Physics

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Graduate Student Affairs:
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Terence T-L. Hwa, Ph.D.
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Barbara Jones, Ph.D., *Academic Senate Distinguished Teaching Award*
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Peter S. Wolynes, Ph.D.
David Y. Wong, Ph.D., *Emeritus*
Herbert F. York, Ph.D., *Emeritus*

Associate Professors

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Frank Wuerthwein, Ph.D.

Assistant Professors

Michael M. Fogler, Ph.D.
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Brian G. Keating, Ph.D.
Thomas W. Murphy, Jr., Ph.D.
Paolo Padoan, Ph.D.
Douglas E. Smith, Ph.D.

Adjunct Professors

Hans Kobrak, Ph.D., *Emeritus*
Ferenc Mezei, Ph.D.
Tihiro Ohkawa, Ph.D.
Raj K. Pathria, Ph.D.
Ronald E. Waltz, Ph.D.

Senior Lecturers

Richard E. Rothschild, Ph.D., *Research Scientist, Center for Astrophysics and Space Science*

The Department of Physics was established in 1960 as the first new department of the UCSD campus. Since then it has developed a strong faculty and student body with unusually diversified interests which lie primarily in the following areas:

1. Physics of elementary particles
2. Quantum liquids and superconductivity
3. Solid state and statistical physics
4. Plasma physics
5. Astrophysics and space physics
6. Atomic and molecular collision and structure
7. Biophysics
8. Geophysics
9. Nonlinear dynamics
10. Computational physics

In addition to on-campus research facilities, the high energy program uses accelerators at SLAC, CERN, and Fermi Laboratory. The astrophysics program uses facilities at Keck, Lick, and Kitt Peak Observatories.

The Undergraduate Program

The Department of Physics offers undergraduate programs leading to the following degrees:

B.S., Physics

B.S., Physics with Specialization in Astrophysics

B.S., Physics with Specialization in Biophysics

B.S., Physics with Specialization in Computational Physics

B.S., Physics with Specialization in Earth Sciences

B.S., Physics with Specialization in Materials Physics

B.A., General Physics

B.A., General Physics/Secondary Education

A grade-point average of 2.0 or higher in the upper-division major program is required for graduation. Students must receive a grade of C– or better in any course to be counted toward fulfillment of the major requirements. In exceptional cases, students with a grade-point average in the major of 2.5 or greater may petition to have one grade of D accepted. All courses (lower- and upper-division) required for the major must be taken for a letter grade.

Shang-keng Ma Award

The Department of Physics presents the Shang-keng Ma Memorial Award at commencement each year to a graduating physics student who has shown exceptional ability and promise during the UCSD undergraduate years. The award was established in 1984 to commemorate the contributions of Professor Ma to the UCSD Department of Physics and to the field of theoretical condensed matter physics.

John Holmes Malmberg Prize

The John Holmes Malmberg Prize is presented annually at commencement to a graduating physics student who is recognized for potential for a career in physics and a measure of experimental inquisitiveness. This prize was established in 1993 in memory of Professor Malmberg who pioneered the use of non-neutral plasmas for sophisticated tests of plasma equilibrium, wave, and transport effects. He was an involved teacher of undergraduate and graduate students and was active in departmental and campus affairs.

Physics Major (B.S. Degree)

The physics major provides a core of basic education in several principle areas of physics, with sufficient flexibility to allow students to prepare either for graduate school or a career in industry. Since in preparing for either goal, more than the required core courses are necessary, it is important for students to meet with a physics department adviser in deciding a schedule.

In the junior year, the emphasis is on macroscopic physics; the two principal physics subjects are electromagnetism and mechanics. The mathematics and computer background required for the physics program is completed in this year.

In the senior year, a sequence of courses in quantum physics provides the student the modern view of atomic and some aspects of subatomic physics and the principal analytical methods appropriate in this domain. The relation of the microscopic to the macroscopic world is the subject of courses in thermodynamics and statistical physics, with illustrations drawn from gas dynamics and solid-state physics. Upper-division laboratories teach students the essentials of physical measurement and building advanced equipment, as well as other aspects of experimental science.

The following courses are required for the physics major:

Lower-Division

1. Physics 4A-B-C-D-E or Physics 2A-B-C-D[1]
2. Physics 2CL and 2DL
3. Chemistry 6A or[2] a programming course such as MAE 9 or MAE 10
4. Mathematics 20C-D-E-F

[1] The Physics 4 series is recommended, but the Physics 2 sequence is acceptable by petition, in which case both

[2] Chemistry 6A and a programming course are required

Upper-Division

1. Physics 100A-B, 105A, 110A, 120A, 130A-B, 140A, and an additional laboratory course from the lab group: 120B, 121, 133, 173
2. Two courses from either the theoretical or experimental pre-grad-school sequence

   Theoretical pre-grad-school sequence: Phys. 100C, 105B, 110B, 130C, 140B

   Experimental pre-grad-school sequence: Phys. 100C, 110B, 120B, 130C, 140B
3. Restricted electives: Three upper-division (four-unit) or graduate courses in physics or mathematics (only one). Courses in other science disciplines may be substituted by petition.

For students wishing to prepare for graduate school it is important that all courses in either the theorist or experimentalist pre-grad-school sequence be taken. Mathematics 120A is also recommended.

Suggested Schedule (pre-graduate-school)

FALL	WINTER	SPRING
JUNIOR YEAR		
Phys. 100A	Phys. 100B	Phys. 120A
Phys. 105A	Phys. elective[3]	Phys. 130A
Phys. 110A	Phys. 105B[2]	
SENIOR YEAR		
Phys. 140A	Phys. 140B[2]	Phys. lab[1]
Phys. 130B	Phys. elective[3]	Phys. elective[3]

[1] Any course from lab group listed above

[2] Any two courses from theoretical or experimental pre-grad-school sequence listed above

[3] Any restricted elective as described above

Suggested Schedule (career in industry)

FALL	WINTER	SPRING
JUNIOR YEAR		
Phys. 100A	Phys. 100B	[pre-grad][4]
Phys. 105A	Phys. elective[3]	Phys. 120A
Phys. 110A	[other][5]	Phys. 130A
SENIOR YEAR		
Phys. 140A	[pre-grad][4]	Phys. elective[3]
Phys. lab[2]	Phys. elective[3]	[other][5]
Phys. 130B	[other][5]	

[2] Any course from lab group listed above

[3] Any restricted elective as described above

[4] any course from either pre-grad-school sequence listed above

[5] any other course as approved by adviser (optional)

Physics Major with Specialization in Astrophysics (B.S. Degree)

The astrophysics specialization is appropriate for students who would like to gain an in-depth understanding of modern astronomy and astrophysics, and/or who wish to prepare for graduate school in astronomy or astrophysics. It is similar to the standard physics major with electives being chosen from astronomically oriented courses. A wide variety of technical, academic, and professional careers are possible for students who choose this specialization.

The following courses are required for the physics major with specialization in astrophysics:

Lower-Division

1. Physics 4A-B-C-D-E or Physics 2A-B-C-D[1]
2. Physics 2CL and 2DL
3. Chemistry 6A or[2] a programming course such as MAE 9 or MAE 10
4. Mathematics 20C-D-E-F

[1] The Physics 4 series is recommended, but the Physics 2 sequence is acceptable, in which case both

[2] Chemistry 6A and a programming course are required.

Upper-Division

1. Physics 100A-B, 105A, 110A, 120A, 130A-B, 140A and an additional laboratory course from the lab group: 120B, 121, 133.
2. Two courses from either the theoretical or experimental pre-grad-school sequence.
3. It is recommended that students take the three quarter astrophysics sequence—Physics 160, 161, 162—but any three courses selected from the following list are acceptable:

   Physics 160. Stellar Astrophysics

   Physics 161. Compact Objects and the Milky Way

   Physics 162, Galaxies and Cosmology

   Physics 163, Solar System

   ECE 120, Solar System Physics

   Chem. 170, Cosmochemistry

   Erth. 130, Geodynamics of Terr. Planets

   MAE 180A, Space Science and Engineering 180 A/B

   Physics 223, Stellar Structure and Evolution; with consent of Instructor

   Physics 224, Interstellar Medium; with consent of Instructor

   Physics 226, Galaxies & Galactic Dynamics; with consent of Instructor

   Physics 227, Cosmology; with consent of Instructor

   Physics 228, High Energy and Compact Objects; with consent of Instructor

   Theoretical pre-grad-school sequence: Phys. 100C, 105B, 110B, 130C, 140B

   Experimental pre-grad-school sequence: Phys. 100C, 110B, 120B, 130C, 140B

Example Schedule

FALL	WINTER	SPRING
JUNIOR YEAR		
Phys 100A	Phys 100B	Phys 120A
Phys 105A	Phys 105B[1]	Phys 130A
Phys 110A		
SENIOR YEAR		
Phys 140A	Phys 140B	Physics Lab[2]
Phys 160	Phys 161	Phys 162
Phys 130B		

[1] Experimentalists may replace 105B with an additional lab.

[2] Any course from lab group listed above

Physics Major with Specialization in Biophysics (B.S. Degree)

The Department of Physics offers an undergraduate program that prepares students for careers in biophysics. This program leads to a degree in "B.S., Physics with Specialization in Biophysics." As a terminal degree, it is an excellent education for students who wish to work in the biotechnology industry, and provides an ideal background for students who plan to attend graduate or professional school in biological or biomedical fields.

This program is intended for students with a strong interest in bringing the concepts and technical advances from the physical sciences to bear on issues in biology. The curriculum is chosen to prepare students as rigorously trained but broad-minded generalists, so that they may attack problems in the biological, biochemical, and biomedical sciences with the tools and confidence that come from rigorous training in the physical sciences.

The curriculum for Physics Major with Specialization in Biophysics is designed to allow premedical students to complete all necessary courses for admission to medical schools.

The lower-division program for physics majors with specialization in biophysics includes basic courses in biology and chemistry as well as physics. Although the sequence Physics 4A through 4E is strongly recommended, students have the choice of petitioning the department to substitute the sequence Physics 2A through 2D.

The following courses are required for the physics major with specialization in biophysics:

Lower-Division

1. Physics 4A-B-C-D-E and 2CL-DL; or Physics 2A-B-C-D and 2CL-DL (Physics 4 sequence is strongly recommended)
2. Chemistry 6A-B-C and 6BL
3. Biology, BILD 1 and BILD 2
4. Mathematics 20A-B-C-D-E-F

The upper-division program includes advanced courses in physics, including two core lecture courses and one core laboratory course in biophysics, as well as organic chemistry.

Upper-Division

1. Physics 100A, 105A, 110A, 120A, 130A, 140A, 171, 172, 173
2. Chemistry 140A

Additional electives, to achieve a count of twelve upper-division courses in the major, may be selected from biology, chemistry and physics. Three additional upper-division courses, in any subject, are required in order to satisfy UCSD requirements.

Premedical students will need to take two additional quarters of organic chemistry (Chemistry 140B and 140C), one quarter of organic chemistry laboratory (Chemistry 143A), and one quarter of an upper level biology course. In addition, some medical schools also require a quarter of biochemistry (Biology BIBC 100 or Chemistry 114A). The premedical requirements may be used to satisfy elective requirements for upper-division courses.

As a guide to prospective students, we consider a schedule of required classes for a Muir College student.

Suggested Schedule

FALL	WINTER	SPRING
FRESHMAN YEAR		
Math. 20A	Chem. 6A	Chem. 6B
	Math. 20B	Chem. 6BL
	Phys. 4A	Math. 20C
		Phys. 4B
SOPHOMORE YEAR		
Chem. 6C	Math. 20E	Math. 20F
Math. 20D	Phys. 4D	Phys. 4E
Phys. 4C	Phys. 2CL	Phys. 2DL
JUNIOR YEAR		
Phys. 100A	BILD 1	BILD 2
Phys. 105A	Chem. 140A	Phys. 120A
Phys. 110A		Phys. 130A
SENIOR YEAR		
	Phys. 172	
Phys. 140A	Elec.	Phys. 173
Phys. 171	Elec.	

B.S. in Physics with Specialization in Computational Physics

The computational physics specialization is designed to support a broad range of career development tracks, so students may pursue (1) a terminal B.S. degree for gainful employment in information technology and high-tech industry, (2) preparation for graduate studies in computational science with an M.S. degree, and (3) graduate work in physics with strong interest in computational physics. This flexibility is afforded by a wide array of restricted electives which allows students to design much of their own program (subject to adviser's approval) while simultaneously maintaining the essential physics-based curriculum. Academic advising will be provided by physics faculty in the Computational Physics Specialization Program to assist students in designing their optimal career development track in the flexible curriculum.

The following courses are required for Physics Major with Specialization in Computational Physics:

Lower-Division

1. Physics 4A-B-C-D-E or Physics 2A-B-C-D[1], Physics 2CL-DL
2. Mathematics 20C-F
3. Chemistry 6A
4. MAE 9, or MAE 10, or CSE 11[2]

[1] The 2A-B-C-D sequence is an allowed substitute by petition.

[2] Electing CSE 11, student is still required to have C or Fortran based programming skills equivalent to MAE 9, or MAE 10.

Upper-Division

1. Physics 100A-B, 105A-B, 110A, 120A, 121, 130A-B, 140A, 141, 142
2. Six restricted electives from following groups:

   Physics 100C, 110B, 120B, 130C, 140B, 173, other upper-division Physics courses, Mathematics 132A-B, 170A-C, 172, 173, 183 CSE 12, 30, 80

   Substitute Upper-Division courses[3]

Suggested Schedule (restricted electives not shown)

FALL	WINTER	SPRING
JUNIOR YEAR		
Phys. 100A	Phys. 100B	Phys. 120A
Phys. 105A	Phys. 105B	Phys. 130A
Phys. 110A		
SENIOR YEAR		
Phys. 140A	Phys. 141	Phys. 142
Phys. 130B	Phys. 121	

[2] Students will choose two required courses from the group Phys. 121, Phys. 141, Phys. 142, and either will drop the third, or take it as one of the six restricted electives

[3] Substitute elective courses (upper-division science, mathematics, engineering, or other) require adviser's approval

Career Track Examples with Restricted Electives

The program of electives is intended to be flexible, and can be tailored to the student's needs and interests in consultation with the academic adviser.

Grad. School Theorist with Computational Interest Track for student with interest in theoretical physics based computational science:

Physics 100C, 110B, 130C, 140B
Mathematics 132A-B

Grad. School Experimentalist with Computational Interest Track for students with interest in experimental physics based computational science:

Physics 100C, 120B, 142
Mathematics 183
CSE 80

Information Technology Track for student with interest in physics based software oriented applications:

Physics 100C, 140B
CSE 12, 30, 80
Mathematics 173

Numerical Science/Engineering Application Developer Track for students with interest in physics and engineering applications of numerical algorithms:

Physics 100C, 140B
Mathematics 170A-C, 172

High Tech Instrumentation Track for students with interest in physics based instrumentation:

Physics 100C, 120B, 140B
Mathematics 183
CSE 12, 80

Physics Major with Specialization in Earth Sciences (B.S. Degree)

The upper-division program for physics majors with specialization in earth sciences is essentially the same as the standard physics major augmented by courses in earth sciences.

Students may wish to incorporate a small portion of the major program into their lower-division studies, for example, Earth Sciences 101.

The following courses are required for the physics major with specialization in earth sciences:

Lower-Division

1. Physics 4A-B-C-D-E and 2CL-DL; or Physics 2A-B-C-D and 2CL-DL (Physics 4 sequence is strongly recommended)
2. Chemistry 6A-B and 6BL
3. Mathematics 20C-F

Upper-Division

1. Physics 100A-B, 105A, 110A-B, 120A, 130A, 140A, plus one upper-division lab*
2. Earth Sciences 101, 102, 103, 120
3. Restricted Electives: three upper-division earth science (four-unit) or graduate courses to be chosen with the approval of the SIO earth sciences adviser
4. Two courses from either the theoretical or experimental pre-grad school sequence.

* Another lab course chosen from Physics 120B, 121, 133, or 173.

Suggested Schedule

FALL	WINTER	SPRING
JUNIOR YEAR		
Phys. 100A	Phys. 100B	Phys. 120A
Phys. 105A	Phys. 110B	Phys. 130A
Phys. 110A	Earth Sci. 102	
Earth Sci. 101		
SENIOR YEAR		
Phys. 140B	Earth Sci. 120	U.D. Lab
Earth Sci. 103	Restr. Elec.	Restr. Elec
		Restr. Elec.

Physics Major with Specialization in Materials Physics (B.S. Degree)

The materials physics specialization is designed to support a broad range of options, so students may pursue (1) a terminal B.S. degree, or preparation for (2) graduate work in materials science, or (3) graduate work in physics. This flexibility is afforded by a wide range of restricted electives which allows students to design much of their own program while simultaneously maintaining the essential physics-based curriculum. Academic advising will be provided by the department to assist the student in navigating through the many options. The B.S. program also serves as the entry to the integrated five-year B.S./M.S. program.

Lower-Division

1. Physics 4A-B-C-D-E or Physics 2A-B-C-D, Physics 2CL-DL
2. Chemistry 6A-B*
3. Mathematics 20C-F
4. MAE 9 or MAE 10 (or equivalent programming experience)

Upper-Division

1. Physics 100A-B, 105A-B, 110A, 120A-B, 130A-B, 140A, 133, 152A-B
2. Four restricted electives, to be chosen from Chemistry 120A-B*; Mathematics 120A; ECE 103, 134, 135A-B, 136, 136L; MAE 160, 110A; or any upper division physics course

* Students who anticipate taking Chemistry 120A-B as an upper-division elective are strongly advised to take Chemistry 6C.

Suggested Schedule (restricted electives not shown)

FALL	WINTER	SPRING
JUNIOR YEAR		
Phys. 100A	Phys. 100B	Phys. 120A
Phys. 105A	Phys. 105B	Phys. 130A
Phys. 110A		
SENIOR YEAR		
Phys. 140A	Phys. 152A	Phys. 152B
Phys. 120B		Phys. 133
Phys. 130B		

Restricted Electives: Example

As examples of restricted electives, a student opting for a terminal B.S. degree (Option 1) might choose to take MAE 160, ECE 103, 136, and Physics 121. Students preparing for graduate work in materials science (Option 2) might consider MAE 160, ECE 103, 134, and a fourth elective. Students preparing for graduate work in physics (Option 3) might consider Physics 100C, 110B, 140B, and a fourth elective. The program of electives is intended to be flexible, and can be tailored to the student's needs and interests in consultation with the academic adviser.

See entry for Integrated Bachelor's/Master's Degree Program in Materials Physics.

General Physics Major (B.A. Degree)

This program covers the essential topics in physics and provides a broadly based education in the natural sciences. Starting with lower-division courses in mathematics, physics, computing, biology and/or chemistry, students proceed to upper-division mechanics, electricity and magnetism, thermal physics, quantum physics, and a physical measurements laboratory course. In addition, students take sixteen units of upper-division elective courses in the natural sciences or mathematics.

While the B.A. program is suitable for students who pursue a terminal degree in physics or use it as a preparation for other professional careers, it is not intended for those who wish to proceed to the Ph.D. in physics. The latter should enroll in the B.S. program.

The following courses are required for the general physics major:

Lower-Division

1. Physics 2A-B-C-D and 2CL-DL
2. Mathematics 20C-F
3. Three restrictive elective courses in science and engineering (a list of acceptable courses is given below)

Upper-Division

1. Physics 100A-B, 105A, 110A-B, 120A, 130A, 140A or Chemistry 127 or 131
2. Restricted Electives: Sixteen units of upper-division courses in science and engineering (excluding mathematics)

Suggested Schedule

FALL	WINTER	SPRING
JUNIOR YEAR		
Phys. 100A	Phys. 100B	Phys. 120A
Phys. 105A	Phys. 110B	Phys. 130A
Phys. 110A		
SENIOR YEAR		
Phys. 140A or	Restr. Elec	Restr. Elec.
Chem. 127 or 131	Restr. Elec.	
Restr. Elec.		

Approved Lower-Division Elective Courses

One course in computing chosen from the following list:

MAE 10, FORTRAN for Engineers

MAE 03, Introduction to Engineering Graphics and Design

CSE 10, Introduction to Programming Techniques

CSE 30, Introduction to Systems Programming

Physics 105B, Mathematical and Computational Physics

Plus **two** of the following courses:

BILD 1, The Cell

BILD 2, Multicellular Life

BILD 3, Organismic and Evolutionary Biology

Chem. 6A, General Chemistry

Chem. 6B, General Chemistry

Chem. 6C, General Chemistry

Chem. 6BL plus 6CL, General Chemistry Lab plus Intro. Analytical Chemistry

General Physics/Secondary Education Major (B.A. Degree)

This program is intended for students preparing for a career as a physics teacher in secondary schools. It covers the essential topics in physics and provides a broadly based education in the natural sciences. The program includes three courses in general chemistry plus a lab, one course in organic chemistry plus a lab, and a course in earth science as required by the Single Subject Credential Program of the state of California. It also includes three courses in Practicum in Learning offered by the Teacher Education Program. This degree is particularly suitable for students pursuing a Single Subject (Physics) credential for high schools. If you are interested in earning a California teaching credential from UCSD, contact the Teacher Education Program (TEP) for information about the prerequisite and professional preparation requirements. It is recommended that you contact TEP as early as possible in your academic career.

The following courses are required for the general physics/secondary education major:

Lower-Division

1. Physics 2A-B-C-D and 2CL-DL
2. Chemistry 6A-B-C and 6BL
3. Earth Sciences 10, 12, or 30
4. Mathematics 20C-F

Upper-Division

1. Physics 100A-B, 105A, 110A-B, 120A, 130A
2. Chemistry 140A and 143A
3. Earth Sciences 101
4. TEP 129A-B-C

Suggested Schedule

FALL	WINTER	SPRING
JUNIOR YEAR		
Phys. 100A	Phys. 100B	Phys. 130A
Phys. 105A	Phys. 110B	Phys. 120A
Phys. 110A	Chem. 140A	Chem. 143A
SENIOR YEAR		
Earth Sci. 101	TEP 129B	TEP 129C
TEP 129A		

Engineering Physics Program

The engineering physics program is offered jointly by the Departments of Physics, MAE, and ECE, and is administered by the Department of ECE. (See "ECE, Engineering Physics Program.") Transfer students who have had prior course work in the major at other institutions must consult with the Department of Physics, Student Affairs Office, 1110-115 Urey Hall Addition to make an appointment to see a faculty adviser.

Minor in Physics

Students may arrange minor programs or programs of concentration in physics by consulting with the Department of Physics Student Affairs Office, 1110-115 Urey Hall Addition, and their college for specific requirements. The Department of Physics requires at least twenty-eight units, of which at least twenty units must be upper-division. All courses must be taken for a letter grade. Lower-division transfer courses are permitted.

Advising Office

All students are assigned an academic adviser. It is strongly recommended students see their adviser at least once a quarter.

Additional advising information may be obtained from the Department of Physics Student Affairs Office, 1110-115 Urey Hall Addition (858) 534-3290.

Honors Program

The Department of Physics offers an Honors Program for students who demonstrate excellence in the major. Students interested in the Honors Program should consult the Student Affairs Office. Eligibility for the Honors Program includes completion of all required lower-division physics courses, ten upper-division physics courses, and a GPA of a least 3.50 in the physics major.

The Honors Program consists of a minimum of eight units of Honors Thesis Research (Physics 199H), an Honors Thesis, and the presentation of the research to faculty and peers at UCSD's Undergraduate Research Conference or an Undergraduate Seminar. Admission to the Honors Program is contingent upon the prior approval of the Honors Thesis "research topic" by the Vice Chair for Education.

Integrated Bachelor's/Master's Degree Program in Materials Physics

The program offers a M.S. in physics with specialization in materials physics. **It is open only to UCSD undergraduates, and is a Plan I program only (thesis).** During the fourth quarter prior to receipt of the B.S. degree, students enrolled in the B.S. degree program with specialization in materials physics (see above) may apply for admission to the M.S. program. To be eligible, students must have completed the first two quarters of their junior year in residence at UCSD and have a GPA of at least 3.0 in both their major and overall undergraduate curriculum. It is strongly recommended that B.S. students who intend to apply to the M.S. program take MAE 160, ECE 103, and ECE 134 as restricted B.S. electives. It is the responsibility of the prospective B.S./M.S. student to select a faculty member (from the Department of Physics or, with physics department approval, from the MAE, ECE, or chemistry departments) who would be willing to serve as the student's adviser and with whom the student would complete at least twelve units of S/U graded research, which could commence as early as the undergraduate senior year. (Taken during the senior year, the units would count only toward the M.S. degree and not toward the B.S.) The student must confirm that the selected faculty adviser will not be on off-campus sabbatical leave during any quarter of the scheduled B.S./M.S. project. Students are expected to meet the requirements for the M.S. degree in one year (three consecutive, contiguous academic quarters) from the date of receipt of the B.S. degree. Any deviation from this plan, such as a break in enrollment for one or more quarters, may result in the student being dropped from the program.

The requirements for the M.S. degree are as follows:

1. Completion of at least twelve and no more than twenty-four units of research, which *may* begin as early as the first quarter of the senior undergraduate year.
2. Completion of three required courses during the fifth (graduate) year (MAT SCI 201A-B-C), and two restricted electives (see below).
3. Completion of restricted elective courses so that the total number of units (research plus required courses plus elective courses) totals no less than 36 units taken as a graduate student. Students accumulate units for their research by enrolling in Physics 295 (M.S. Thesis Research), which may be taken repeatedly.
4. Maintenance of a grade-point average of at least 3.0 for all course work, both cumulatively and for each quarter of enrollment in the B.S./M.S. program.
5. Completion of a thesis, with an oral presentation to, and approval of, a three-member committee from the Department of Physics including the faculty adviser. If the faculty adviser is from outside the physics department, the committee shall consist of the adviser and two members from the physics department faculty.
6. Three complete, separate, and consecutive quarters of full-time residency as a graduate student which will commence the quarter immediately following the quarter in which the B.S. degree is awarded (not counting summer session).
7. Although students may receive research or teaching assistantships if available from their adviser or through the Department of Physics, there is no guarantee of financial support associated with the M.S. program.
8. M.S. candidates will be permitted to serve as teaching assistants, although teaching will not be a requirement for the degree. Students who obtain a teaching assistantship should make sure that it does not interfere with completion of the M.S. degree requirements within the one year time frame allotted.

M.S. Program: Fifth Year Curriculum

1. MAT SCI 201A-B-C
2. Physics 295 (M.S. Thesis Research)
3. Two restricted electives, to be chosen from Physics 201, 211A-B; MAT SCI 227, 240A-B-C; ECE 231, 233: other courses allowed by petition

The Graduate Program

The Department of Physics offers curricula leading to the following degrees:

M.S., Physics
C.Phil., Physics
Ph.D., Physics
Ph.D., Physics (Biophysics)

Biophysics students will receive their M.S. and C.Phil. degrees in physics. Only their Ph.D. will be in physics (biophysics).

Entering graduate students are required to have a sound knowledge of undergraduate mechanics, electricity and magnetism; to have had senior courses or their equivalent in atomic and quantum physics, nuclear physics, and thermodynamics; and to have taken upper-division laboratory work. An introductory course in solid-state physics is desirable.

Requirements for the master of science degree can be met according to Plan II (comprehensive examination). (See "Graduate Studies: The Master's Degree.") The comprehensive examination is identical to the first-year departmental examination for Ph.D. students. A list of acceptable courses is available in the Department of Physics Graduate Student Affairs office. There is no foreign language requirement.

Doctoral Degree Program

The department has developed a flexible Ph.D. program which provides a broad, advanced education in physics while at the same time giving students opportunity for emphasizing their special interests. This program consists of graduate courses, apprenticeship in research, teaching experience, and thesis research.

Entering students are assigned a faculty adviser to guide them in their program. Many students spend their first year as teaching assistants or fellows and begin apprentice research in their second year. When a student's association with a research area and research supervisor is well established, a faculty research progress committee is formed with the responsibility of conducting an annual review of progress and, at the appropriate time, initiating the formation of a doctoral committee. After three years of graduate study, or earlier, students complete the departmental examinations and begin thesis research. Students specializing in biophysics make up deficiencies in biology and chemistry during the first two years and complete the departmental examinations by the end of their third year of graduate study. There is no foreign language requirement.

Entrance Testing

An entrance test covering undergraduate physics is given to entering students during the first week of orientation to give better guidance to students in their graduate program. The results are not entered in the student's file. Entering students are encouraged, but not obliged, to bring the results to the first meeting with their academic adviser. Entering students may elect to take the departmental examination instead of taking the entrance test.

Requirements for the Ph.D.

Students are required to pass a departmental examination, advanced graduate courses, a qualifying examination, teaching requirement and a final defense of the thesis as described below.

1. DEPARTMENTAL EXAMINATION

Physics students are required to take the departmental examination after completing one year of graduate work at UCSD. The examination is on the level of material usually covered in upper-division courses and the graduate courses listed below:

Fall

Physics 200A (Theoretical Mechanics)
Physics 201 (Mathematical Physics)
Physics 212A (Quantum Mechanics)

Winter

Physics 200B (Theoretical Mechanics)
Physics 203A (Adv. Classical Electrodynamics)
Physics 212B (Quantum Mechanics)

Spring

Physics 203B (Adv. Classical Electrodynamics)
Physics 210A (Equilibrium Statistical Mechanics)
Physics 212C (Quantum Mechanics)

The examination is offered twice a year, at the beginning of the fall and spring quarters, and lasts two days, four hours per day. The examination may be repeated once, the next time it is offered.

Biophysics students take the departmental examination after completing two years of graduate work.

2. ADVANCED GRADUATE COURSES

Physics students are required to take five advanced graduate courses (with a grade of C or better) from at least three of the groups listed below no later than the end of the third year of graduate work. A 3.0 average in four of the five courses is required. (In lieu of the course requirement, students may petition to take an oral examination covering three areas of physics.)

Group 1: Physics 218A-B-C (Plasma); 234 (Nonneutral Plas.); 235 (Nonlin. Plas. Th.)

Group 2: Physics 210B (Nonequil. Stat. Mech.); 210C, 211A, 211B (Solid State); 219 (C.M./Matl. Sci. Lab), 230 (Adv. Solid State); 232 (Electronic Materials); 236 (Many-body Th.)

Group 3: Physics 214 (Elem. Part.); 215A-B-C (Part. & Fields); 217 (Renorm. Field Th.); 229 (App. Quant. Mech.)

Group 4: Physics 220 (Group Th.); 221A, 221B (Nonlinear Dyn.); Physics 241 and 242 (Comp. Phys); Mathematics 210A-B, 210C (Mathematics Physics); Mathematics 259A-B-C (Geom. Physics)

Group 5: Physics 225A-B (Relativ.); 271 (Bio. Neurons/Net); 272 (Bio. Molecules)

Group 6: Physics 223 (Stel. Str.); 224 (Intrstel. Med.); 226 (Gal. & Gal. Dyn.); 227 (Cosmology), 228 (HE Astro. & Comp. Obj.)

Biophysics students select five courses from biology, biochemistry, chemistry, or physics in consultation with their adviser. At least three courses must be graduate courses.

3. QUALIFYING EXAMINATION AND ADVANCEMENT TO CANDIDACY

In order to be advanced to candidacy, students must have met the departmental requirements and obtained a faculty research supervisor. At the time of application for advancement to candidacy, a doctoral committee responsible for the remainder of the student's graduate program is appointed by the Graduate Council. The committee conducts the Ph.D. qualifying examination during which students must demonstrate the ability to engage in thesis research. Usually this involves the presentation of a plan for the thesis research project. The committee may ask questions directly or indirectly related to the project and questions on general physics which it determines to be relevant. Upon successful completion of this examination, students are advanced to candidacy and are awarded the Candidate of Philosophy degree.

4. INSTRUCTION IN PHYSICS TEACHING

All graduate students are required to participate in the physics undergraduate teaching program as part of their career training. The main component of this requirement is an evaluated classroom-based teaching activity. All graduate student teaching accomplishments are subject to the approval of the vice chair for education. There are several ways to satisfying the teaching requirement, including: (1) leading discussions as a teaching assistant, (2) practical classroom teaching, under faculty supervision, (3) participation in an approved teaching development program offered by the Department of Physics or the campus Center for Teaching Development, or (4) transferred teaching credit from another institution or department. Students who satisfy the requirement by teaching at UCSD should enroll in Physics 500 during the quarter in which they complete it.

5. THESIS DEFENSE

When students have completed their theses, they are asked to present and defend them before their doctoral committees.

TIME LIMITS FOR PROGRESS TO THE PH.D.

In accordance with university policy, the Department of Physics has established the following time limits for progress to the Ph.D. A student's research progress committee helps ensure that these time limits are met.

	Theorists	Experimentalists
Advancement to Candidacy	4 years	5 years
Total Registered Time and Support	7 years	8 years

Departmental Colloquium

The department offers a weekly colloquium on topics of current interest in physics and on departmental research programs. Students are expected to register and attend the colloquium.

Supplementary Course Work and Seminars

The department offers regular seminars in several areas of current interest. Students are strongly urged to enroll for credit in seminars related to their research interests and, when appropriate, to enroll in advanced graduate courses beyond the departmental requirement. To help beginning students choose a research area and a research supervisor, the department offers a special seminar (Physics 261) that surveys physics research at UCSD.

Course Credit by Examination

Students have an option of obtaining credit for a physics graduate course by taking the final examination without participating in any class exercises. They must, however, officially register for the course and notify the instructor and the Department of Physics graduate student affairs office of their intention no later than the first week of the course.

COURSES

LOWER-DIVISION

The Physics 1 sequence is primarily intended for biology.

The Physics 2 sequence is intended for physical science and engineering majors and those biological science majors with strong mathematical aptitude.

The Physics 4 sequence is intended for all physics majors and for students with an interest in physics. This five-quarter sequence covers the same topics as the Physics 2 sequence, but it covers these topics more slowly and in more depth. The Physics 4 sequence provides a solid foundation for the upper-division courses required for the physics major.

Note: Since some of the material is duplicated in the Physics 1, 2 and 4 sequences, credit cannot be obtained for both. Please check with the Physics Student Affairs Office when switching sequences. (Example: Physics 1A followed by Physics 2A, no credit for Physics 2A.)

Physics 5, 6, 7, 8, 9, 10, 11, and 12 are intended for non-science majors. Physics 5, 6, 7, 8, 9, 10, and 12 do not use calculus while Physics 11 uses some calculus.

1A. Mechanics (3)
First quarter of a three-quarter introductory physics course, geared towards life-science majors. Equilibrium and motion of particles in Newtonian mechanics, examples from astronomy, biology and sports, oscillations and waves, vibrating strings and sound. *Prerequisites: Mathematics 10A or 20A, prior or concurrent enrollment in Mathematics 10B or 20B, concurrent enrollment in Physics 1AL laboratory.* (F,W,S)

1AL. Mechanics Laboratory (2)
Physics laboratory course to accompany Physics 1A. Experiments in mechanics. *Prerequisite: concurrent enrollment in Physics 1A.* (F,W,S)

1B. Electricity and Magnetism (3)
Second quarter of a three-quarter introductory physics course geared toward life-science majors. Electric fields, magnetic fields, DC and AC circuitry. *Prerequisites: Physics 1A, 1AL and prior or concurrent enrollment in Mathematics 10C-D or 20C. Concurrent enrollment in Physics 1BL.* (F,W,S)

1BL. Electricity and Magnetism Laboratory (2)
Physics laboratory course to accompany Physics 1B. Experiments in electricity and magnetism. Course materials fee is required. *Prerequisite: concurrent enrollment in Physics 1B.* (F, W, S)

1C. Waves, Optics, and Modern Physics (3)
Third quarter of a three-quarter introductory physics course geared toward life-science majors. Behavior of systems under combined thermal and electric forces, the interaction of light with matter as illustrated through optics and quantum mechanics. Examples from biology and instrumentation. (First offered winter 2005) *Prerequisites: Physics 1B, 1BL, Mathemat-ics 10C or 10D or 20C. Concurrent enrollment in Physics 1CL.* (F, W, S)

1CL. Waves, Optics, and Modern Physics Laboratory (2)
Physics laboratory course to accompany Physics 1C. Experiments in waves, optics, and modern physics. Course materials fee is required. First offered in winter 2005. *Prerequisite: concurrent enrollment in Physics 1C.* (F, W, S)

2A. Physics–Mechanics (4)
A calculus-based science-engineering general physics course covering vectors, motion in one and two dimensions, Newton's first and second laws, work and energy, conservation of energy, linear momentum, collisions, rotational kinematics, rotational dynamics, equilibrium of rigid bodies, oscillations, gravitation. *Prerequisites: Mathematics 20A, and concurrent enrollment in Mathematics 20B.* (F,W,S)

2B. Physics–Electricity and Magnetism (4)
Continuation of Physics 2A covering charge and matter, the electric field, Gauss's law, electric potential, capacitors and dielectrics, current and resistance, electromotive force and circuits, the magnetic field, Ampere's law, Faraday's law, inductance, electromagnetic oscillations, alternating currents and Maxwell's equations. *Prerequisites: Physics 2A, Mathematics 20B, and concurrent enrollment in Mathematics 20C.* (F,W,S)

2BL. Physics Laboratory–Mechanics and Electrostatics (2)
One hour lecture and three hours' laboratory. Experiments include gravitational force, linear and rotational motion, conservation of energy and momentum, collisions, oscillations and springs, gyroscopes. Experiments on electrostatics involve charge, electric field, potential, and capacitance. Data reduction and error analysis are required for written laboratory reports. *Prerequisite: concurrent enrollment in Physics 2B or 4C.* (F,W,S) Course materials fee is required.

2C. Physics–Fluids, Waves, Thermodynamics, and Optics (4)
Continuation of Physics 2B covering fluid mechanics, waves in elastic media, sound waves, temperature, heat and the first law of thermodynamics, kinetic theory of gases, entropy and the second law of thermodynamics, Maxwell's equations, electromagnetic waves, geometric optics, interference and diffraction. *Prerequisites: Physics 2B, Mathematics 20C, and concurrent enrollment in Mathematics 20D.* (F,W,S)

2CL. Physics Laboratory–Electricity and Magnetism, Waves, and Optics (2)
One hour lecture and three hours' laboratory. Experiments on refraction, interference/diffraction using lasers and microwaves; lenses and the eye; acoustics; oscilloscope and L-R-C circuits; oscillations, resonance and damping, measurement of magnetic fields; and the mechanical equivalence of heat. *Prerequisites: prior or concurrent enrollment in Physics 1C, 2C, or 4D.* (F,W,S) Course materials fee is required.

2D. Physics–Relativity and Quantum Physics (4)
A modern physics course covering atomic view of matter, electricity and radiation, atomic models of Rutherford and Bohr, relativity, X-rays, wave and particle duality, matter waves, Schrπdinger's equation, atomic view of solids, natural radioactivity. *Prerequisites: Physics 2B and Mathematics 20D.* (F,W,S)

2DL. Physics Laboratory–Modern Physics (2)
One hour of lecture and three hours of laboratory. Experiments to be chosen from refraction, diffraction and interference of microwaves, Hall effect, thermal band gap, optical spectra, coherence of light, photoelectric effect, e/m ratio of particles, radioactive decays, and plasma physics. *Prerequisites: 2BL or 2CL, prior or concurrent enrollment in Physics 2D or 4E.* (S) Course materials fee is required.

4A. Physics for Physics Majors–Mechanics (4)
The first quarter of a five-quarter calculus-based physics sequence for physics majors and students with a serious interest in physics. The topics covered are vectors, particle kinematics and dynamics, work and energy, conservation of energy, conservation of momentum, collisions, rotational kinematics and dynamics, equilibrium of rigid bodies. *Prerequisites: Mathematics 20A and concurrent enrollment in Mathematics 20B.* (W)

4B. Physics for Physics Majors–Mechanics, Fluids, Waves, and Heat (4)
Continuation of Physics 4A covering oscillations, gravity, fluid statics and dynamics, waves in elastic media, sound waves, heat and the first law of thermodynamics, kinetic theory of gases, second law of thermodynamics, gaseous mixtures and chemical reactions. *Prerequisites: Physics 4A, Mathematics 20B and concurrent enrollment in Mathematics 20C.* (S)

4C. Physics for Physics Majors–Electricity and Magnetism (4)
Continuation of Physics 4B covering charge and Coulomb's law, electric field, Gauss's law, electric potential, capacitors and dielectrics, current and resistance, magnetic field, Ampere's law, Faraday's law, inductance, magnetic properties of matter, LRC circuits, Maxwell's equations. *Prerequisites: Physics 4B, Mathematics 20C and concurrent enrollment in Mathematics 20E.* (F)

4D. Physics for Physics Majors–Electromagnetic Waves, Optics, and Special Relativity (4)
Continuation of Physics 4C covering electromagnetic waves and the nature of light, cavities and wave guides, electromagnetic radiation, reflection and refraction with applications to geometrical optics, interference, diffraction, holography, special relativity. *Prerequisites: Physics 4C, Mathematics 20D and concurrent enrollment in Mathematics 20F.* (W)

4E. Physics for Physics Majors–Quantum Physics (4)
Continuation of Physics 4D covering experimental basis of quantum mechanics: Schrödinger equation and simple applications; spin; structure of atoms and molecules; selected topics from solid state, nuclear, and elementary particle physics. *Prerequisites: Physics 4D, Mathematics 20E, and concurrent enrollment in Mathematics 20D.* (S)

5. The Universe (4)
Introduction to astronomy. Topics include the earth's place in the universe; the atom and light; the birth, life, and death of stars; the Milky Way galaxy; normal and active galaxies; and cosmology. Physics 5 or 7, and Earth Sciences 10 and 30 form a three-quarter sequence. Students may not receive credit for both Physics 5 and Physics 7. Restricted to P/NP grading option if taken after Physics 1A, 2A, or 4A. (F,S)

6. Physics of Space Science and Exploration (4)
Descriptive introduction to basic physics concepts relevant to space science and exploration. Topics include gravity; orbits, weightlessness, and Kepler's laws; the Earth's physical environment (including its atmosphere, its magnetic field, and radiation from the sun); and light as an electromagnetic wave. These topics form the basis for an introduction to the space program and discussion of the scientific reasons for performing experiments or observations in space. Restricted to P/NP grading option if taken after Physics 1A, 2A, or 4A. (W)

7. Introductory Astronomy (4)
Introduction to astronomy and astrophysics. Topics same as Physics 5. This course uses basic pre-calculus level mathematics (algebra, proportions, logs, similar triangles). Physics 5 or 7 and Earth Sciences 10 and 30 form a three-quarter sequence. Students may not receive credit for both Physics 5 and Physics 7. Restricted to P/NP grading option if taken after Physics 1A, 2A, or 4A. (W)

8. Physics of Everyday Life (4)
Examines phenomena and technology encountered in daily life from a physics perspective. Topics include waves, musical instruments, telecommunication, sports, appliances, transportation, computers, and energy sources. Physics concepts will be introduced and discussed as needed employing some algebra. No prior physics knowledge is required. Restricted to P/NP grading option if taken after Physics 1A, 2A, or 4A. (S)

9. The Solar System (4)
A non-mathematical exploration of our Solar System and other planetary systems for non-science majors. The sun, terrestrial and giant planets, satellites, asteroids, comets and meteors. The formation of planetary systems, space exploration, the development and search for life. (F)

10. Concepts in Physics (4)
This is a one-quarter general physics course for non-science majors. Topics covered are motion, energy, heat, waves, electric current, radiation, light, atoms and molecules, nuclear fission and fusion. This course emphasizes concepts with minimal mathematical formulation. *Prerequisite: college algebra or equivalent.* Restricted to P/NP grading option if taken after Physics 1A, 2A, or 4A. (W)

11. Survey of Physics (4)
Survey of physics for non-science majors with strong mathematical background, including calculus. Physics 11 describes the laws of motion, gravity, energy, momentum, and relativity. A laboratory component consists of two experiments with gravity and conservation principles. *Prerequisites: Mathematics 10A or 20A and concurrent enrollment in Math 10B or 20B.* (F)

12. Energy and the Environment (4)
A course covering energy fundamentals, energy use in an industrial society and the impact of large-scale energy consumption. It addresses topics on fossil fuel, heat engines, solar energy, nuclear energy, energy conservation, transportation, air pollution and global effects. Concepts and quantitative analysis. (S)

87. Freshman Seminar in Physics and Astrophysics (1)
The Freshman Seminar Program is designed to provide new students with the opportunity to explore an intellectual topic with a faculty member in a small seminar setting. Freshman seminars are offered in all campus departments and undergraduate colleges, and topics vary from quarter to quarter. Enrollment is limited to fifteen to twenty students, with preference given to entering freshmen.

90. Undergraduate Seminar–Physics Today (1)
Undergraduate seminars organized around the research interests of various faculty members. *Prerequisite: none.* (F,W,S)

91. Undergraduate Seminar on Physics (1)
Undergraduate seminars organized around the research interests of various faculty members. (F,W,S)

99. Independent Study (2)
Independent reading or research on a topic by special arrangement with a faculty member. *(P/NP grading only.) Prerequisites: lower-division standing. Completion of thirty units at UCSD undergraduate study, a minimum UCSD GPA of 3.0, and a completed and approved "Special Studies" form. Department stamp required.*

UPPER-DIVISION

100A. Electromagnetism (4)
Coulomb's law, electric fields, electrostatics; conductors and dielectrics; steady currents, elements of circuit theory. Four hours lecture. *Prerequisites: Physics 2C or 4D, Mathematics 20D; 20E, 20F.* (Concurrent enrollment in Math. 20F permitted.) (F)

100B. Electromagnetism (4)
Magnetic fields and magnetostatics, magnetic materials, induction, AC circuits, displacement currents; development of Maxwell's equations. Four hours lecture. *Prerequisite: Physics 100A.* (W)

100C. Electromagnetism (4)
Electromagnetic waves, radiation theory; application to optics; motion of charged particles in electromagnetic fields; relation of electromagnetism to relativistic concepts. Four hours lecture. *Prerequisite: Physics 100B.* (S)

105A. Mathematical and Computational Physics (4)
A combined analytic and mathematica-based numerical approach to the solution of common applied mathematics problems in physics and engineering. Topics: Fourier series and integrals, special functions, initial and boundary value problems, Green's functions; heat, Laplace and wave equations. *Prerequisites: Mathematics 20E and 20F and Physics 4E or 2D.* (F)

105B. Mathematical and Computational Physics (4)
A continuation of Physics 105A covering selected advanced topics in applied mathematical and numerical methods. Topics include statistics, diffusion and Monte-Carlo simulations; Laplace equation and numerical methods for nonseparable geometries; waves in inhomogeneous media, WKB analysis; nonlinear systems and chaos. *Prerequisite: Physics 105A.* (W)

107/207. Macromolecule Structure Determination by X-ray Crystallography (4)
This course will describe the different steps used in solving for a three dimensional structure of a macromolecule using X-ray crystallography. Topics covered: theory of X-ray diffraction by a crystal; X-ray sources & detectors; crystallization of a protein; crystal symmetry; solution of phase problem by the isomorphous replacement method; anomalous scattering; molecular replacement method; model building and phase improvement; structure refinement. *Prerequisites: Mathematics 20D and Physics 100A, or BIBC 100 or Chemistry 114A or consent of instructor.* (F) (Not offered in 2004–2005)

110A. Mechanics (4)
Coordinate transformations, review of Newtonian mechanics, linear oscillations, gravitation, calculus of

variations, Hamilton's principle, Lagrangian dynamics, Hamilton's equations, central force motion. Four hours lecture. *Prerequisites: Physics 2C or 4D, Mathematics 20D, 20E, 20F (concurrent enrollment in Mathematics 20F permitted).* (F)

110B. Mechanics (4)
Noninertial reference systems, dynamics of rigid bodies, coupled oscillators, special relativity, continuous systems. *Prerequisites: Physics 110A and Mathematics 20E.* (W)

120A-B. Physical Measurements (4-4)
A laboratory-lecture course in physical measurements with an emphasis on electronic methods. Topics include circuit theory, special circuits. Fourier analysis, noise, transmission lines, transistor theory, amplifiers, feedback, operational amplifiers, oscillators, pulse circuits, digital electronics. Three hours lecture, four hours laboratory. *Prerequisites: Physics 2CL and 2DL, Physics 100A.* (S,F) Course materials fee is required.

121. Experimental Techniques (4)
A laboratory-lecture course on the performance of scientific experiments with an emphasis on the use of microcomputers for control and data handling. Topics include microcomputer-architecture, interfacing, and programming, digital to analog and analog to digital conversion, asynchronous buses, interrupt and control techniques, transducers, actuators, digital signal processing–signal filtering, deconvolution, averaging and detection, construction techniques–soldering, parts selection, assembly methods, project management–planning, funding, scheduling, and utilization of personnel. Three hours lecture, four hours laboratory. *Prerequisite: Physics 120A or equivalent.* (W) Course materials fee is required.

129/229. Applied Quantum Mechanics (4)
Fundamental Quantum Theory: Schrödinger equation and probabilistic interpretation, illustrated by electron in quantum box. Rectilinear particle motion: bound states, bonding, scattering and tunneling, device dynamics. Harmonic oscillators: phonons and photons in cavity. Perturbation theory. Angular momentum and spin: particle statistics. Graduate students will have longer homework assignments and an additional take-home exam. *Prerequisites: (Math. 20D and 20F) or (Math. 102 and 110) or MAE 105 or Phys. 105A.* (W)

130A. Quantum Physics (4)
Phenomena which led to the development of quantum mechanics. Wave mechanics; the Schrödinger equation, interpretation of the wave function, the uncertainty principle, piece-wise constant potentials, simple harmonic oscillator, central field and the hydrogen atom. Observables and measurements. Four hours lecture. *Prerequisites: Physics 2C or 2D, 4E, or equivalent.* (S)

130B. Quantum Physics (4)
Matrix mechanics, angular momentum and spin, Stern-Gerlach experiments, dynamics of two-state systems, approximation methods, the complete hydrogen spectrum, identical particles. Four hours lecture. *Prerequisite: Physics 130A.* (F)

130C. Quantum Physics (4)
Scattering theory, symmetry and conservation laws, systems of interacting particles, interaction of electromagnetic radiation with matter, Fermi golden rule, the relativistic electron. *Prerequisites: Physics 100C or equivalent, 130B.* (W)

133/219. Condensed Matter/Materials Science Laboratory (4)
A project-oriented laboratory course utilizing state-of-the-art experimental techniques in materials science. The course prepares students for research in a modern condensed matter-materials science laboratory. Under supervision, the students develop their own experimental ideas after investigating current research literature. With the use of sophisticated state-of- the-art instrumentation students conduct research, write a research paper, and make verbal presentations. *Prerequisites: Physics 2CL and 2DL for undergraduates; Physics 152A or Physics 211A for graduate students.* (S) Course materials fee is required.

137. String Theory (4)
Quantum mechanics and gravity. Electromagnetism from gravity and extra dimensions. Unification of forces. Quantum black holes. Properties of strings and branes. *Prerequisites: Physics 100A and 110A or consent of instructor, Physics 130A may be taken concurrently.* (S)

140A. Statistical and Thermal Physics (4)
Integrated treatment of thermodynamics and statistical mechanics; statistical treatment of entropy, review of elementary probability theory, canonical distribution, partition function, free energy, phase equilibrium, introduction to ideal quantum gases. *Prerequisites: Physics 130A, or consent of instructor.* (F)

140B. Statistical and Thermal Physics (4)
Applications of the theory of ideal quantum gases in condensed matter physics, nuclear physics and astrophysics; advanced thermodynamics, the third law, chemical equilibrium, low temperature physics; kinetic theory and transport in non-equilibrium systems; introduction to critical phenomena including mean field theory. *Prerequisites: Physics 140A, or consent of instructor.* (W)

141.Computational Physics I: Probabilistic Models and Simulations (4)
Project-based computational physics laboratory course with student's choice of Fortran90/95, or C/C++. Applications from materials science to the structure of the early universe are chosen from molecular dynamics, classical and quantum Monte Carlo methods, physical Langevin/Fokker-Planck processes, and other modern topics. *Prerequisite: upper-division standing or consent of instructor.* (W)

142. Computational Physics II: PDE and Matrix Models (4)
Project-based computational physics laboratory course for modern physics and engineering problems with student's choice of Fortran90/95, or C/C++. Applications of finite element PDE models are chosen from quantum mechanics and nanodevices, fluid dynamics, electromagnetism, materials physics, and other modern topics. *Prerequisite: upper-division standing or consent of instructor.* (S)

151. Elementary Plasma Physics (4)
Particle motions, plasmas as fluids, waves, diffusion, equilibrium and stability, nonlinear effects, controlled fusion. Three hours lecture. *Prerequisites: Math. 20D or consent of instructor. Physics 100 (B,C) or ECE 107 and Physics 110A are suggested.* Cross listed with MAE 117A. (S)

152A. Condensed Matter Physics (4)
Physics of the solid state. Binding mechanisms, crystal structures and symmetries, diffraction, reciprocal space, phonons, free and nearly free electron models, energy bands, solid state thermodynamics, kinetic theory and transport, semiconductors. *Prerequisites: Physics 130A or Chemistry 133, and Physics 140A.* (W)

152B. Electronic Materials (4)
Physics of electronic materials. Semiconductors: bands, donors and acceptors, devices. Metals: Fermi surface, screening, optical properties. Insulators: dia-/ferro-electrics, displacive transitions. Magnets: dia-/para-/ferro-/antiferro-magnetism, phase transitions, low temperature properties. Superconductors: pairing, Meissner effect, flux quantization, BCS theory. *Prerequisite: Physics 152A or consent of instructor.* (S)

154. Nuclear and Particle Physics (4)
The strong, electromagnetic and weak interactions of elementary particles at high energies. Symmetries and conservation laws. Introduction to the calculation of particle decay widths and scattering cross-sections using Feynman diagrams. Relativistic equations of motion, including the Dirac equation. *Prerequisites: Physics 130B.*

155. Nonlinear Dynamics (4)
Qualitative aspects of Hamiltonian and dissipative dynamical systems: stability of orbits, integrability of Hamiltonian systems, chaos and nonperiodic motion, transition to chaos. Examples to be drawn from mechanics, fluid mechanics, and related physical systems. Numerical work and graphical display and interpretation will be emphasized. Three hours lecture. *Prerequisites: Physics 100B and 110B.* (S)

160. Stellar Astrophysics (4)
Introduction to stellar astrophysics: observational properties of stars, solar physics, radiation and energy transport in stars, stellar spectroscopy, nuclear processes in stars, stellar structure and evolution, degenerate matter and compact stellar objects, supernovae and nucleosynthesis. Physics 160, 161, and 162 may be taken as a three-quarter sequence for students interested in pursuing graduate study in astrophysics or individually as topics of interest. *Prerequisite: Physics 2 or 4 sequence or equivalent.* (F)

161. Black Holes and The Milky Way Galaxy (4)
The structure and content of the Milky Way galaxy and the physics of black holes. Topics will be selected from: general relativity, theory and observation of black holes, galactic x-ray sources, galactic structure, physical processes in the interstellar medium, star formation. Physics 160, 161, and 162 may be taken as a three-quarter sequence for students interested in pursuing graduate study in astrophysics or individually as topics of interest. *Prerequisites: Physics 2 or 4 sequence or equivalent.* (W)

162. Galaxies and Cosmology (4)
The structure and properties of galaxies, galaxy dynamics and dark matter, the expanding universe, plus some of the following topics: the big bang, early universe, galaxy formation and evolution, large scale structure, active galaxies and quasars. Physics 160, 161, and 162 may be taken as a three-quarter sequence for students interested in pursuing graduate study in astrophysics or individually as topics of interest. *Prerequisites: Physics 2 or 4 sequence or equivalent.* (S)

163. Exploring the Solar System (4)
Topics will include: the early solar system, and planetary formation; an introduction to the Sun and planets; the solar wind and its interaction with planets; spacecraft instruments and observations; the search for life in the solar system; and the search for planets

outside our solar system. *Prerequisites: Physics 2A-B or Physics 4A-4C.* (F)

171/271. Biophysics of Neurons and Networks (4-4)
Fundamental limits to measurements on nervous systems, the biophysics of excitable membranes and neurons, and the fundamentals of recurrent neuronal networks. The emphasis is on information processing by the nervous system through physical reasoning and mathematical anaylsis. Three hours lecture. The graduate version, Physics 271, will include a report at the level of a research proposal. *Prerequisites: Physics 100A and 110A, BILD 1, Chemistry 6C and Physics 140A, for graduate students, consent of instructor.* The graduate version, Physics 271, will include a report at the level of a research proposal. (F)

172/272. Biophysics of Molecules (4-4)
Physical concepts and techniques used to study the structure and function of biological molecules, the thermodynamics and kinetics of biological activity, and physical descriptions of biological processes. Examples from enzyme action, protein folding, photobiology, and molecular motors. Three hours lecture. *Prerequisites: Physics 100A and 110A, BILD 1, Chemistry 6C and Physics 130A; and graduate students, consent of instructor.* The graduate version, Physics 272, will include a report at the level of a research proposal. (W)

173. Modern Physics Laboratory: Biological and Quantum Physics (4)
A selection of experiments in contemporary physics and biophysics. Students select among pulsed NMR, Mossbauer, Zeeman effect, light scattering, holography, optical trapping, voltage clamp and genetic transcription of ion channels in oocytes, flourescent imaging, and flight control in flies. *Prerequisites: Physics 120A, BILD 1 and Chemistry 6BL.* (S)

180/280. Teaching and Learning Physics (4)
How people learn and understand key concepts in physics. Readings in physics, physics education research, and cognitive science. Field work teaching and evaluating pre-college and college students. Useful for students interested in teaching and learning physical sciences. *Prerequisites: Physics 1, 2, or 4 series, or consent of instructor.*

191. Undergraduate Seminar on Physics (1)
Undergraduate seminars organized around the research interests of various faculty members. *Prerequisite: Physics 2A or 4A series.*

195. Physics Instruction (2-4)
Students will be responsible for and teach a class section of a lower-division physics course. They will also attend a weekly meeting on teaching methods and materials conducted by the professor who supervises their teaching. (P/NP grades only.) *Prerequisite: consent of instructor.* (F,W,S)

197. Physics Internship (4)
An enrichment program which provides work experience with industry, government offices, etc., under the supervision of a faculty member and industrial supervisor. *Prerequisite: Completion of 90 units with 2.5 GPA and consent of faculty adviser.*

198. Directed Group Study (2 or 4)
Directed group study on a topic or in a field not included in the regular departmental curriculum. (P/NP grades only.) *Prerequisites: consent of instructor and departmental chair.* (F,W,S)

199. Research for Undergraduates (2 or 4)
Independent reading or research on a problem by special arrangement with a faculty member. (P/NP grades only.) *Prerequisites: consent of instructor and departmental chair.* (F,W,S)

199H. Honors Thesis Research for Undergraduates (2-4)
Honors thesis research for seniors participating in the Honors Program. Research is conducted under the supervision of a physics faculty member. *Prerequisite: admission to the Honors Program in physics.* (F,W,S)

GRADUATE

200A. Theoretical Mechanics (4)
Lagrange's equations and Hamilton's principle; symmetry and constants of the motion. Applications to: charged particle motion; central forces and scattering theory; small oscillations; anharmonic oscillations; rigid body motion; continuum mechanics. *Prerequisite: Physics 110B or equivalent.* (F)

200B. Theoretical Mechanics (4)
Hamilton's equations, canonical transformations; Hamilton-Jacobi theory; action-angle variables and adiabatic invariants; introduction to canonical perturbation theory, nonintegrable systems and chaos; Liouville equation; ergodicity and mixing; entropy; statistical ensembles. *Prerequisite: Physics 200A.* (W)

201. Mathematical Physics (5)
An introduction to mathematical methods used in theoretical physics. Topics include: a review of complex variable theory, applications of the Cauchy residue theorem, asymptotic series, method of steepest descent, Fourier and Laplace transforms, series solutions for ODE's and related special functions, Sturm Liouville theory, variational principles, boundary value problems, and Green's function techniques. (F)

203A. Advanced Classical Electrodynamics (5)
Electrostatics, symmetries of Laplace's equation and methods for solution, boundary value problems, electrostatics in macroscopic media, magnetostatics, Maxwell's equations, Green functions for Maxwell's equations, plane wave solutions, plane waves in macroscopic media. *Prerequisite: Physics 100C or equivalent.* (W)

203B. Advanced Classical Electrodynamics (4)
Special theory of relativity, covariant formulation of electrodynamics, radiation from current distributions and accelerated charges, multipole radiation fields, waveguides and resonant cavities. *Prerequisite: Physics 203A.* (S)

107/207. Macromolecule Structure Determination by X-ray Crystallography (4)
This course will describe the different steps used in solving for a three-dimensional structure of a macromolecule using X-ray crystallography. Topics covered: theory of X-ray diffraction by a crystal; X-ray sources & detectors; crystallization of a protein; crystal symmetry; solution of phase problem by the isomorphous replacement method; anomalous scattering; molecular replacement method; model building and phase improvement; structure refinement. *Prerequisites: Mathematics 20D, Physics 100A, or BIBC 100 or Chemistry 114A or consent of instructor.* (F)

210A. Equilibrium Statistical Mechanics (4)
Approach to equilibrium: BBGKY hierarchy; Boltzmann equation; H-theorem. Ensemble theory; thermodynamic potentials. Quantum statistics; Bose condensation. Interacting systems: Cluster expansion; phase transition via mean-field theory; the Ginzburg criterion. *Prerequisites: Physics 140A-B, 152A, 200A-B, or equivalent; concurrent enrollment in Physics 212C.* (S)

210B. Nonequilibrium Statistical Mechanics (4)
Transport phenomena; kinetic theory and the Chapman-Enskog method; hydrodynamic theory; nonlinear effects and the mode coupling method. Stochastic processes; Langevin and Focker-Planck equation; fluctuation-dissipation relation; multiplicative processes; dynamic field theory; Martin-Siggia-Rose formalism; dynamical scaling theory. *Prerequisite: Physics 210A.* (F)

210C. Statistical Field Theory (4)
Phase transition and critical phenomena: Landau-Ginzburg model and statistical field theory; Goldstone modes; breakdown of mean-field theory. Universality; scaling theory; the renormalization group. Epsilon expansion; large-N expansion; the nonlinear-sigma model. Topological defects; duality; the Kosterlitz-Thouless transition. *Prerequisite: Physics 210A or consent of instructor.* (W)

211A. Solid-State Physics (5)
The first of a two-quarter course in solid-state physics. Covers a range of solid-state phenomena that can be understood within an independent particle description. Topics include: chemical versus band-theoretical description of solids, electronic band structure calculation, lattice dynamics, transport phenomena and electrodynamics in metals, optical properties, semiconductor physics. *Prerequisite: Physics 152A or equivalent.* (F)

211B. Solid-State Physics (4)
Continuation of 211A. Deals with collective effects in solids arising from interactions between constituents. Topics include electron-electron and electron-phonon interactions, screening, band structure effects, Landau Fermi liquid theory. Magnetism in metals and insulators, superconductivity; occurrence, phenomenology, and microscopic theory. *Prerequisites: Physics 210A, 211A.* (offered in alternate years) (W)

212A. Quantum Mechanics (4)
Hilbert space formulation of quantum mechanics and application to simple systems: states and observables, uncertainty relations and measurements, time evolution, and mixed states and density matrix. Symmetries: commuting observables and symmetries, rotation group representations, Clebsh-Gordon coefficients, Wigner-Eckhardt theorem, and discrete symmetries (parity, time reversal, etc.). *Prerequisite: Physics 130B or equivalent.* (F)

212B. Quantum Mechanics (4)
Time independent perturbation theory: non-degenerate and degenerate cases, Zeeman effect, fine structure, exclusion principle, and many-electron atoms. Time dependent perturbation theory: interaction picture and Dyson series, transition rates. Radiation theory: quantization of EM field, calculation of atomic level transition rates, line width, and spontaneous decay. *Prerequisite: Physics 212A.* (W)

212C. Quantum Mechanics (4)
Scattering theory: Lippman-Schwinger formalism, Born approximation, partial waves, inelastic processes, and spin dependence. Path integrals: introductions and simple examples, rigid rotator, and Bohm-Aharonov effect. Dirac equation: single particle equation, hydrogen atom, and holes. *Prerequisites: Physics 212A-B.* (S)

214. Physics of Elementary Particles (4)
Classification of particles using symmetries and invariance principles, quarks and leptons, quantum electrodynamics, weak interactions, e^+p^- interactions, deep-inelastic lepton-nucleon scattering, pp collisions, introduction to QCD. *Prerequisite: Physics 215A.* (W)

215A. Particles and Fields (4)
The first quarter of a three-quarter course on field theory and elementary particle physics. Topics covered include the relation between symmetries and conservation laws, the calculation of cross sections and reaction rates, covariant perturbation theory, and quantum electrodynamics. (F)

215B. Particles and Fields (4)
Continuation of 215A. Gauge theory quantization by means of path integrals, SU(3) symmetry and the quark model, spontaneous symmetry breakdown, introduction to QCD and the Glashow-Weinberg-Salam model of weak interactions, basic issues of renormalization. *Prerequisite: Physics 215A.* (W)

215C. Particles and Fields (4)
Modern applications of the renormalization group in quantum chromodynamics and the weak interactions. Unified gauge theories, particle cosmology, and special topics in particle theory. *Prerequisites: Physics 215A-B.* (offered in alternate years) (S)

217. Field Theory and the Renormalization Group (4)
Application of field theory techniques and the renormalization group method to problems in condensed matter or particle physics. Topics will vary and may include: spin-glass and other systems dominated by quenched disorders; polymer statistics and liquid crystals; bosonization and many-body quantum systems in 1+1 dimensions; quantum chromodynamics and the electroweak model. *Prerequisites: Physics 210C, 212C, or consent of instructor.* (offered in alternate years) (S)

218A. Plasma Physics (4)
The basic physics of plasmas is discussed for the simple case of an unmagnetized plasma. Topics include: thermal equilibrium statistical properties, fluid and Landau theory of electron and ion plasma waves, velocity space instabilities, quasi-linear theory, fluctuations, scattering or radiation, Fokker-Planck equation. (F)

218B. Plasma Physics (4)
This course deals with magnetized plasma. Topics include: Appleton-Hartree theory of waves in cold plasma, waves in warm plasma (Bernstein waves, cyclotron damping). MHD equations, MHD waves, low frequency modes, and the adiabatic theory of particle orbits. *Prerequisite: Physics 218A.* (W)

218C. Plasma Physics (4)
This course deals with the physics of confined plasmas with particular relevance to controlled fusion. Topics include: topology of magnetic fields, confined plasma equilibria, energy principles, ballooning and kink instabilities, resistive MHD modes (tearing, rippling and pressure-driven), gyrokinetic theory, microinstabilities and anomalous transport, and laser-plasma interactions relevant to inertial fusion. *Prerequisite: Physics 218B.* (S)

133/219. Condensed Matter/Materials Science Laboratory (4)
A project-oriented laboratory course utilizing state-of-the-art experimental techniques in materials science. The course prepares students for research in a modern condensed matter-materials science laboratory. Under supervision, the students develop their own experimental ideas after investigating current research literature. With the use of sophisticated state-of-the-art instrumentation students conduct research, write a research paper, and make verbal presentations. Prerequisites: *Physics 2CL and 2DL for undergraduates; Physics 152A or Physics 211A for graduate students. (S)*

220. Group Theoretical Methods in Physics (4)
Study of group theoretical methods with applications to problems in high energy, atomic, and condensed matter physics. Representation theory, tensor methods, Clebsh-Gordan series. Young tableaux. The course will cover discrete groups, Lie groups and Lie algebras, with emphasis on permutation, orthogonal, and unitary groups. *Prerequisite: Physics 212C.* (S)

221A. Nonlinear and Nonequilibrium Dynamics of Physical Systems (4)
An introduction to the modern theory of dynamical systems and applications thereof. Topics include maps and flows, bifurcation theory and normal form analysis, chaotic attractors in dissipative systems, Hamiltonian dynamics and the KAM theorem, and time series analysis. Examples from real physical systems will be stressed throughout. *Prerequisite: Physics 200B.* (offered in alternate years) (W)

221B. Nonlinear and Nonequilibrium Dynamics of Physical Systems (4)
Nonlinear dynamics in spatially extended systems. Material to be covered includes fluid mechanical instabilities, the amplitude equation approach to pattern formation, reaction-diffusion dynamics, integrable systems and solitons, and an introduction to coherent structures and spatio-temporal chaos. *Prerequisites: Physics 210B and 221A.* (offered in alternate years) (S)

223. Stellar Structure and Evolution (4)
Energy generation, flow, hydrostatic equilibrium, equation of state. Dependence of stellar parameters (central surface temperature, radius, luminosity, etc.) on stellar mass and relation to physical constants. Relationship of these parameters to the H-R diagram and stellar evolution. Stellar interiors, opacity sources, radiative and convective energy flow. Nuclear reactions, neutrino processes. Polytropic models. White dwarfs and neutron stars. *Prerequisites: Physics 130C or equivalent, Physics 140A-B or equivalent.* (S/U grades permitted.) (offered in alternate years) (F)

224. Physics of the Interstellar Medium (4)
Gaseous nebulae, molecular clouds, ionized regions, and dust. Low energy processes in neutral and ionized gases. Interaction of matter with radiation, emission and absorption processes, formation of atomic lines. Energy balance, steady state temperatures, and the physics and properties of dust. Masers and molecular line emission. Dynamics and shocks in the interstellar medium. *Prerequisites: Physics 130A-B or equivalent, Physics 140A-B or equivalent.* (S/U grades permitted.) (offered in alternate years)

225A-B. General Relativity (4-4)
This is a two-quarter course on gravitation and the general theory of relativity. The first quarter is intended to be offered every year and may be taken independently of the second quarter. The second quarter will be offered in alternate years. Topics covered in the first quarter include special relativity, differential geometry, the equivalence principle, the Einstein field equations, and experimental and observational tests of gravitation theories. The second quarter will focus on more advanced topics, including gravitational collapse, Schwarzschild and Kerr geometries, black holes, gravitational radiation, cosmology, and quantum gravitation. (225B offered in alternate years) (F,W)

226. Galaxies and Galactic Dynamics (4)
The structure and dynamics of galaxies. Topics include potential theory, the theory of stellar orbits, self-consistent equilibria of stellar systems, stability and dynamics of stellar systems including relaxation and approach to equilibrium. Collisions between galaxies, galactic evolution, dark matter, and galaxy formation. *Prerequisite: consent of instructor.* (offered in alternate years)

227. Cosmology (4)
An advanced survey of topics in physical cosmology. The Friedmann models and the large-scale structure of the universe, including the observational determination of H_0 (the Hubble constant) and q_0 (the deceleration parameter). Galaxy number counts. A systematic exposition of the physics of the early universe, including vacuum phase transitions; inflation; the generation of net baryon number, fluctuations, topological defects and textures. Primordial nucleosynthesis, both standard and nonstandard models. Growth and decay of adiabatic and isocurvature density fluctuations. Discussion of dark matter candidates and constraints from observation and experiment. Nucleocosmo-chronology and the determination of the age of the universe. *Prerequisite: consent of instructor.* (offered in alternate years)

228. High-Energy Astrophysics and Compact Objects (4)
The physics of compact objects, including the equation of state of dense matter and stellar stability theory. Maximum mass of neutron stars, white dwarfs, and super-massive objects. Black holes and accretion disks. Compact x-ray sources and transient phenomena, including x-ray and γ-ray bursts. The fundamental physics of electromagnetic radiation mechanisms: synchrotron radiation, Compton scattering, thermal and nonthermal bremsstrahlung, pair production, pulsars. particle acceleration models, neutrino production and energy loss mechanisms, supernovae, and neutron star production. *Prerequisites: Physics 130A-B-C or equivalent.* (offered in alternate years)

129/229. Applied Quantum Mechanics (4)
Fundamental Quantum Theory: Schrödinger equation and probabilistic interpretation, illustrated by electron in quantum box. Rectilinear particle motion: bound states, bonding, scattering and tunneling, device dynamics. Harmonic oscillators: phonons and photons in cavity. Perturbation theory. Angular momentum and spin: particle statistics. Graduate students will have longer homework assignments and an additional take-home final. *Prerequisites: (Math. 20D and 20F) or (Math. 102 and 110) or MAE 105 or Phys. 105A.* (W)

230. Advanced Solid-State Physics (1-4)
Selection of advanced topics in solid-state physics; material covered may vary from year to year. Examples of topics covered: disordered systems, surface physics, strong-coupling superconductivity, quantum Hall effect, low-dimensional solids, heavy fermion systems, high-temperature superconductivity, solid and liquid helium. (Offered in alternate years.) *Prerequisite: Physics 211B.*

152B/232. Electronic Materials (4)
Physics of electronic materials. Semiconductors: bands, donors and acceptors, devices. Metals: Fermi surface, screening, optical properties. Insulators: dia-/ferro-electrics, displacive transitions. Magnets: dia-/para-/ferro-/antiferro-magnetism, phase transitions, low temperature properties. Superconductors: pair-

ing, Meissner effect, flux quantization, BCS theory. *Prerequisites: Physics 152A, Phys 211 or consent of instructor.* Graduate students in Phys 232 will complete a special topics paper. (S)

235. Nonlinear Plasma Theory (4)
This course deals with nonlinear phenomena in plasmas. Topics include: orbit perturbation theory, stochasticity, Arnold diffusion, nonlinear wave-particle and wave-wave interaction, resonance broadening, basics of fluid and plasma turbulence, closure methods, models of coherent structures. *Prerequisite: Physics 218C or consent of instructor.* (offered in alternate years) (W)

239. Special Topics (1–3)
From time to time a member of the regular faculty or a resident visitor will find it possible to give a self-contained short course on an advanced topic in his or her special area of research. This course is not offered on a regular basis, but it is estimated that it will be given once each academic year. (S/U grades permitted.)

250. Condensed Matter Physics Seminar (0–1)
Discussion of current research in physics of the solid state and of other condensed matter. (S/U grades only.) (F,W,S)

251. High-Energy Physics Seminar (0–1)
Discussions of current research in nuclear physics, principally in the field of elementary particles. (S/U grades only.) (F,W,S)

252. Plasma Physics Seminar (0–1)
Discussions of recent research in plasma physics. (S/U grades only.) (F,W,S)

253. Astrophysics and Space Physics Seminar (0–1)
Discussions of recent research in astrophysics and space physics. (S/U grades only.) (F,W,S)

257. High-Energy Physics Special Topics Seminar (0–1)
Discussions of current research in high-energy physics. (S/U grades only.) (F,W,S)

258. Astrophysics and Space Physics Special Topics Seminar (0–1)
Discussions of current research in astrophysics and space physics. (S/U grades only.) (F,W,S)

260. Physics Colloquium (0–1)
Discussions of recent research in physics directed to the entire physics community. (S/U grades only.) (F,W,S)

261. Seminar on Physics Research at UCSD (0–1)
Discussions of current research conducted by faculty members in the Department of Physics. (S/U grades only.) (W,S)

262. Complex Dynamical Systems Seminar (0–1)
Discussions of recent research in nonlinear and nonequilibrium physics. (S/U grades only.) (F,W,S)

265. Neuronal Networks Topics Seminar (1)
Discussion of current research on neuronal systems and dynamics. (F,W,S)

266. Recent Topics in Condensed Matter Physics (1–3)
The course is dedicated to recent developments in the area of condensed matter physics through lectures given by graduate students and postdocs. The course teaches practical skills, delivering research lectures, and answering questions in front of a research audience. *Prerequisite: physics graduate students in good standing.* (F,W,S)

171/271. Biophysics of Neurons and Networks (4–4)
Fundamental limits to measurements on nervous systems, the biophysics of excitable membranes and neurons, and the fundamentals of recurrent neuronal networks. The emphasis is on information processing by the nervous system through physical reasoning and mathematical anaylsis. Three hours lecture. The graduate version, Physics 271, will include a report at the level of a research proposal. *Prerequisites: Physics 100A and 110A, BILD 1, Chemistry 6C and Physics 140A, for graduate students, consent of instructor.* The graduate version, Physics 271, will include a report at the level of a research proposal. (W)

172/272. Biophysics of Molecules (4–4)
Physical concepts and techniques used to study the structure and function of biological molecules, the thermodynamics and kinetics of biological activity, and physical descriptions of biological processes. Examples from enzyme action, protein folding, photobiology, and molecular motors. Three hours lecture. *Prerequisites: Physics 100A and 110A, BILD 1, Chemistry 6C and Physics 130A and graduate students consent of instructor.* The graduate version, Physics 272, will include a report at the level of a research proposal. (S)

180/280. Teaching and Learning Physics (4)
How people learn and understand key concepts in physics. Readings in physics, physics education research, and cognitive science. Field work teaching and evaluating pre-college and college students. Useful for students interested in teaching and learning physical sciences. Undergraduate students are required to read and discuss papers in class. Graduate students are expected to read the papers and prepare an annotated bibliography on the background literature, then lead the in-class discussion on the topics covered in the papers. *Prerequisites: Physics 1, 2, or 4 series, or consent of instructor.*

295. M.S. Thesis Research in Materials Physics (1–12)
Directed research on M.S. dissertation topic. (F,W,S)

297. Special Studies in Physics (1–4)
Studies of special topics in physics under the direction of a faculty member. *Prerequisites: consent of instructor and departmental vice chair, education.* (S/U grades permitted.) (F,W,S)

298. Directed Study in Physics (1-12)
Research studies under the direction of a faculty member. (S/U grades permitted.) (F,W,S)

299. Thesis Research in Physics (1-12)
Directed research on dissertation topic. (F,W,S)

500. Instruction in Physics Teaching (1-4)
This course, designed for graduate students, includes discussion of teaching, techniques and materials necessary to teach physics courses. One meeting per week with course instructors, one meeting per week in an assigned recitation section, problem session, or laboratory section. Students are required to take a total of two units of Physics 500. (F,W,S)