restriction: Graduate students only.

PHYSICS 261C. Seminar in Plasma Physics. 1 Unit.

Advanced topics in plasma physics: wave propagation, nonlinear effects, kinetic theory and turbulence, stability problems, transport coefficients, containment, and diagnostics. Applications to controlled fusion and astrophysics.

Grading Option: Satisfactory/unsatisfactory only.

Restriction: Graduate students only.

PHYSICS 263A. Seminar in Particle Physics. 1 Unit.

Discussion of advanced topics and reports of current research results in theoretical and experimental particle physics and cosmic rays.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.

Restriction: Graduate students only.

PHYSICS 263B. Seminar in Particle Physics. 1 Unit.

Discussion of advanced topics and reports of current research results in theoretical and experimental particle physics and cosmic rays.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.

Restriction: Graduate students only.

PHYSICS 263C. Seminar in Particle Physics. 1 Unit.

Discussion of advanced topics and reports of current research results in theoretical and experimental particle physics and cosmic rays.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.

Restriction: Graduate students only.

PHYSICS 265A. Seminar in Astrophysics. 1 Unit.

Acquaints students with current research in astrophysics. Lecturers from the Department of Physics and Astronomy and from other institutions.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.

Restriction: Graduate students only.

PHYSICS 265B. Seminar in Astrophysics. 1 Unit.

Acquaints students with current research in astrophysics. Lecturers from the Department of Physics and Astronomy and from other institutions.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.

Restriction: Graduate students only.

PHYSICS 265C. Seminar in Astrophysics. 1 Unit.

Acquaints students with current research in astrophysics. Lecturers from the Department of Physics and Astronomy and from other institutions.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.

Restriction: Graduate students only.

PHYSICS 266. Current Topics in Chemical and Materials Physics. 1 Unit.

The subjects covered vary from year to year. Connection between fundamental principles and implementations in practice in science, industry, and technology.

Repeatability: May be repeated for credit unlimited times.

Same as CHEM 266.

PHYSICS 267A. Current Problems in Particle Physics. 4 Units.

Presentation and discussion of current research and theory in particle physics. Lectures given by staff and students.

Repeatability: May be repeated for credit unlimited times.

PHYSICS 267B. Current Problems in Particle Physics. 4 Units.

Presentation and discussion of current research and theory in particle physics. Lectures given by staff and students.

Repeatability: May be repeated for credit unlimited times.

PHYSICS 267C. Current Problems in Particle Physics. 4 Units.

Presentation and discussion of current research and theory in particle physics. Lectures given by staff and students.

Repeatability: May be repeated for credit unlimited times.

PHYSICS 268. Seminar in Systems Microbiology Research. 1 Unit.

A research and journal club seminar that covers topics on bacteria and phage using approaches and principles from biology, engineering, and physics.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.

Same as CBEMS 268, MOL BIO 268.

Restriction: Upper-division students only. Graduate students only.

PHYSICS 269. Seminar in Teaching Physics. 2 Units.

Techniques for effective teaching. Covers active listening and student engagement, problem-solving skills, peer instruction and collaborative learning, and evaluation. Required of all new Teaching Assistants.

Grading Option: Satisfactory/unsatisfactory only.

PHYSICS 273. Technical Communication Skills. 2 Units.

Development of effective communication skills, oral and written presentations, through examples and practice.

Grading Option: Satisfactory/unsatisfactory only.

Same as CHEM 273.

PHYSICS 291. Research Seminar. 1-4 Units.

Detailed discussion of research problems of current interest in the Department. Format, content, and frequency of the course are variable.

Repeatability: May be repeated for credit unlimited times.

Restriction: Graduate students only.

PHYSICS 295. Experimental Research. 4-12 Units.

With the approval of a faculty member, a student may pursue a research program in experimental physics. Typical areas include astrophysics, condensed matter physics, elementary particle physics, and plasma physics.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.

Restriction: Graduate students only. School of Physical Sciences students only.

PHYSICS 296. Theoretical Research. 4-12 Units.

With approval of a faculty member, a student may pursue a research program in theoretical physics. Typical areas include astrophysics, condensed matter physics, elementary particle physics, and plasma physics.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.

Restriction: Graduate students only. School of Physical Sciences students only.

PHYSICS 298. Physics Colloquium. 1 Unit.

Seminar held each week, in which a current research topic is explored. Frequently, off-campus researchers are invited to present the seminar, and on occasion a faculty member or researcher from the Department will speak.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.

Restriction: School of Physical Sciences students only.

PHYSICS 299. Reading of Special Topic. 4-12 Units.

With special consent from a faculty member who will agree to supervise the program, a student may receive course credit for individual study of some area of physics.

Restriction: Graduate students only.

PHYSICS 395. Laboratory Teaching. 1 Unit.

Required of and limited to teaching assistants of undergraduate laboratory courses. Designed to teach the necessary skills required of teaching assistants for these courses.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.

PHYSICS 399. University Teaching. 1-4 Units.

Required of and limited to Teaching Assistants.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.