# Physics

Graduate work leading to the PhD degree is offered in the Department of Physics. Students may petition for an MA degree on their way to a PhD. Please note that the department will not consider applications from students who intend to work toward the MA degree only. In certain cases, students may petition for a terminal MA degree. Research is a major part of the PhD program, and research opportunities exist across the full spectrum of theoretical and experimental physics, including astrophysics and cosmology; atomic, molecular and optical physics; biophysics; condensed matter; elementary particles and fields; fusion and plasma; low-temperature physics; mathematical physics; nuclear physics; quantum information; space physics; and statistical mechanics.

At the Lawrence Berkeley National Laboratory, extensive opportunities exist for research in astrophysics, elementary particle and nuclear physics, condensed matter physics and materials science, and plasma and nuclear physics. Space physics, interplanetary studies, solar plasma research, physics of the upper atmosphere, and cosmological problems are pursued both in the Physics Department and at the Space Sciences Laboratory.

## Admission to the University

### Minimum Requirements for Admission

The following minimum requirements apply to all graduate programs and will be verified by the Graduate Division:

1. A bachelor's degree or recognized equivalent from an accredited institution;
2. A grade point average of B or better (3.0);
3. If the applicant has completed a basic degree from a country or political entity (e.g., Quebec) where English is not the official language, adequate proficiency in English to do graduate work, as evidenced by a TOEFL score of at least 90 on the iBT test, 570 on the paper-and-pencil test, or an IELTS Band score of at least 7 on a 9-point scale (note that individual programs may set higher levels for any of these); and
4. Sufficient undergraduate training to do graduate work in the given field.

### Applicants Who Already Hold a Graduate Degree

The Graduate Council views academic degrees not as vocational training certificates, but as evidence of broad training in research methods, independent study, and articulation of learning. Therefore, applicants who already have academic graduate degrees should be able to pursue new subject matter at an advanced level without the need to enroll in a related or similar graduate program.

Programs may consider students for an additional academic master's or professional master's degree only if the additional degree is in a distinctly different field.

Applicants admitted to a doctoral program that requires a master's degree to be earned at Berkeley as a prerequisite (even though the applicant already has a master's degree from another institution in the same or a closely allied field of study) will be permitted to undertake the second master's degree, despite the overlap in field.

The Graduate Division will admit students for a second doctoral degree only if they meet the following guidelines:

1. Applicants with doctoral degrees may be admitted for an additional doctoral degree only if that degree program is in a general area of knowledge distinctly different from the field in which they earned their original degree. For example, a physics PhD could be admitted to a doctoral degree program in music or history; however, a student with a doctoral degree in mathematics would not be permitted to add a PhD in statistics.
2. Applicants who hold the PhD degree may be admitted to a professional doctorate or professional master's degree program if there is no duplication of training involved.

Applicants may apply only to one single degree program or one concurrent degree program per admission cycle.

## Required Documents for Applications

1. **Transcripts:** Applicants may upload *unofficial* transcripts with your application for the departmental initial review. Unofficial transcripts must contain specific information including the name of the applicant, name of the school, all courses, grades, units, & degree conferral (if applicable).
2. **Letters of recommendation:** Applicants may request online letters of recommendation through the online application system. Hard copies of recommendation letters must be sent directly to the program, by the recommender, not the Graduate Admissions.
3. **Evidence of English language proficiency:** All applicants who have completed a basic degree from a country or political entity in which the official language is not English are required to submit official evidence of English language proficiency. This applies to institutions from Bangladesh, Burma, Nepal, India, Pakistan, Latin America, the Middle East, the People's Republic of China, Taiwan, Japan, Korea, Southeast Asia, most European countries, and Quebec (Canada). However, applicants who, at the time of application, have already completed at least one year of full-time academic course work with grades of B or better at a US university may submit an official transcript from the US university to fulfill this requirement. The following courses will not fulfill this requirement:
    - courses in English as a Second Language,
    - courses conducted in a language other than English,
    - courses that will be completed after the application is submitted, and
    - courses of a non-academic nature.

Applicants who have previously applied to Berkeley must also submit new test scores that meet the current minimum requirement from one of the standardized tests. Official TOEFL score reports must be sent directly from Educational Test Services (ETS). The institution code for Berkeley is 4833 for Graduate Organizations. Official IELTS score reports must be sent electronically from the testing center to University of California, Berkeley, Graduate Division, Sproul Hall, Rm 318 MC 5900, Berkeley, CA 94720. TOEFL and IELTS score reports are only valid for two years prior to beginning the graduate program at UC Berkeley. Note: score reports can not expire before the month of June.

## Where to Apply

Visit the Berkeley Graduate Division application page (http://grad.berkeley.edu/admissions/apply/).

## Admission to the Program

The Department of Physics ordinarily admits only those applicants who have scholastic records well above a B+ average and who have completed the equivalent of the undergraduate major in physics. This program includes upper division courses in mechanics (4 semester units), electromagnetism and optics (8 semester units), statistical and thermal physics (4 semester units), quantum mechanics (8 semester units), and advanced undergraduate laboratory (5 semester units). Courses in atomic, nuclear and solid state physics, astronomy and applied mathematics are recommended as electives. Not all courses in the major are required for admission. Some courses required for the major program but not previously taken may have to be made up in the first year of graduate work. Applicants are required to submit a list of courses taken in physics and mathematics with course number, and applicable textbook, as well as a list of courses in progress.

In determining the admissibility of a prospective graduate student the department attempts to carefully weigh all relevant factors, including transcripts of academic work, test scores, letters of recommendation, research experience, and a statement of purpose. We recognize the diverse experiences of our applicants and therefore encourage them to submit supporting materials.

The Graduate Program in Physics is designed for those intending to pursue work leading to the PhD. After completing the necessary course work and examination requirements, an MA degree can be awarded. However, the department does not consider applications from those intending to work toward the MA degree only.

The master's degree in Physics is conferred according to Graduate Division degree policies. Students in the physics doctoral program may apply for the MA degree. The Physics MA candidate must complete:

**1) Curriculum**

| | | |
|---|---|---|
| PHYSICS 209 | Classical Electromagnetism | 5 |
| PHYSICS 211 | Equilibrium Statistical Physics | 4 |
| PHYSICS 221A | Quantum Mechanics | 5 |
| PHYSICS 221B | Quantum Mechanics | 5 |

Note: Required courses (19.0 units) must be taken for a letter grade or 19 replacement units if subject waivers have been granted for prior coursework.

**2) 16 additional units of approved upper division and graduate courses, which may include** PHYSICS 251 **and** PHYSICS 375

Note: Total units required for MA degree is 35 semester units of upper division and graduate work in physics (or related fields) with an average grade of at least B. Eighteen of these units must represent graduate courses in physics. Neither upper division courses required in the Physics Major Program nor PHYSICS 290 seminars, PHYSICS 295, PHYSICS 299, PHYSICS 301, or PHYSICS 602 may be used to satisfy the 35 unit requirement. No more than one-third of the 16 elective units may be fulfilled by courses graded Satisfactory, and then only if approved by the head graduate adviser.

**3) Pass a comprehensive examination (passing the Physics preliminary examination constitutes passing the comprehensive exam).**

## Normative Time Requirements

The normative time for completing a PhD in Physics is six years.

## Time to Advancement

### Curriculum

**Courses Required**

| | | |
|---|---|---|
| PHYSICS 209 | Classical Electromagnetism | 5 |
| PHYSICS 211 | Equilibrium Statistical Physics | 4 |
| PHYSICS 221A | Quantum Mechanics | 5 |
| PHYSICS 221B | Quantum Mechanics | 5 |
| Physics electives: | | |
| Graduate | | 11 |
| Graduate/Upper Division | | 8 |

Graduate students are required to take a minimum of 38 units of approved upper division or graduate elective courses (excluding any upper division courses required for the undergraduate major). The department requires that students take the following courses which total 19 units: Physics 209 (Classical Electromagnetism), Physics 211 (Equilibrium Statistical Physics) and Physics 221A-221B (Quantum Mechanics). Thus, the normative program includes an additional 19 units (five semester courses) of approved upper division or graduate elective courses. At least 11 units must be in the 200 series courses. Some of the 19 elective units could include courses in mathematics, biophysics, astrophysics, or from other science and engineering departments. Physics 290, 295, 299, 301, and 602 are excluded from the 19 elective units. Physics 209, 211 and 221A-221B must be completed for a letter grade (with a minimum average grade of B). No more than one-third of the 19 elective units may be fulfilled by courses graded Satisfactory, and then only with the approval of the Department. Entering students are required to enroll in Physics 209 and 221A in the fall semester of their first year and Physics 211 and 221B in the spring semester of their first year. Exceptions to this requirement are made for 1) students who do not have sufficient background to enroll in these courses and have a written recommendation from their faculty mentor and approval from the head graduate adviser to delay enrollment to take preparatory classes, 2) students who have taken the equivalent of these courses elsewhere and receive written approval from the Department to be exempted.

If a student has taken courses equivalent to Physics 209, 211 or 221A-221B, then subject credit may be granted for each of these course requirements. A faculty committee will review your course syllabi and transcript. A waiver form can be obtained from the Physics Student Affairs Officer detailing all required documents. If the committee agrees that the student has satisfied the course requirement at another institution, the student must secure the Head Graduate Adviser's approval. The student must also take and pass the associated section of the preliminary exam. Please note that official course waiver approval will not be granted until after the preliminary exam results have been announced. If course waivers are approved, units for the waived required courses do not have to be replaced for PhD course requirements. If a student has satisfied all first-year required graduate courses elsewhere, they are only required to take an additional 19 units to satisfy remaining PhD course requirements. (Note that units for required courses must be replaced for MA degree course requirements even if the courses

themselves are waived; for more information please see MA degree requirements).

In exceptional cases, students transferring from other graduate programs may request a partial waiver of the 19 elective unit requirement. Such requests must be made at the time of application for admission to the Department.

## Preliminary Examination

The preliminary examination is designed to ensure that students command a broad spectrum of undergraduate physics prior to their engaging in graduate research. The preliminary exam is a written exam composed of four sections, grouped by general subject areas of undergraduate physics. All four sections of the preliminary examination are offered at the beginning of both Fall and Spring semesters. A student who has passed all four sections of the exam will have passed the preliminary examination. The Department expects students to pass the examination within the first three semesters of graduate study (see further notes on this below).

*The preliminary exam is intended as one tool for helping the Department evaluate that students are making adequate progress towards their PhD. The determination of a student's academic standing in the Department will be based on a student's entire record, including performance on the prelim exam, undergraduate coursework, graduate coursework, and research performance where appropriate. Consequently, a student would not be asked to leave the Department based solely on performance on the written preliminary exam.*

The written exam has four sections, covering (1) classical mechanics, (2) electromagnetism and optics, and special relativity, (3) thermodynamics and statistical physics, and (4) quantum mechanics. Note that these divisions do not preclude the possibility of questions on one section that draw from subject matter emphasized in a different section. (For example, a question that touches on thermodynamics in the quantum mechanics section.) A student who passes any section of the written exam need not take that section again. Each section lasts three hours and covers traditional, textbook style problems, as well as more comprehensive questions that specifically test physical and numerical insight (e.g. order-of-magnitude estimates including physical constants, analyzing physical situations by application of general principles instead of complex calculations, etc.). *A student's individual performance on each section of the exam, and not ranking relative to other students, will determine whether that student has passed or failed the section. In other words, there is no predetermined percentage of students to pass/fail the exam.*

Students are encouraged, but not required, to attempt the examination during their first semester. Students are required to have attempted all of the written sections in their second semester. The status of students who have not yet passed all sections of the preliminary examination will be reviewed by a faculty committee each semester, beginning in the student's third semester, and recommendations of further action will be made. The Department Chair must approve exceptions to this schedule; all exceptions, except those due to illness or emergency, must be approved in advance.

The academic record of a student in their *third semester* who has not passed all four written sections will be reviewed. Near the beginning of the third semester (as prelim exam results become available) a faculty committee, in consultation with the student's faculty mentor, will review the student's academic record and performance on the prelims to determine whether a sufficient breadth of undergraduate physics has been demonstrated. This review may include meeting with the student to ask questions to further assess the student's understanding of undergraduate physics, focusing primarily although not exclusively on the not-yet-passed sections of the exam, to discuss the student's background and how best to address remaining deficiencies. If their determination is that the student has a sufficient breadth of undergraduate physics, the student will be determined to have passed the prelim exam, and will be allowed to proceed with research. If the committee's determination is that this understanding is not yet demonstrated, they will recommend that the student be sent a warning letter by the Department Chair, and will specify requirements (including a timeline) for the student to return to making sufficient academic progress. These requirements could include taking and passing with a B or better grade specific undergraduate courses during the third and/or fourth semester, and/or retaking and passing sections of the prelim exam not yet passed at the start of the fourth semester. This review could also result in additional recommendations to the student, such as serving as GSI for a course deemed appropriate to reinforce previous undergraduate coursework. *The intent of this third-semester review by the faculty committee is to determine if deficiencies exist in a student's knowledge of undergraduate physics, and if so, what actions are required of the student to address these deficiencies.*

A faculty committee will then review the student's efforts towards returning to good academic progress at the beginning of the *fourth semester*. This 4th semester review may also include meeting with the student to ask questions to assess the student's understanding of undergraduate physics. This faculty committee will review the student's entire academic record – including performance on the preliminary exam, coursework, and intended research plans – and recommend to the Department Chair whether the student is making sufficient academic progress and may be allowed to proceed with research. The Head Graduate Adviser or Department Chair will report the results to the Graduate Division. If requirements established in the 3rd semester review include undergraduate courses taken in the fourth semester, this 4th semester review can be deferred until the grades in these courses are determined, but in no case can this review be extended past the end of the student's 4th semester. This review is not intended to create additional requirements, but to determine if previous requirements have been met, and in particular should not require any further attempts at passing any section of the preliminary exam. *The intent of this fourth-semester review by the faculty committee is to determine whether a student has mastered sufficient undergraduate physics to start PhD level research by the end of the 2nd year. If the committee concludes that such mastery is not present, they will recommend to the Department Chair that the student be asked to leave the program due to inadequate progress towards the PhD.*

A revision in this schedule can be granted, for one or more sections of the preliminary exam, for any student with an incomplete undergraduate physics education as determined by consultation between the student and the student's faculty mentor. Both the Head Graduate Advisor and the Department Chair must approve this revised schedule. Any student exercising this option is expected to take one or more undergraduate physics courses at UC Berkeley during the first one or two semesters. This student should follow the regular schedule outlined above for any sections of the exam not affected by the revised schedule, and is allowed to attempt the delayed section(s) at the start of their first one or two semesters for practice, in which case the student would not be required to repeat any sections that have been passed during this period. The student would then be expected to take all sections of the exam not yet passed at the beginning of the 3rd semester, and to repeat any unpassed sections at the start of the 4th semester. A faculty committee will be asked to assess this student following this exam if there are still sections

not passed, following guidelines above, and can either determine that the student has demonstrated a sufficient breadth of undergraduate physics, and hence has passed the prelim exam, or to recommend that the student be sent a warning letter with specific requirements and a timeline for being returned to making sufficient academic progress; the most likely requirement and timeline for this is to be asked to study over the following summer and to attempt the still unpassed sections a final time at the start of the 5th semester. *The intent of this 4th and potentially 5th semester review by the faculty committee is that a student shall either be determined to have mastered sufficient undergraduate physics to start PhD level research by the start of their 3rd year, or else be asked to leave the program due to inadequate progress towards the PhD. Delays in this decision beyond the start of the 3rd year are highly discouraged and will only be considered under exceptional circumstances.*

## Qualifying Examination

Within 2-3 semesters of beginning research, the Department expects students to take the University's Oral Qualifying Examination covering his or her research field and related areas. This exam is required for advancement to PhD candidacy, and signifies that the student is prepared and qualified to undertake research, not that the student has already completed a significant body of work towards the PhD. It is therefore expected to occur for most students in the 3rd year, and no later than the 4th year. A student is considered to have begun research when they first register for Physics 299 or fill out the department advising form showing that a research advisor has accepted the student for PhD work, at which time the research advisor becomes responsible for guidance and mentoring of the student. The examination is administered by a four-member committee (consisting of three Physics Department and one outside faculty member, including the research advisor) approved by the Graduate Division on behalf of the Graduate Council, and may be repeated once at the recommendation of the examining committee. The Department expects that all committees include at least one theorist and one experimentalist. For students with advisors from outside the department or who are not members of the Academic Senate (e.g., with appointments at LBNL or SSL), permission for a five-member committee may be requested from Grad Division to allow both the non-faculty and faculty advisor to be on the committee; in this case, approval of the proposed research by the Head Graduate Advisor and the Chair of the Department must also be obtained before the student takes their qualifying exam.

Rules and requirements associated with the Qualifying Exam are set by the Graduate Division on behalf of the Graduate Council. The committee membership and the conduct of the exam are therefore subject to Graduate Division approval. The exam is oral and lasts 2-3 hours. The Graduate Division specifies that the purpose of the Qualifying Exam is "to ascertain the breadth of the student's comprehension of fundamental facts and principles that apply to at least three subjects areas related to the major field of study and whether the student has the ability to think incisively and critically about the theoretical and the practical aspects of these areas." Grad Division also states that this oral qualifying exam serves a significant additional function. "Not only teaching, but the formal interaction with one's students and colleagues at colloquia, annual meetings of professional societies and the like, often require the ability to synthesize rapidly, organize clearly, and argue cogently in an oral setting.... It is consequently necessary for the University to ensure that a proper examination is given incorporating [these skills]."

The Qualifying Exam requires that the student, in consultation with his or her advisor, identify three topics which in the Physics Department are expected to be a proposed Thesis Topic, an Area of Research, and a General Area of Research. The General Area of Research is taken to be the sub-field within physics (e.g. astrophysics, biophysics, particle physics, condensed matter physics); the Area of Research to be a still broad but more narrowly defined field within the sub-field (e.g. magnetism, or QCD). For fields where these choices are not obvious, the student should suggest appropriately broad topics contiguous to their Thesis Topic. The choice of topics is subject to the approval of the Physics Department Head Graduate Adviser, per Graduate Council Requirements. Qualifying Exams in the Physics Department begin with a presentation from the student that is expected to last approximately, but no more than, 45 minutes, during and after which questions related to the presentation are typically asked. The presentation should focus on the student's research goals and necessary background material, including the proposed Thesis Topic and the Area of Research that encompasses the thesis topic, as well as a proposed schedule for finishing the PhD and goals/milestones in that schedule. After this presentation, following a short break if desired, members of the committee will further question the student both about the presentation itself and about the broader subject areas included in the General Area of Research, testing the student's "ability to think incisively and critically about the theoretical and the practical aspects of these areas". The Department expects these questions to be related to the student's research field, but to be broad in nature rather than narrowly related to the thesis itself. Ability to give a coherent and organized presentation and to answer questions on the three topics in an oral setting is also required for passing this exam. Note that adjustments may be made on the basis of campus policies for cases in which an otherwise able individual is prevented from meeting an oral requirement by a physical disability.

## Physics

Expand all course descriptions [+]Collapse all course descriptions [-]

## PHYSICS C201 Introduction to Nano-Science and Engineering 3 Units

Terms offered: Spring 2015, Spring 2013, Spring 2012
A three-module introduction to the fundamental topics of Nano-Science and Engineering (NSE) theory and research within chemistry, physics, biology, and engineering. This course includes quantum and solid-state physics; chemical synthesis, growth fabrication, and characterization techniques; structures and properties of semiconductors, polymer, and biomedical materials on nanoscales; and devices based on nanostructures. Students must take this course to satisfy the NSE Designated Emphasis core requirement.
Introduction to Nano-Science and Engineering: Read More [+]

**Rules & Requirements**

**Prerequisites:** Major in physical science such as chemistry, physics, etc., or engineering; consent of advisor or instructor

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

**Instructors:** Gronsky, S.W. Lee, Wu

**Also listed as:** BIO ENG C280/MAT SCI C261/NSE C201

Introduction to Nano-Science and Engineering: Read Less [-]

## PHYSICS C202 Astrophysical Fluid Dynamics 4 Units

Terms offered: Spring 2023, Spring 2022, Spring 2021
Principles of gas dynamics, self-gravitating fluids, magnetohydrodynamics and elementary kinetic theory. Aspects of convection, fluid oscillations, linear instabilities, spiral density waves, shock waves, turbulence, accretion disks, stellar winds, and jets.
Astrophysical Fluid Dynamics: Read More [+]

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

**Instructors:** Chiang, Kasen, Ma, Quataert, White

**Also listed as:** ASTRON C202

Astrophysical Fluid Dynamics: Read Less [-]

## PHYSICS C203 Computational Nanoscience 3 Units

Terms offered: Spring 2009, Spring 2008, Spring 2006
A multidisciplinary overview of computational nanoscience for both theorists and experimentalists. This course teaches the main ideas behind different simulation methods; how to decompose a problem into "simulatable" constituents; how to simulate the same thing two different ways; knowing what you are doing and why thinking is still important; the importance of talking to experimentalists; what to do with your data and how to judge its validity; why multiscale modeling is both important and nonsense.
Computational Nanoscience: Read More [+]

**Rules & Requirements**

**Prerequisites:** Graduate standing or consent of instructor

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

**Also listed as:** NSE C242

Computational Nanoscience: Read Less [-]

## PHYSICS 205A Advanced Dynamics 4 Units

Terms offered: Spring 2022, Spring 2021, Spring 2019
Lagrange and Hamiltonian dynamics, variational methods, symmetry, kinematics and dynamics of rotation, canonical variables and transformations, perturbation theory, nonlinear dynamics, KAM theory, solitons and integrable pdes.
Advanced Dynamics: Read More [+]

**Rules & Requirements**

**Prerequisites:** 105 or equivalent

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Advanced Dynamics: Read Less [-]

## PHYSICS 205B Advanced Dynamics 4 Units

Terms offered: Spring 2023, Spring 2020, Spring 2018
Nonlinear dynamics of dissipative systems, attractors, perturbation theory, bifurcation theory, pattern formation. Emphasis on recent developments, including turbulence.
Advanced Dynamics: Read More [+]

**Rules & Requirements**

**Prerequisites:** 205A

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Advanced Dynamics: Read Less [-]

## PHYSICS C207 Radiation Processes in Astronomy 4 Units

Terms offered: Fall 2022, Fall 2021, Fall 2020
An introduction to the basic physics of astronomy and astrophysics at the graduate level. Principles of energy transfer by radiation. Elements of classical and quantum theory of photon emission; bremsstrahlung, cyclotron and synchrotron radiation. Compton scattering, atomic, molecular and nuclear electromagnetic transitions. Collisional excitation of atoms, molecules and nuclei.
Radiation Processes in Astronomy: Read More [+]

**Rules & Requirements**

**Prerequisites:** Physics 105, 110A; 110B concurrently; open to advanced undergraduates with GPA of 3.70

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

**Instructors:** Chiang, Kasen, Quataert

**Also listed as:** ASTRON C207

Radiation Processes in Astronomy: Read Less [-]

## PHYSICS 209 Classical Electromagnetism 5 Units

Terms offered: Fall 2022, Fall 2021, Fall 2020
Maxwell's equations, gauge transformations and tensors. Complete development of special relativity, with applications. Plane waves in material media, polarization, Fresnel equations, attenuation, and dispersion. Wave equation with sources, retarded solution for potentials, and fields. Cartesian and spherical multipole expansions, vector spherical harmonics, examples of radiating systems, diffraction, and optical theorem. Fields of charges in arbitrary motion, radiated power, relativistic (synchrotron) radiation, and radiation in collisions.
Classical Electromagnetism: Read More [+]

**Rules & Requirements**

**Prerequisites:** 110A-110B or consent of instructor

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Classical Electromagnetism: Read Less [-]

## PHYSICS 211 Equilibrium Statistical Physics 4 Units

Terms offered: Spring 2023, Spring 2022, Spring 2021
Foundations of statistical physics. Ensemble theory. Degenerate systems. Systems of interacting particles.
Equilibrium Statistical Physics: Read More [+]

**Rules & Requirements**

**Prerequisites:** 112 or equivalent

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Equilibrium Statistical Physics: Read Less [-]

## PHYSICS 212 Nonequilibrium Statistical Physics 4 Units

Terms offered: Fall 2022, Fall 2021, Fall 2020
Time dependent processes. Kinetic equations. Transport processes. Irreversibility. Theory of many-particle systems. Critical phenomena and renormalization group. Theory of phase transitions.
Nonequilibrium Statistical Physics: Read More [+]
**Rules & Requirements**

**Prerequisites:** 112 and 221A-221B, or equivalents

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Nonequilibrium Statistical Physics: Read Less [-]

## PHYSICS 216 Special Topics in Many-Body Physics 4 Units

Terms offered: Spring 2023, Spring 2022, Spring 2021
Quantum theory of many-particle systems. Applications of theory and technique to physical systems. Pairing phenomena, superfluidity, equation of state, critical phenomena, phase transitions, nuclear matter.
Special Topics in Many-Body Physics: Read More [+]
**Rules & Requirements**

**Prerequisites:** 221A-221B or equivalent recommended

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Special Topics in Many-Body Physics: Read Less [-]

## PHYSICS C218 Modern Optical Microscopy for the Modern Biologist 3 Units

Terms offered: Spring 2023, Spring 2022, Spring 2021
This course is intended for graduate students in the early stages of their thesis research who are contemplating using modern microscopy tools as part of their work. It endeavors to cut through the confusion of the wide array of new imaging methods, with a practical description of the pros and cons of each. In addition to providing an intuitive physical understanding how these microscopes work, the course will offer hands on experience with cutting-edge microscopes where students will be able to see firsthand how different imaging modalities perform on their own samples, and where they will be able to access computational tools for the visualization and analysis of their data.
Modern Optical Microscopy for the Modern Biologist: Read More [+]
**Rules & Requirements**

**Credit Restrictions:** Students will receive no credit for MCELLBI 205 after completing MCELLBI 205, or MCELLBI 205. A deficient grade in MCELLBI 205 may be removed by taking MCELLBI 205, or MCELLBI 205.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

**Instructors:** Betzig, Ji

**Formerly known as:** Molecular and Cell Biology 205

**Also listed as:** MCELLBI C205

Modern Optical Microscopy for the Modern Biologist: Read Less [-]

## PHYSICS 221A Quantum Mechanics 5 Units

Terms offered: Fall 2022, Fall 2021, Fall 2020
Basic assumptions of quantum mechanics; quantum theory of measurement; matrix mechanics; Schroedinger theory; symmetry and invariance principles; theory of angular momentum; stationary state problems; variational principles; time independent perturbation theory; time dependent perturbation theory; theory of scattering.
Quantum Mechanics: Read More [+]
**Rules & Requirements**

**Prerequisites:** 137A-137B or equivalent

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Quantum Mechanics: Read Less [-]

## PHYSICS 221B Quantum Mechanics 5 Units

Terms offered: Spring 2023, Spring 2022, Spring 2021
Many-body methods, radiation field quantization, relativistic quantum mechanics, applications.
Quantum Mechanics: Read More [+]

**Rules & Requirements**

**Prerequisites:** 221A

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Quantum Mechanics: Read Less [-]

## PHYSICS 226 Particle Physics Phenomenology 4 Units

Terms offered: Fall 2022, Fall 2021, Fall 2020
Introduction to particle physics phenomena. Emphasis is placed on experimental tests of particle physics models. Topics include Quark model spectroscopy; weak decays; overview of detectors and accelerators; e+e- annihilation; parton model; electron-proton and neutrino-proton scattering; special topics of current interest.
Particle Physics Phenomenology: Read More [+]

**Rules & Requirements**

**Prerequisites:** 221A-221B or equivalent or consent of instructor

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Particle Physics Phenomenology: Read Less [-]

## PHYSICS C228 Extragalactic Astronomy and Cosmology 3 Units

Terms offered: Fall 2022, Spring 2021, Fall 2016
A survey of physical cosmology - the study of the origin, evolution, and fate of the universe. Topics include the Friedmann-Robertson-Walker model, thermal history and big bang nucleosynthesis, evidence and nature of dark matter and dark energy, the formation and growth of galaxies and large scale structure, the anisotropy of the cosmic microwave radiation, inflation in the early universe, tests of cosmological models, and current research areas. The course complements the material of Astronomy 218.
Extragalactic Astronomy and Cosmology: Read More [+]

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

**Instructors:** Holzapfel, Lee, Ma, Seljak, White

**Also listed as:** ASTRON C228

Extragalactic Astronomy and Cosmology: Read Less [-]

## PHYSICS 229 Advanced Cosmology 3 Units

Terms offered: Spring 2023, Spring 2021, Spring 2019
Advanced topics in physical and early-universe cosmology. Topics include the expanding Universe, evidence and nature of dark matter and dark energy, relativistic perturbation theory, models of cosmological inflation, the formation and growth of large scale structure and the anisotropy of the cosmic microwave background, and current research areas. The course extends the material of C228.
Advanced Cosmology: Read More [+]

**Rules & Requirements**

**Prerequisites:** Physics/Astronomy C228 or equivalent or consent of instructor

**Hours & Format**

**Fall and/or spring:**
15 weeks - 3 hours of lecture per week
15 weeks - 3 hours of lecture per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Advanced Cosmology: Read Less [-]

## PHYSICS 230 Quantum and Nonlinear Optics 3 Units

Terms offered: Not yet offered
The detailed theory and experimental basis of quantum and nonlinear optics is presented and used to exhibit basic concepts of quantum measurements and noise, stochastic processes and dissipative quantum systems. Topics covered may include the second-quantization treatment of electromagnetic fields, photodetection, coherence properties of quantum-optical fields, light-atom interactions, cavity quantum electrodynamics, several non-linear optical systems, squeezed light and its applications, aspects of quantum information science, and selected topics at the forefront of modern optics research.
Quantum and Nonlinear Optics: Read More [+]
**Rules & Requirements**

**Prerequisites:** Physics 110A, Physics 137A, Physics 137B, or consent of instructor

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Quantum and Nonlinear Optics: Read Less [-]

## PHYSICS 231 General Relativity 4 Units

Terms offered: Spring 2023, Spring 2022, Spring 2021
An introduction to Einstein's theory of gravitation. Tensor analysis, general relativistic models for matter and electromagnetism, Einstein's field equations. Applications, for example, to the solar system, dense stars, black holes, and cosmology.
General Relativity: Read More [+]
**Rules & Requirements**

**Prerequisites:** Physics 110B or Physics 139 (or equivalent) or consent of instructor/department

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

General Relativity: Read Less [-]

## PHYSICS 232A Quantum Field Theory I 4 Units

Terms offered: Fall 2022, Fall 2021, Fall 2020
Introduction to quantum field theory: canonical quantization of scalar, electromagnetic, and Dirac fields; derivation of Feynman rules; regularization and renormalization; introduction to the renormalization group; elements of the path integral.
Quantum Field Theory I: Read More [+]
**Rules & Requirements**

**Prerequisites:** Concurrent enrollment in 221A or 221B or consent of instructor

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Quantum Field Theory I: Read Less [-]

## PHYSICS 232B Quantum Field Theory II 4 Units

Terms offered: Spring 2023, Spring 2022, Spring 2021
Renormalization of Yang-Mills gauge theories: BRST quantization of gauge theories; nonperturbative dynamics; renormalization group; basics of effective field theory; large N; solitons; instantons; dualities. Selected current topics.
Quantum Field Theory II: Read More [+]
**Rules & Requirements**

**Prerequisites:** 232A or equivalent or consent of instructor

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Quantum Field Theory II: Read Less [-]

## PHYSICS 233A Standard Model and Beyond I 4 Units

Terms offered: Spring 2023, Spring 2022, Spring 2021
Introduction to the Standard Model of particle physics and its applications: construction of the Standard Model; Higgs mechanism; phenomenology of weak interactions; QCD and the chiral Lagrangian; quark mixing and flavor physics.
Standard Model and Beyond I: Read More [+]
**Rules & Requirements**

**Prerequisites:** 232A or equivalent or consent of instructor (concurrent enrollment in 232B is recommended)

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Standard Model and Beyond I: Read Less [-]

## PHYSICS 233B Standard Model and Beyond II 4 Units

Terms offered: Fall 2021, Fall 2020, Fall 2019
Advanced topics in the Standard Model and beyond, selected from: open problems in the Standard Model; supersymmetric models; grand unification; neutrino physics; flat and warped extra dimensions; axions; inflation; baryogenesis; dark matter; the multiverse; other current topics.
Standard Model and Beyond II: Read More [+]
**Rules & Requirements**

**Prerequisites:** 233A or equivalent or consent of instructor

**Repeat rules:** Course may be repeated for credit with instructor consent.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Standard Model and Beyond II: Read Less [-]

## PHYSICS 234A String Theory I 4 Units

Terms offered: Fall 2021, Fall 2020, Fall 2019
Perturbative theory of the bosonic strings, superstrings, and heterotic strings: NSR and GS formulations; 2d CFT; strings in background fields; T-duality; effective spacetime supergravity; perturbative description of D-branes; elements of compactifications and string phenomemology; perturbative mirror symmetry.
String Theory I: Read More [+]
**Rules & Requirements**

**Prerequisites:** 232A or equivalent or consent of instructor. 232B is recommended

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

String Theory I: Read Less [-]

## PHYSICS 234B String Theory II 4 Units

Terms offered: Spring 2023, Spring 2021, Spring 2020
Nonperturbative apsects of string theory. Topics selected from black holes; black branes; Bekenstein-Hawking entropy; D-branes; string dualities; M-theory; holographic principle and its realizations; AdS/CFT correspondence; gauge theory/gravity dualities; flux compactifications; cosmology in string theory; topological string theories. Selected current topics.
String Theory II: Read More [+]
**Rules & Requirements**

**Prerequisites:** 234A or equivalent or consent of instructor

**Repeat rules:** Course may be repeated for credit with instructor consent.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

String Theory II: Read Less [-]

## PHYSICS 238 Advanced Atomic, Molecular, and Optical Physics 4 Units

Terms offered: Fall 2021, Fall 2020, Fall 2019
Contemporary topics in atomic, molecular, and optical physics are presented at an advanced level. These topics may include one or several of the following, at the discretion of the instructor: mechanical effects of light-atom interactions, ultra-cold atomic physics, molecular physics, resonance optics of multi-level atoms, and probing particle physics with atoms and molecules.
Advanced Atomic, Molecular, and Optical Physics: Read More [+]
**Rules & Requirements**

**Prerequisites:** 110A, 130, 137A-137B, and 138; or consent of instructor

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Advanced Atomic, Molecular, and Optical Physics: Read Less [-]

## PHYSICS 238A Modern Atomic Physics 3 Units

Terms offered: Spring 2023
Atomic, molecular, and optical physics is at once a precise and quantitative description of atoms, molecules and light; a generalized toolbox for manipulating and probing quantum systems; and an active field of contemporary research. This course exposes students to all these aspects. Lectures will cover topics such as atomic structure and spectra, the interaction of atoms with static and time-varying electromagnetic fields, some topics in quantum electrodynamics, methods of resonant manipulation of quantum systems, and resonance optics. Through lectures, discussion sessions, and homework assignments, students encounter contemporary research foci.
Modern Atomic Physics: Read More [+]
**Rules & Requirements**

**Prerequisites:** Physics 110A, Physics 137A, Physics 137B, or consent of instructor

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Modern Atomic Physics: Read Less [-]

## PHYSICS 238B Advanced Atomic, Molecular, and Optical Physics 4 Units

Terms offered: Not yet offered
Contemporary topics in atomic, molecular, and optical physics are presented at an advanced level. These topics may include one or several of the following, at the discretion of the instructor: mechanical effects of light-atom interactions, ultra-cold atomic physics, molecular physics, resonance optics of multi-level atoms, and probing particle physics with atoms and molecules.
Advanced Atomic, Molecular, and Optical Physics: Read More [+]
**Rules & Requirements**

**Prerequisites:** Physics 110A; Physics 137A; Physics 137B; Physics 130 or 230; Physics 138 or 238A

**Credit Restrictions:** Students will receive no credit for PHYSICS 238B after completing PHYSICS 238. A deficient grade in PHYSICS 238B may be removed by taking PHYSICS 238.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Advanced Atomic, Molecular, and Optical Physics: Read Less [-]

## PHYSICS 240A Quantum Theory of Solids 4 Units

Terms offered: Fall 2022, Fall 2021, Fall 2020
Excitations and interactions in solids; crystal structures, symmetries, Bloch's theorem; energy bands; electron dynamics; impurity states; lattice dynamics, phonons; many-electron interactions; density functional theory; dielectric functions, conductivity and optical properties.
Quantum Theory of Solids: Read More [+]
**Rules & Requirements**

**Prerequisites:** 141A-141B and 221A-221B or equivalents, or consent of instructor; 240A is prerequisite to 240B

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Quantum Theory of Solids: Read Less [-]

## PHYSICS 240B Quantum Theory of Solids 4 Units

Terms offered: Spring 2023, Spring 2022, Spring 2021
Optical properties, excitons; electron-phonon interactions, polarons; quantum oscillations, Fermi surfaces; magnetoresistance; quantum Hall effect; transport processes, Boltzmann equation; superconductivity, BCS theory; many-body perturbation theory, Green's functions.
Quantum Theory of Solids: Read More [+]
**Rules & Requirements**

**Prerequisites:** 141A-141B and 221A-221B or equivalents, or consent of instructor; 240A is prerequisite to 240B

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Quantum Theory of Solids: Read Less [-]

## PHYSICS 242A Theoretical Plasma Physics 4 Units

Terms offered: Fall 2021, Fall 2019, Fall 2017
Analysis of plasma behavior according to the Vlasov, Fokker-Planck equations, guiding center and hydromagnetic descriptions. Study of equilibria, stability, linear and nonlinear waves, transport, and laser-plasma interactions.
Theoretical Plasma Physics: Read More [+]
**Rules & Requirements**

**Prerequisites:** Physics 142, or consent of instructor

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Theoretical Plasma Physics: Read Less [-]

## PHYSICS 242B Theoretical Plasma Physics 4 Units

Terms offered: Spring 2020, Spring 2016, Spring 2012
Analysis of plasma behavior according to the Vlasov, Fokker-Planck equations, guiding center and hydromagnetic descriptions. Study of equilibria, stability, linear and nonlinear waves, transport, and laser-plasma interactions.
Theoretical Plasma Physics: Read More [+]
**Rules & Requirements**

**Prerequisites:** Physics 142, or consent of instructor

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Theoretical Plasma Physics: Read Less [-]

## PHYSICS 250 Special Topics in Physics 2 - 4 Units

Terms offered: Fall 2021, Fall 2019, Spring 2019
Topics will vary from semester to semester. See Department of Physics announcements.
Special Topics in Physics: Read More [+]
**Rules & Requirements**

**Prerequisites:** Consent of instructor

**Repeat rules:** Course may be repeated for credit with instructor consent.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2-4 hours of lecture per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Special Topics in Physics: Read Less [-]

## PHYSICS 251 Introduction to Graduate Research in Physics 1 Unit

Terms offered: Fall 2022, Fall 2021, Fall 2020
A survey of experimental and theoretical research in the Department of Physics, designed for first-year graduate students. One regular meeting each week with supplementary visits to experimental laboratories. Meetings include discussions with research staff.
Introduction to Graduate Research in Physics: Read More [+]
**Rules & Requirements**

**Prerequisites:** Graduate standing in Department of Physics or consent of instructor

**Hours & Format**

**Fall and/or spring:** 15 weeks - 1 hour of lecture per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Introduction to Graduate Research in Physics: Read Less [-]

## PHYSICS C254 High Energy Astrophysics 3 Units

Terms offered: Spring 2023, Spring 2022, Fall 2018, Spring 2017
Basic physics of high energy radiation processes in an astrophysics environment. Cosmic ray production and propagation. Applications selected from pulsars, x-ray sources, supernovae, interstellar medium, extragalactic radio sources, quasars, and big-bang cosmologies.
High Energy Astrophysics: Read More [+]
**Rules & Requirements**

**Prerequisites:** 201 or consent of instructor. 202 recommended

**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

**Instructors:** Boggs, Quataert

**Formerly known as:** Physics C254, Astronomy C254

**Also listed as:** ASTRON C254

High Energy Astrophysics: Read Less [-]

## PHYSICS C285 Theoretical Astrophysics Seminar 1 Unit

Terms offered: Spring 2023, Fall 2022, Spring 2022, Fall 2019, Spring 2019
The study of theoretical astrophysics.
Theoretical Astrophysics Seminar: Read More [+]
**Hours & Format**

**Fall and/or spring:** 15 weeks - 1 hour of lecture per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

**Instructor:** Quataert

**Also listed as:** ASTRON C285

Theoretical Astrophysics Seminar: Read Less [-]

## PHYSICS 288 Bayesian Data Analysis and Machine Learning for Physical Sciences 4 Units

Terms offered: Fall 2022, Fall 2021, Fall 2020
The course design covers data analysis and machine learning, highlighting their importance to the physical sciences. It covers data analysis with linear and nonlinear regression, logistic regression, and gaussian processes. It covers concepts in machine learning such as unsupervised and supervised regression and classification learning. It develops Bayesian statistics and information theory, covering concepts such as information, entropy, posteriors, MCMC, latent variables, graphical models and hierarchical Bayesian modeling. It covers numerical analysis topics such as integration and ODE, linear algebra, multi-dimensional optimization, and Fourier transforms.
Bayesian Data Analysis and Machine Learning for Physical Sciences: Read More [+]
**Hours & Format**

**Fall and/or spring:** 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Letter grade.

Bayesian Data Analysis and Machine Learning for Physical Sciences: Read Less [-]

## PHYSICS 290A Seminar 2 Units

Terms offered: Spring 2023, Fall 2022, Spring 2022
Seminar: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar: Read Less [-]

## PHYSICS 290B Seminar 2 Units

Terms offered: Spring 2023, Fall 2022, Spring 2022
Seminar: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar: Read Less [-]

## PHYSICS 290D Seminar 2 Units

Terms offered: Fall 2005, Fall 2004, Fall 2003
Seminar: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar: Read Less [-]

## PHYSICS 290E Seminar 2 Units

Terms offered: Spring 2023, Fall 2022, Spring 2022
Seminar: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar: Read Less [-]

## PHYSICS 290F Seminar 2 Units

Terms offered: Spring 2023, Fall 2022, Spring 2022
Seminar: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar: Read Less [-]

## PHYSICS 290G Seminar 2 Units

Terms offered: Fall 2006, Spring 2006, Fall 2005
Seminar: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar: Read Less [-]

## PHYSICS 290H Seminar 2 Units

Terms offered: Spring 2017, Spring 2016, Spring 2015
Seminar: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar: Read Less [-]

## PHYSICS 290I Seminar 2 Units

Terms offered: Spring 2014, Spring 1999, Spring 1998
Seminar: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar: Read Less [-]

## PHYSICS 290J Seminar 2 Units

Terms offered: Prior to 2007
Seminar: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar: Read Less [-]

## PHYSICS 290K Seminar 2 Units

Terms offered: Spring 2023, Fall 2022, Spring 2022
Seminar: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar: Read Less [-]

## PHYSICS 290L Seminar 2 Units

Terms offered: Fall 2012, Fall 2000
Seminar: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar: Read Less [-]

## PHYSICS 290N Seminar in Non-Neutral Plasmas 2 Units

Terms offered: Spring 2007, Fall 2006, Spring 2006
Seminar in Non-Neutral Plasmas: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar in Non-Neutral Plasmas: Read Less [-]

## PHYSICS 290P Seminar 2 Units

Terms offered: Spring 2023, Fall 2022, Spring 2022
Seminar: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar: Read Less [-]

## PHYSICS 290Q Seminar in Quantum Optics 2 Units

Terms offered: Prior to 2007
Seminar in Quantum Optics: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar in Quantum Optics: Read Less [-]

## PHYSICS 290R Seminar 2 Units

Terms offered: Prior to 2007
Seminar: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar: Read Less [-]

## PHYSICS 290S Seminar 2 Units

Terms offered: Spring 2023, Fall 2022, Spring 2022
Seminar: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar: Read Less [-]

## PHYSICS 290T Seminar 2 Units

Terms offered: Spring 2000, Fall 1999, Spring 1999
Seminar: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar: Read Less [-]

## PHYSICS 290X Seminar 2 Units

Terms offered: Fall 2006, Spring 2006, Fall 2005
Seminar: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar: Read Less [-]

## PHYSICS 290Y Seminar 2 Units

Terms offered: Fall 2006, Spring 2006, Fall 2005
Seminar: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar: Read Less [-]

## PHYSICS 290Z Seminar 2 Units

Terms offered: Spring 2023, Fall 2022, Spring 2022
Seminar: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Seminar: Read Less [-]

## PHYSICS C290C Cosmology 2 Units

Terms offered: Spring 2023, Fall 2022, Spring 2022, Fall 2021
Cosmology: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

**Instructors:** White, Cohn

**Formerly known as:** Physics C290C, Astronomy C290C

**Also listed as:** ASTRON C290C

Cosmology: Read Less [-]

## PHYSICS 295 Special Study for Graduate Students 1 - 4 Units

Terms offered: Fall 2021, Fall 2015, Fall 2014
This course is arranged to allow qualified graduate students to investigate possible research fields or to pursue problems of interest through reading or non-laboratory study under the direction of faculty members who agree to give such supervision.
Special Study for Graduate Students: Read More [+]
**Rules & Requirements**

**Prerequisites:** Graduate standing

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 1-4 hours of independent study per week

**Summer:**
6 weeks - 1-4 hours of independent study per week
8 weeks - 1-4 hours of independent study per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Special Study for Graduate Students: Read Less [-]

## PHYSICS 297 Careers for Physical Science PhDs 1 Unit

Terms offered: Spring 2018
This course exposes graduate students and postdocs in the physical sciences to non-academic careers. Each session hosts speakers who have transitioned from a PhD in the physical sciences to a variety of industries, including data science, quantitative finance, software/hardware engineering, consulting, and more.
Careers for Physical Science PhDs: Read More [+]
**Rules & Requirements**

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 1 hour of seminar per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Careers for Physical Science PhDs: Read Less [-]

## PHYSICS 299 Research 1 - 12 Units

Terms offered: Spring 2023, Fall 2022, Spring 2022
Research: Read More [+]
**Rules & Requirements**

**Prerequisites:** Graduate standing

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 0 hours of independent study per week

**Summer:**
6 weeks - 1-12 hours of independent study per week
8 weeks - 1-12 hours of independent study per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Research: Read Less [-]

## PHYSICS 301 Advanced Professional Preparation: Supervised Teaching of Physics 1 - 2 Units

Terms offered: Spring 2023, Fall 2022, Spring 2022
Discussion, problem review and development, guidance of physics laboratory experiments, course development.
Advanced Professional Preparation: Supervised Teaching of Physics: Read More [+]
**Rules & Requirements**

**Prerequisites:** 300

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 1 hour of independent study per week

**Additional Details**

**Subject/Course Level:** Physics/Professional course for teachers or prospective teachers

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Advanced Professional Preparation: Supervised Teaching of Physics: Read Less [-]

## PHYSICS 375 Professional Preparation: Supervised Teaching of Physics 2 Units

Terms offered: Fall 2021, Fall 2020, Fall 2019
Mandatory for first time GSIs. Topics include teaching theory, effective teaching methods, educational objectives, alternatives to standard classroom methods, reciprocal classroom visitations, and guided group and self-analysis of videotapes.
Professional Preparation: Supervised Teaching of Physics: Read More [+]
**Rules & Requirements**

**Prerequisites:** Graduate standing or consent of instructor; may be taken concurrently with 301

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of lecture per week

**Additional Details**

**Subject/Course Level:** Physics/Professional course for teachers or prospective teachers

**Grading:** Offered for satisfactory/unsatisfactory grade only.

**Formerly known as:** Physics 300

Professional Preparation: Supervised Teaching of Physics: Read Less [-]

## PHYSICS 602 Individual Study for Doctoral Students 1 - 8 Units

Terms offered: Spring 2016, Fall 2015, Spring 2015
Individual study in consultation with the major field adviser intended to provide an opportunity for qualified students to prepare themselves for the various examinations required of candidates for the Ph.D.
Individual Study for Doctoral Students: Read More [+]
**Rules & Requirements**

**Prerequisites:** For qualified graduate students

**Credit Restrictions:** Course does not satisfy unit or residence requirements for doctoral degree.

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

**Fall and/or spring:** 15 weeks - 1-8 hours of independent study per week

**Summer:**
6 weeks - 1-8 hours of independent study per week
8 weeks - 1-8 hours of independent study per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate examination preparation

**Grading:** Offered for satisfactory/unsatisfactory grade only.

Individual Study for Doctoral Students: Read Less [-]

## PHYSICS 700 Departmental Colloquium 0.0 Units

Terms offered: Spring 2017, Fall 2016
Physics Department weekly colloquium.
Departmental Colloquium: Read More [+]
**Hours & Format**

**Fall and/or spring:** 15 weeks - 2 hours of colloquium per week

**Additional Details**

**Subject/Course Level:** Physics/Graduate examination preparation

**Grading:** The grading option will be decided by the instructor when the class is offered.

**Formerly known as:** Physics 800

Departmental Colloquium: Read Less [-]