

PH.D. REQUIREMENTS IN THE DEPARTMENT OF PHYSICS AND ASTRONOMY

Completion of the Ph.D. requires (1) completion of 72 semester hours of coursework with satisfactory grades in each course and an overall average of **B** (3.00) or higher; (2) successfully passing a Qualifying Examination administered by a committee of the Graduate Faculty; and (3) writing and defending the dissertation. The dissertation is to be an original, publishable contribution to the scientific literature in the student's field of specialization, and must be defended in a public forum. The following paragraphs provide details.

1. Course Requirements

The Graduate School requires a total of 72 hours of credit (formal course work plus registered research hours) prior to receiving the Ph.D. Within these 72 hours, the Department of Physics and Astronomy requires 28 hours of formal course work¹ including:

- Six core courses covering the foundations of physics, as detailed below, totaling 16 credit hours;
- One graduate-level course totaling 3 or more hours in the Department but outside the student's field of specialization (a "breadth course");
- Additional graduate-level courses to make a total of 28 semester-hours in any subject relevant to the student's overall program of graduate study and research.
- Six semesters of Physics colloquium, three of which should be taken before the qualifying exam; and,
- A minimum of two semesters of Teaching practicum colloquium are to be taken at any time before the thesis defense.

A student must earn a grade of B or higher in each course counted towards these 28 hours. Satisfactory grades ("S") have to be obtained in Phys 8001 – Physics Colloquium, and Phys 8003 – Teaching practicum.

Core courses provide the foundation for deeper connections to elective course-work and research. Students in the Vanderbilt Physics and Astronomy Ph.D. program may choose to concentrate in either physics or astronomy; the core requirements for each concentration are detailed below. There are two ways to satisfy each core course requirement: take and pass the course with a grade of B or higher; or take and pass an alternate written exam on the material covered by that particular course with a score equivalent to a grade B or higher. Students are not permitted to retake core courses. Instead, a student who receives a B- or lower grade in any core course has a second chance to meet the course requirement by taking and passing the corresponding alternate written exam. These exams are offered annually just before the start of the fall (spring) semester for material covered in courses offered during the fall or spring semesters. The students taking the exam are required to sign

¹ The Graduate School requires only 24 semester-hours of formal coursework. The Departmental requirement is higher because of the number and breadth of courses required to properly prepare for a career in physics or astronomy. Additional course work maybe recommended by individual advisors.

up by notifying the DGS by August 1st/December 20th, for the fall/spring exams, respectively. Note that exceptionally well-prepared incoming students may take and pass one or more of the alternate written exams to place out of the corresponding core course(s). A failure to pass the exam before the respective course is taken is not going to count against the two chances to satisfy the course requirement. Students who place out of one or more core courses do not receive credit hours from the Graduate School and will need to take additional elective courses to accumulate the required 28 semester-hours of formal coursework.

Students who fail to satisfy any one of the core course requirements – due to a low course grade and failure on the alternate written exam – may be dropped from the Ph.D. program at the discretion of the Graduate Program Committee.

1A. TRANSFER CREDIT

Students who have taken graduate courses elsewhere may petition the Graduate Program Committee to have those courses evaluated for transfer credit to avoid unnecessary duplication and speed the student's entry into research. In order to transfer any number of core courses for credit, transfer students must take any one of the core courses offered at Vanderbilt and earn a grade of A- or better.

1B. CORE COURSE REQUIREMENTS

Students concentrating in physics must complete the following courses in the first two years of graduate study:

- **Physics 8000:** Research Seminar
- **Physics 8010:** Classical Mechanics
- **Physics 8020:** Electrodynamics I
- **Physics 8030:** Quantum Mechanics I
- **Physics 8040:** Statistical Mechanics
- **one of the following courses:**
 - **Physics 8021:** Electrodynamics II
 - **Physics 8031:** Quantum Mechanics II
 - **Physics 8152:** Condensed Matter Theory (Quantum Mechanics of Solids)
 - **CPBP 8306:** Introduction to Chemical and Physical Biology

1C. BREADTH COURSES AND ELECTIVES

One “breadth course” is required of all students. These are advanced graduate level courses (typically 8XXX level) from physics or related fields outside the student's field of specialization. The elective courses may be filled from any graduate-level courses that are appropriate for the student's program; DGS approval is needed for courses offered outside the Department of Physics and Astronomy. The chart in Appendix A shows the courses available in the Department that count as breadth or elective for students pursuing any of the five research concentrations.

The departmental colloquium is another required course aimed to provide breath in the student's education. The colloquium course **Physics 8001** has to be passed with a satisfactory grade 3 times before the qualifying exam, and six times before the thesis defense.

1D. TEACHING REQUIREMENT

Teaching experience is important for the student's learning and future career. The **Teaching practicum, Phys 8003**, is required of all students for a minimum of two semesters. Typically, the graduate students in the department would teach for 5-6 semesters.

2. The Qualifying Examination

The doctoral degree in Physics & Astronomy requires students to write and defend a dissertation that presents the results of independent research. To progress to that point, each student must first pass the Qualifying Examination to become a Doctoral Candidate.² According to the Graduate School bulletin, "the purpose of the Qualifying Examination is to test the student's knowledge of the field of specialization, to assess familiarity with the published research in the field, and to determine whether the student possesses those critical and analytical skills needed for a scholarly career." In Physics & Astronomy, the Qualifying Examination requires each student to independently write and orally defend a research proposal. The topic is of the student's choosing, and may be the same as her/his current research. The Qualifying Examination is administered by the student's Ph.D. committee, and only the committee members and the student are present. Passing the Qualifying Examination marks the student's formal entry into dissertation research under the supervision of her/his thesis advisor and the Ph.D. committee. The Qualifying Exam should not be seen as a hurdle, but as an important part of one's training to become an independent scientist.

2A. PH.D. COMMITTEE

The Ph.D. committee administers the Qualifying Examination and subsequently monitors the student's progress towards the completion of the thesis. The committee comprises at least four members of the Graduate Faculty. To ensure consistency among Qualifying Examinations, at least one member of the committee should be a current or recent member of the Graduate Program Committee; and by Graduate School rule, at least one member of the committee must be from outside the Department or program in which the student plans to do her/his dissertation research. The composition of the committee is proposed by the advisor in consultation with the student and must be approved in writing by the Director of Graduate Studies (DGS) to ensure breadth and level of expertise.

2B. PREPARING FOR THE QUALIFYING EXAMINATION

The Qualifying Examination in the Department is taken during the fourth semester (under exceptional circumstances, a student may petition the Graduate Program Committee to delay the Qualifying Exam until the sixth semester³). The Examination is offered in just one annual cycle – culminating in the oral examination by late April or early May. By Graduate School rules, students

² Advancing to candidacy makes one eligible to register for dissertation research credits (PHYS 399).

³The Graduate School requirement is that the Qualifying Examination must be passed by the end of the 8th semester, but postponing it is too late to permit completion of an acceptable dissertation project in the desired time frame of approximately five years.

taking the qualifying exam must have completed all requirements for formal course work (Section 1) with a GPA of 3.0 or better in all courses taken for credit.

The steps needed to prepare for the Qualifying Examination are:

- The student should get involved in research as soon as possible – certainly no later than the summer after her/his first year of study. To begin by summer, the student should interview potential faculty advisors in the spring of the first year to identify those with space to take on a summer research assistant. During the first two years of study, a student may explore research opportunities in several groups, but she/he must select a faculty Ph.D. advisor at least one semester before an anticipated Qualifying Examination date.
- The student and the advisor agree on the other members of the Ph.D. committee. The student then contacts members of the committee to ascertain their willingness to serve. Once the composition of the Ph.D. committee is decided and all the proposed committee members have agreed to serve, the **advisor** completes the “Request to Appoint Committee” form (Appendix B) to the DGS for approval and notification of the Graduate School. During the annual exam cycle, the committee membership should be finalized and the form submitted by February 1.
- The student prepares a 1-page abstract that outlines the proposal’s research topic, hypothesis and specific aims. The student is encouraged to consult with his/her advisor and others with expertise to come up with and refine an appropriate research topic, but the abstract must be the student’s independent work. The student may seek critiques of the abstract and/or reviews of the grammar/English-usage from others, so long as these critiques are disclosed as a footnote to the abstract (for example, "S. Bose and R. Bacon provided critiques of the abstract. G. Chaucer reviewed my English usage). This abstract should be submitted electronically (.pdf preferred) to the DGS. The exact due date will be set by the DGS, but will be approximately February 15. The abstract will be reviewed by the Graduate Program Committee (GPC), focusing on the following questions: Is the research topic appropriate? Is the hypothesis well formed and testable? Is the scope sufficiently focused (doable during a typical graduate career of three to four years)? The GPC will provide the student with written feedback on the appropriateness of her/his proposal in approximately one week. The student will then revise the abstract and resubmit it to the DGS and to all members of the student’s Ph.D. committee. The exact due date will be set by the DGS, but will be approximately March 1. The student’s Ph.D. committee will perform a similar review of the abstract and determine whether it provides an adequate basis for a full proposal. If so, the committee will provide additional written feedback and inform the student to begin preparing the full proposal. If not, the committee will provide written feedback and require the student to submit a revised abstract within two weeks.
- After receiving permission to prepare the full proposal, the student should contact all committee members to set a date for the oral part of the Qualifying Examination. The student is advised that getting a committee of five faculty persons to be available simultaneously in time and space is not a trivial task! During the annual exam cycle, the oral exam should be scheduled for the last two weeks of April or first week of May. Only in extraordinary circumstances should the exam be delayed

beyond this point. Once a date is agreed upon, the **advisor** notifies the DGS and Graduate School no later than three weeks before the proposed date. Note that the Graduate School issues the notice of the Examination at least two weeks in advance.

- Regardless of when the oral part of the Qualifying Examination is scheduled, the written proposal must be submitted to the DGS and the student's Ph.D. committee by a specific date. This date will be set by the DGS, typically April 1, and will be the same for all students taking the exam during a specific cycle. The written proposal **must not exceed 8 pages** (single-spaced, 12-pt font). Within this space, the proposal should have four sections:
 1. Rationale or Background & Significance. This section provides background information and justification for the proposal. An important part of preparing the proposal is a thorough review of the current literature. This review should be concisely summarized here.
 2. Hypothesis. This short section (~1 paragraph) should describe the specific hypothesis to be tested.
 3. Specific Aims or Research Objectives. This section will largely follow the previously approved abstract, but the student can make changes as she/he more fully develops the proposal.
 4. Research Plan. This section should detail the experimental/theoretical plan to meet the Specific Aims. The student is advised to number the specific aims and use the same numbering scheme for sub-sections of the Research Plan. This section should describe the experimental/theoretical strategies and design, but it should not provide the sort of detailed Materials & Methods section one would find in a journal article. This section should sketch anticipated outcomes and some discussion of how the plan might be adjusted with different outcomes.

The written proposal should certainly cite the relevant literature and include a bibliography. The bibliography itself does not count against the 8-page limit. The student may include figures and tables in the text, but these do count against the page limit. As with the abstract, the written proposal must be the student's independent work. The student may seek clarifications and advice from experts, but must record (in a footnote or endnote) a list of those consulted and on what topics. The student may also seek assistance with grammar/English-usage so long as these critiques are also disclosed in a footnote or endnote.

- The student's Ph.D. committee will review and evaluate the written proposal. This evaluation will be completed at least two days before the scheduled oral examination. If the written proposal is deemed adequate, then the oral examination will proceed as scheduled; however, if the committee identifies serious deficiencies in the written proposal, then the oral exam will be postponed. If postponed, the scheduled exam time will be used for the committee to provide constructive criticism to the student on how she/he can address the identified deficiencies. The student will then have two weeks to submit a revised proposal and reschedule the oral examination as soon as possible.

2C. THE QUALIFYING EXAMINATION

During the oral Qualifying Examination, the student defends her/his research proposal. The exam is limited to a maximum of two hours. The student is allotted a maximum of 15 minutes to provide an overview of the proposal. This is a strict limit, so committee members are asked to restrict questions to points of clarification during the student's presentation. The remainder of the two hours is reserved for the committee to ask questions in which the student should be prepared to discuss the general background of the proposal and its significance; to discuss relevant experimental approaches, including their theoretical bases and limitations; to outline anticipated results; and to interpret the meaning of these results. The student should be particularly prepared to discuss the interpretation of alternative results proposed by the committee. Although the primary focus of the questions will be on the research proposal, the committee may and likely will probe into the student's core knowledge of physics and astronomy.

Students are **strongly encouraged** to prepare for the oral examination by gathering student peers for mock oral exams.

Copies of the student's prepared slides must be made available to the committee members at least one working day before the examination. By rule of the Graduate School, attendance at the Qualifying Examination is limited to only the Ph.D. committee members and the student.

The committee will decide within one day whether or not the student has passed the Qualifying Examination. Within one week, the committee will provide a written report to the student and to the GPC describing the student's performance on the examination. Even if the student was judged to have passed the examination, the report should address any deficiencies in preparation that were evident during the examination. If the student was judged to have failed the examination, the report should note the serious deficiencies that caused this failure; the committee may also offer their judgment on whether retaking the examination would be in the best interest of the student. A second attempt at passing the Qualifying Examination must be completed before the beginning of the subsequent fall semester. By Graduate School rule, only two attempts are allowed for passing the Qualifying Examination.

3. The Ph.D. Dissertation

3A. PROPOSAL FOR THE PH.D. DISSERTATION

After passing the Qualifying Examination, the student is officially admitted to candidacy for the Ph.D. He/she will develop a topical focus for the Ph.D. dissertation grounded in the subfield chosen for that Examination. The dissertation topic should be an original research proposition that advances the frontiers of science in the field of specialization. While consultation with the advisor will be crucial to this process, it is to be emphasized that *the proposal for the dissertation is the responsibility of the student*. Within two semesters of passing the Qualifying Examination, the student will present a specific proposal to the Ph.D. committee. This proposal can be, and likely should be, based on the proposal that the student successfully defended during her/his Qualifying Examination. At this stage, the proposal should contain at the minimum a chapter-by-chapter outline of the dissertation, a report on the research already carried out, and a specific plan for completing the remainder. As a general rule, students should plan to complete the dissertation within three years of passing the Qualifying Examination, so that the dissertation can be submitted five to six years after entering the Graduate School. By Graduate School rule, all requirements for

the degree of Doctor of Philosophy must be completed within four years of passing the Qualifying Examination.

3B. ANNUAL MEETINGS OF THE PH.D. COMMITTEE

After the dissertation topic is approved, the student will meet with the Ph.D. committee at least annually to report on research completed to date, publications planned or in progress, and an estimate of the time, resources and analysis required to complete the dissertation project. The committee members may ask questions, critique the work presented by the student, or make suggestions about the project. The Chair of the Ph.D. committee (usually the Ph.D. advisor) is responsible for preparing a brief written report of the meeting that will be sent to the candidate and to the Director of Graduate Studies. This report may also be reviewed by the Graduate Program Committee as it monitors student progress.

3C. PUBLICATION REQUIREMENTS

The research in any dissertation project is expected to contribute measurably to scientific progress in the field of specialization, thus publication in peer-reviewed journals is an essential component of the Ph.D. research program. While the venue, number and timing of publications varies according to subfield, students should expect to play a major role in a first paper no later than the end of the third year of graduate study. By the time the dissertation is completed, the student must present to the Ph.D. committee at least one paper that has been accepted in a peer-reviewed journal. The Ph.D. committee may make an exception when the student is a member of a large collaboration that has long lead-times for publication. In such cases, the student must present a manuscript that has been approved by the appropriate review committee for submission to a refereed journal. The Ph.D. committee is responsible for verifying that the number and quality of the student's publication record is appropriate for the field of specialization.

3D. COMPLETION OF THE DISSERTATION AND THE PH.D. DEFENSE

The *Graduate School Bulletin* and the Graduate School Web site give the essential information about the format of the Ph.D. dissertation and the defense. The defense is a public examination, and should be characterized by a spirited scientific debate on the strengths and weaknesses of the thesis presented by the student. In addition, the Department stipulates the following:

- The **Ph.D. advisor** will inform the Dean of the Graduate School at least two weeks in advance of the date and place of the defense, so that the event can be published in the Vanderbilt University electronic calendar. The Department administrative staff will advertise the dissertation title, and the date and place of the defense in order to promote attendance by faculty, research staff and other students.
- The **Ph.D. candidate** must present a complete copy of the thesis to the committee members *at least two weeks* before the defense. *This is both a Departmental and Graduate School requirement.*
- At the defense, the candidate will present the critical points of the dissertation for no more than 45 minutes; during this presentation, questioning will be generally restricted to matters

of clarification. After the presentation is finished, questioning by attendees other than the Ph.D. committee will be permitted for about half an hour.

- After the public questioning is concluded, the Committee will continue the questioning of the candidate in executive session for up to an hour. The Committee will then caucus in private to evaluate the defense and assign a grade.

The possible grade outcomes for the defense are (1) pass, (2) pass conditional upon changes made to the dissertation recommended by members of the committee, or (3) fail. In case (2) the committee may grant discretion to the principal advisor to enforce the changes to be made to the thesis recommended by the committee. The members may sign the paperwork certifying completion of a passing dissertation, but the advisor will submit the committee's report to the Graduate School only after the changes made are satisfactory in the opinion of the advisor.

APPENDIX A: CORE, ELECTIVE AND BREADTH COURSES OFFER IN THE DEPARTMENT OF PHYSICS AND ASTRONOMY

		Core	Electives	Breadth courses by concentration				
				Nucl	HEP	CMO	BIO	MED
8000	Seminar	X						
8001	Physics Colloquium			X	X	X	X	X
8003	Teaching Practicum	X						
8005	Mathematical Methods of Physics		X					
8010	Particle and Continuum Mechanics	X						
8020	Advanced Electrodynamics I	X						
8021	Advanced Electrodynamics II	X	X					
8030	Quantum Mechanics I	X						
8031	Quantum Mechanics II	X	X			X	X	X
8040	Statistical Mechanics	X						
8100	Selected Topics in Theoretical Physics		X	TBD	TBD	TBD	TBD	TBD
8105	Special Topics in Experimental Physics		X	TBD	TBD	TBD	TBD	TBD
8120	Biomolecular Physics		X	X	X	X		X
8122	Physics of Living Systems		X	X	X	X		X
8124	Physical Measurements on Bio Systems		X	X	X	X		X
8126	Theoretical and Exp. Systems Biology		X	X	X	X		X
8128	Biophysical Electrodynamics		X	X	X	X		X
8140	Nuclear Theory		X		X	X	X	X
8142	Relativistic Heavy Ion Physics		X		X	X	X	X

8144	Experimental Nuclear Physics		X		X	X	X	X
8150	Electromagnetic Spectroscopy		X	X	X		X	X
8152	Condensed Matter Theory	X	X	X	X		X	X
8154	Nanoscale Condensed-Matter Physics		X	X	X		X	X
8156	Surface Structure and Dynamics		X	X	X		X	X
8158	Inter. of Photons with Atoms, Molecules and Solids		X	X	X		X	X
8159	Exp. Nanoscale Fabrication and Characterization		X	X	X		X	X
8160	General Relativity		X	X	X	X	X	X
8161	Cosmology		X	X	X/0		X	X
8164	Many-Body Quantum Mechanics		X					
8170	Quantum Field Theory I		X			X	X	X
8171	Quantum Field Theory II		X			X	X	X
A8010	Radiative Processes		X	X	X	X	X	X
A8020	Special Topics in Astrophysics		X	X	X	X	X	X
A8020	Observational and Computational Astro		X	X	X	X	X	X
A8030	Stellar Astrophysics		X	X	X	X	X	X
A8040	Structure and Dynamics of Galaxies		X	X	X	X	X	X
A8050	Structure Formation in Universe		X	X	X	X	X	X
A8060	Methods in Observational and Computational Astronomy		X	X	X	X	X	X