APPLIED PHYSICS

Courses offered by the Department of Applied Physics are listed under the subject code APPPHYS on the Stanford Bulletin’s ExploreCourses web site.

The Department of Applied Physics offers qualified students with backgrounds in physics or engineering the opportunity to do graduate course work and research in the physics relevant to technical applications and natural phenomena. These areas include accelerator physics, biophysics, condensed matter physics, nanostructured materials, quantum electronics and photonics, quantum optics and quantum information, space science and astrophysics, synchrotron radiation and applications.

Student research is supervised by the faculty members and also by various members of other departments such as Biology, Chemistry, Electrical Engineering, Materials Science and Engineering, Physics, the SLAC National Accelerator Laboratory, and faculty of the Medical School who are engaged in related research fields.

Research activities are carried out in laboratories including the Geballe Laboratory for Advanced Materials (GLAM), the Edward L. Ginzton Laboratory (GINZTON), the Hansen Experimental Physics Laboratory (HEPL), the SLAC National Accelerator Laboratory, the Center for Probing the Nanoscale, and the Stanford Institute for Materials and Energy Science (SIMES).

The number of graduate students admitted to Applied Physics is limited. Applications to the Master of Science and Ph.D. programs should be received by December 11, 2019. M.S. and Ph.D. students normally enter the department the following Autumn Quarter. The general and subject GREs are required for both the Ph.D. and master’s programs. Written requests for a waiver due to extraordinary circumstances are entertained.

Graduate Programs in Applied Physics

The Department of Applied Physics offers three types of advanced degrees:

- the Doctor of Philosophy
- the coterminal Master of Science in Applied and Engineering Physics
- the Master of Science in Applied Physics, either as a terminal degree or an en route degree to the Ph.D. for students already enrolled in the Applied Physics Ph.D. program.

Admission requirements for graduate work in the Master of Science and Ph.D. programs in Applied Physics include a bachelor’s degree in Physics or an equivalent engineering degree. Students entering the program from an engineering curriculum should expect to spend at least an additional quarter of study acquiring the background to meet the requirements for the M.S. and Ph.D. degrees in Applied Physics.

Learning Outcomes (Graduate)

The purpose of the master’s program is to further develop knowledge and skills in Applied Physics and to prepare students for a professional career or doctoral studies. This is achieved through completion of courses, in the primary field as well as related areas, and experience with independent work and specialization.

The Ph.D. is conferred upon candidates who have demonstrated substantial scholarship and the ability to conduct independent research and analysis in Applied Physics. Through completion of advanced course work and rigorous skills training, the doctoral program prepares students to make original contributions to the knowledge of Applied Physics and to interpret and present the results of such research.

Coterminal Master of Science in Applied and Engineering Physics

Stanford undergraduates, regardless of undergraduate major, who are interested in a M.S. degree at the intersection of applied physics and engineering may choose to apply for the coterminal Master of Science program in Applied and Engineering Physics. The program is designed to be completed in the fifth year at Stanford. Students with accelerated undergraduate programs may be able to complete their B.S. and coterminal M.S. in four years.

Application and Admission

Undergraduates must be admitted to the program and enrolled as a graduate student for at least one quarter prior to B.S. conferral. Applications are due on the last day of class of the Spring Quarter (June 5, 2019) for Autumn 2019 matriculation and at least four weeks before the last day of class in the previous quarter for Winter or Spring matriculation (November 6, 2019 for Winter matriculation, February 13, 2020 for Spring matriculation, and June 3, 2020 for Autumn 2020 matriculation). All application materials must be submitted directly to the Applied Physics department office by the deadlines. To apply for admission to the Applied and Engineering Physics coterminal M.S. program, students must submit the coterminal application which consists of the following:

- Application for Admission to Coterminal Master’s Program (https://registrar.stanford.edu/students/coterm-degree-programs/applying-coterm)
- Statement of Purpose
- Unofficial Transcript
- Two Letters of Recommendation from members of the Stanford faculty
- Supplemental Form (http://www.stanford.edu/dept/app-physics/cgi-bin/aep-application-process)

University Coterminal Requirements

Coterminal master’s degree candidates are expected to complete all master’s degree requirements as described in this bulletin. University requirements for the coterminal master’s degree are described in the “Coterminal Master’s Program (http://exploredegrees.stanford.edu/cotermdegrees)” section. University requirements for the master’s degree are described in the “Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees/#masterstext)” section of this bulletin.

After accepting admission to this coterminal master’s degree program, students may request transfer of courses from the undergraduate to the graduate career to satisfy requirements for the master’s degree. Transfer of courses to the graduate career requires review and approval of both the undergraduate and graduate programs on a case by case basis.

In this master’s program, courses taken three quarters prior to the first graduate quarter, or later, are eligible for consideration for transfer to the graduate career. No courses taken prior to the first quarter of the sophomore year may be used to meet master’s degree requirements.

Course transfers are not possible after the bachelor’s degree has been conferred.

The University requires that the graduate adviser be assigned in the student’s first graduate quarter even though the undergraduate career may still be open. The University also requires that the Master’s Degree Program Proposal be completed by the student and approved by the department by the end of the student’s first graduate quarter.
Program Requirements

Coterminal M.S. students are required to take 45 units of course work during their graduate career. Of these 45 units, the following are required.

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<thead>
<tr>
<th>Units</th>
<th>Courses</th>
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<tbody>
<tr>
<td>4</td>
<td>APPPHYS 201 Electrons and Photons</td>
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<tr>
<td>4</td>
<td>APPPHYS 203 Atoms, Fields and Photons</td>
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<tr>
<td>4</td>
<td>APPPHYS 204 Quantum Materials</td>
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<tr>
<td>4</td>
<td>APPPHYS 205 Introduction to Biophysics</td>
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</tbody>
</table>

Three Engineering Depth Courses

At least one must be at the 300 level and the other courses must be at the 200 level or above to provide depth in one area. To be approved by the Applied Physics academic adviser.

One Laboratory or Methods Course

3-4

APPPHYS 207 Laboratory Electronics
APPPHYS 208 Laboratory Electronics
APPPHYS 215 Numerical Methods for Physicists and Engineers
APPPHYS 217 Estimation and Control Methods for Applied Physics (offered 2019-20)
APPPHYS 232 Advanced Imaging Lab in Biophysics
EE 234 Photonics Laboratory
EE 251 High-Frequency Circuit Design Laboratory
EE 312 Integrated Circuit Fabrication Laboratory
ENGR 341 Micro/Nano Systems Design and Fabrication
ENGR 342 MEMS Laboratory II
MATSCI 322 Transmission Electron Microscopy Laboratory
MATSCI 331 Atom-based computational methods for materials

Seminar

3

Approved Technical Electives

6-12

6 units minimum that brings up the total units to 45

Total Units

45

The seminar requirement can be fulfilled by either (i) taking one formal seminar course for credit each term, and/or (ii) enrolling in Applied Physics 290 and attending a minimum of 8 informal talks or formal research seminars during each of the three terms. Students enrolling in Applied Physics 290 must submit with their final M.S. program proposal a list of the 8 talks/seminars with a paragraph describing the content, signed by their academic adviser.

Approved Technical Electives

These include APPPHYS, CS, CME, EE, ME, BIOE, MATSCI, PHYSICS courses (see http://www.stanford.edu/dept/app-physics/cgi-bin/academic-programs/) as well as those courses that are formally approved by the Applied Physics Graduate Studies Committee through petition.

Any request for a course transfer from the undergraduate career is subject to approval of the undergraduate and graduate departments.

Master of Science in Applied Physics

The University’s basic requirements for the master’s degree are discussed in the “Graduate Degrees” section of this bulletin. The minimum requirements for the degree are 45 units, of which at least 39 units must be graduate-level courses in applied physics, engineering, mathematics, and physics. The required program consists of the following:

Advanced Mechanics

Select one of the following:

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<th>Units</th>
<th>Courses</th>
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<tbody>
<tr>
<td>3</td>
<td>PHYSICS 210 Advanced Mechanics</td>
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<tr>
<td></td>
<td>PHYSICS 211 Continuum Mechanics (approved substitute)</td>
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</table>

Electrodynamics

3

PHYSICS 220 Classical Electrodynamics

Quantum Mechanics

Select two of the following:

<table>
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<th>Units</th>
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<tr>
<td>6</td>
<td>PHYSICS 230 Graduate Quantum Mechanics I</td>
</tr>
<tr>
<td></td>
<td>PHYSICS 231 Graduate Quantum Mechanics II</td>
</tr>
<tr>
<td></td>
<td>EE 222 Applied Quantum Mechanics I (approved substitute)</td>
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<td></td>
<td>EE 223 Applied Quantum Mechanics II (approved substitute)</td>
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<tr>
<td></td>
<td>PHYSICS 234 Advanced Topics in Quantum Mechanics (approved substitute)</td>
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<td></td>
<td>PHYSICS 330 Quantum Field Theory I (approved substitute)</td>
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<tr>
<td></td>
<td>PHYSICS 331 Quantum Field Theory II (approved substitute)</td>
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<tr>
<td></td>
<td>PHYSICS 332 Quantum Field Theory III (approved substitute)</td>
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</tbody>
</table>

APPPHYS 290 Directed Studies in Applied Physics

1-unit seminar courses

Examples of suitable courses include:

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<th>Courses</th>
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<tr>
<td>EE 222 Applied Quantum Mechanics I</td>
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<tr>
<td>EE 223 Applied Quantum Mechanics II</td>
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<tr>
<td>EE 236A Modern Optics</td>
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<td>EE 236C Lasers</td>
</tr>
<tr>
<td>EE 332 Laser Dynamics</td>
</tr>
<tr>
<td>EE 346 Introduction to Nonlinear Optics</td>
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<tr>
<td>PHYSICS 372 Condensed Matter Theory I</td>
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<tr>
<td>PHYSICS 373 Condensed Matter Theory II</td>
</tr>
</tbody>
</table>

1. Courses in Physics and Mathematics to overcome deficiencies, if any, in undergraduate preparation.

2. Basic graduate courses (letter grade required):

   • 33 units of additional advanced courses in science and/or engineering. May be any combination of APPPHYS 290 Directed Studies in Applied Physics, any 1-unit course, and regular courses. At least 18 of these 33 units must be taken for a letter grade. 15 of these 18 units must be at the 200-level or above. Only 6 units below the 200-level are permitted without approval by the Applied Physics Graduate Study Committee.

3. A final overall grade point average (GPA) of 3.0 (B) is required for courses used to fulfill degree requirements.

There are no department nor University examinations. There is no thesis component. If a student is admitted to the M.S. program only, but later wishes to change to the Ph.D. program, the student must apply to the department’s admissions committee.

Doctor of Philosophy in Applied Physics

The University’s basic requirements for the Ph.D. including residency, dissertation, and examinations are discussed in the “Graduate Degrees
Course work, research, qualifying for Ph.D. candidacy, a research progress report, a University oral examination, and a dissertation as follows:

1. **Course Work:**

   **Statistical Physics**
   - Select one of the following: ¹
     - APPPHYS 217 Estimation and Control Methods for Applied Physics (offered 2019-20)
     - APPPHY 315 Methods in Computational Biology
     - PHYSICS 212 Statistical Mechanics
   
   **Electrodynamics**¹
   - Select one of the following:
     - APPPHYS 201 Electrons and Photons
     - PHYSICS 220 Classical Electrodynamics
   
   **Quantum Mechanics**
   - Select one of the following: ¹
     - APPPHY 204 Quantum Materials
     - PHYSICS 230 Graduate Quantum Mechanics I
     - PHYSICS 231 Graduate Quantum Mechanics II
   
   **Laboratory**
   - Select one of the following: ²
     - APPPHY 207 Laboratory Electronics
     - APPPHY 208 Laboratory Electronics
     - APPPHY 232 Advanced Imaging Lab in Biophysics
     - BIOE 370 Microfluidic Device Laboratory
     - EE 234 Photonics Laboratory
     - EE 312 Integrated Circuit Fabrication Laboratory
     - MATSCI 171 Energy Materials Laboratory
     - MATSCI 172 X-Ray Diffraction Laboratory
     - MATSCI 173 Mechanical Behavior Laboratory
     - PHYSICS 301 Astrophysics Laboratory
   
1. Additional courses to fulfill this requirement are being reviewed by the department curriculum committee and will be added here when they have been approved.

2. Students who took APPPHY 304 or APPPHY 305 in previous years may also count these courses towards this requirement.

a. Courses in Physics and Mathematics to overcome deficiencies, if any, in undergraduate preparation.

b. **Basic graduate courses:** These requirements may be totally or partly satisfied with equivalent courses taken elsewhere, pending the approval of the graduate study committee. Letter grades required for all courses:

c. 18 units of additional advanced courses in science and/or engineering. At least one course in each of two areas other that those of the student’s research specialization is required. Only 3 units at the 300 or above level may be taken on a satisfactory/no credit basis. Units from APPPHY 290, APPPHY 390, and any 1-unit courses do not count towards this requirement. Examples of suitable courses include:

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<td>EE 236A</td>
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<td>EE 332</td>
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<td>EE 346</td>
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<tr>
<td>PHYSICS 372</td>
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<td>PHYSICS 373</td>
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</tbody>
</table>

d. Additional units of courses as needed to meet the minimum residency requirement of 135. Directed study and research units as well as 1-unit seminar courses can be included.

e. A final average overall grade point average (GPA) of 3.0 (B) is required for courses used to fulfill degree requirements.

f. Students are normally expected to complete the specified course requirements by the end of their third year of graduate study.

2. **Research:** may be conducted in a science/engineering field under the supervision of a member of the Applied Physics faculty or appropriate faculty from other departments. If the primary adviser is from a department other than Applied Physics, the student must appoint a co-adviser from the Applied Physics department.

3. **Ph.D. Candidacy:** satisfactory progress in academic and research work, together with passing the Ph.D. candidacy qualifying examination, qualifies the student to apply for Ph.D. candidacy, and must be completed before the third year of graduate registration. The examination consists of a seminar on a suitable subject delivered by the student before a committee consisting of the chair (who is from the graduate studies committee), a faculty member from outside the department chosen by the student, and the third member is from the AP faculty (courtesy appointment is okay).

4. **Research Progress Report:** normally before the end of the Winter Quarter of the fourth year of enrollment in graduate study at Stanford, the student arranges to give an oral research progress report, which could be last up to two hours.

5. **University Ph.D. Oral Examination:** consists of a public seminar in defense of the dissertation, followed by private questioning of the candidate by the University examining committee.

6. **Dissertation:** must be approved and signed by the Ph.D. reading committee.

**Graduate Advising Expectations**

The Department of Applied Physics is committed to providing academic advising in support of graduate student scholarly and professional development. When most effective, this advising relationship entails collaborative and sustained engagement by both the adviser and the advisee. As a best practice, advising expectations should be periodically discussed and reviewed to ensure mutual understanding. Both the adviser and the advisee are expected to maintain professionalism and integrity.

In addition, the Faculty Candidacy Chair, Professor Daniel Fisher, is available for consultation during the academic year by email and during office hours. The Applied Physics student services office is also an important part of the advising team. Staff in the office inform students and advisers about University and department requirements.
procedures, and opportunities, and maintain the official records of advising assignments and approvals.

Faculty advisers guide students in key areas such as selecting courses, designing and conducting research, developing of teaching pedagogy, navigating policies and degree requirements, and exploring academic opportunities and professional pathways.

Graduate students are active contributors to the advising relationship, proactively seeking academic and professional guidance and taking responsibility for informing themselves of policies and degree requirements for their graduate program.

For a statement of University policy on graduate advising, see the "Graduate Advising (http://exploredegrees.stanford.edu/graduatedegrees/#advisingandcredentialstext)" section of this bulletin.

**Master of Science Advising**

At the start of graduate study, each student is assigned a master's program adviser: a member of our faculty who provides guidance in course selection, course planning, and in exploring short and long term academic opportunities and professional pathways. The program adviser serves as the first resource for consultation and advice about a student's academic program. Usually, the same faculty member serves as program adviser for the duration of master's study. In rare instances, a formal adviser change request may be considered. See the Applied Physics student services office for additional information on this process.

**Ph.D. Advising**

Academic advisers are assigned to incoming first year students by the graduate study committee based on their interest of studies. Faculty academic advisers guide students in key areas such as selecting courses, designing and conducting research, developing of teaching pedagogy, navigating policies and degree requirements, and exploring academic opportunities and professional pathways. Each individual program, designed by the student in consultation with the academic adviser, should represent a strong and cohesive program reflecting the student’s major field of interest. Based on the research interest, students and research advisers mutually agree to work on the research together and establish a collaborative relationship. When the research adviser is from outside the Applied Physics department, the student must also identify a co-adviser from departmental primary faculty to provide guidance on departmental requirements and opportunities.

_Emeriti: (Professors) Malcolm R. Beasley, Arthur Bienenstock, Alexander L. Fetter, Theodore H. Geballe, Stephen E. Harris, Walter A. Harrison, Peter A. Sturrock, Yoshihisa Yamamoto; (Professors, Research) Helmut Wiedemann, Herman Winick; (Courtesy), Douglas D. Osheroff_

**Chair:** Martin M. Fejer

**Chair of Graduate Studies Committee:** Daniel S. Fisher


**Associate Professors:** Benjamin L. Lev, David A. Reis, Mark J. Schnitzer

**Assistant Professors:** Surya Ganguli, Amir H. Safavi-Naeini, Benjamin Good

**Professor (Research):** Michel J-F. Digonnet

_Courtesy Associate Professors:_ William J. Greenleaf, Zhirong Huang, Andrew J. Spakowitz

_Courtesy Professors:_ Mark L. Brongersma, Bruce M. Clemens, Shanhui Fan, David Goldhaber-Gordon, James S. Harris, Lambertus Hesselink, David A. B. Miller, W. E. Moerner, Jelena Vuckovic, Shoucheng Zhang

_Adjunct Professors:_ Thomas M. Baer, Raymond G. Beausoleil, John D. Fox, Richard M. Martin