UNIVERSITY OF NOTRE DAME

DEPARTMENT OF PHYSICS AND ASTRONOMY

Guide for Graduate Students 2022-2023

Contents

Preface

The purpose of this guide is to explain the rules and procedures of the Department of Physics and Astronomy as they pertain to physics graduate students. As specified by the Graduate School, all graduate programs are expected to have a guide that sets out the basic policies of the program and also provides guidance on the department's expectations.

Part I of this guide describes the basic academic coursework and requirements, including the preliminary examination. Part II describes the research portion of the program, including research advisors, mentoring committees, candidacy, and the Ph.D. dissertation. Part III discusses general administrative policies, including financial support. Additional reference information is contained in the appendices, notably including the departmental policy on *Teaching Assistant Rights, Responsibilities, and Procedures* (Appendix E).

You are also strongly encouraged to read the Academic Code of the Graduate School (ACGS) and be familiar with its rules and procedures. The ACGS establishes the minimum standards for all graduate programs. Individual programs such as physics must follow these minimum standards but may require higher standards than those of the ACGS. Further information on certain Graduate School policies may also be found in the Graduate Bulletin of Information (*e.g.*, for funding policies and program requirements) and in other guidelines on the Graduate School web site (*e.g.*, for dissertation requirements). All these resources may be found on the Graduate School's policies page:

`https://graduateschool.nd.edu/policies-forms/`

Every attempt has been made to have this guide as accurate and up-to-date as possible. It is updated yearly, with new versions released at the start of the fall semester. While every attempt is made to make this information error-free, in the case that conflicting information is found, original Graduate School sources take precedence over this graduate guide.

Part I

Academics

1 Ph.D. curriculum

The purpose of the curriculum is to prepare you as a physicist. Your coursework will help you to attain the broad knowledge you will need to interact with other physicists, to function within your discipline, and to adapt as your interests and research directions evolve over the years. Your coursework will also provide you with more specific knowledge and techniques for your immediate research aims.

Overview of course offerings. The course offerings of the department can be organized roughly as follows:

> **Core curriculum.** The *core curriculum* (Sec. 1.1) covers background material common to all physicists.
>
> **Research area courses.** *Research area courses* (Sec. 1.2) focus on a specific subdiscipline of physics, at either an introductory or advanced level.
>
> **Methods courses.** *Methods courses* (Sec. 1.3) provide knowledge of methods (experimental, observational, computational, statistical, *etc.*) used in physics research.
>
> **Professional development courses.** These courses (Scientific Writing for Physicists and Physics Teaching Practicum) help you to develop professional proficiency (Sec. 1.4).
>
> **Colloquium and seminars.** Ideas at the forefront of our field are communicated researcher-to-researcher, through *colloquia* and *seminars*. (Sec. 1.5).
>
> **Research and dissertation.** Starting in your second semester, typically, you will be registering for *research and dissertation* credit (Sec. 1.6).

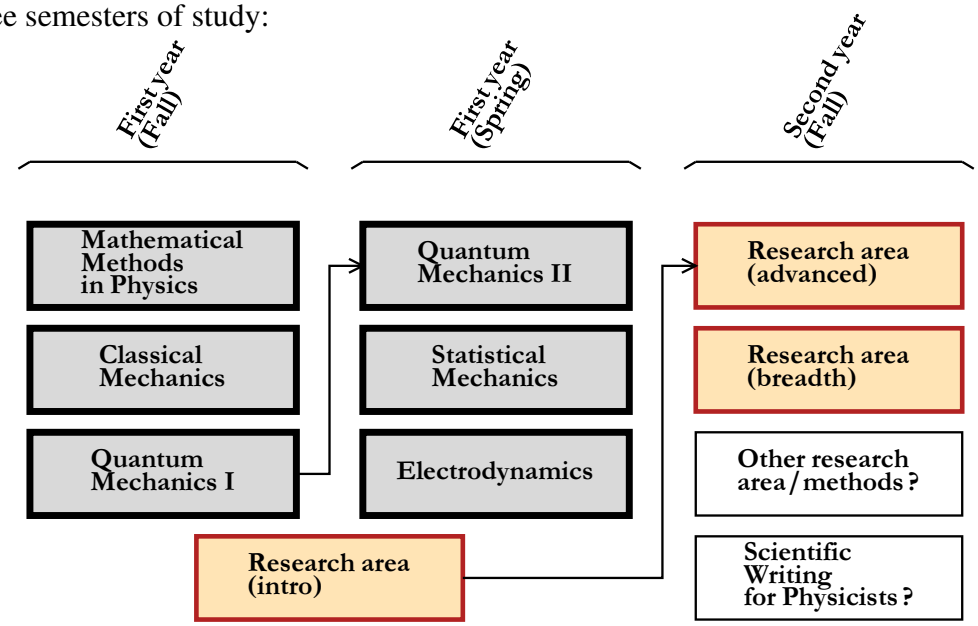
Summary of course requirements. To provide structure and ensure certain common ground, there are certain baseline requirements, for all students in the department. These constitute 27 hours (or nine 3-credit courses) of *graded* coursework.

> **Core curriculum.** All six courses in the core curriculum (Sec. 1.1) are required.
>
> **Research area course requirement.** At least three research area courses must be taken. At least one of these must be outside of your own research area (for *breadth*), and at least one must be at an advanced level (80000-level or higher). Guidelines as to which courses which can (or cannot) count towards the research area course requirement may be found in Sec. 1.2.

Experimental proficiency requirement. Furthermore, if you have not previously taken a laboratory course at the advanced undergraduate or graduate level (or equivalent), then you are required to take an approved graduate experimental methods course at Notre Dame. The courses which the department has currently approved for this purpose are:

> PHYS 60210 Modern Observational Techniques
> PHYS 61701 Modern Methods for Experimental Nuclear Physics
> PHYS 71010 Methods of Experimental Physics

Typical course sequence. The following diagram outlines a typical course sequence for the first three semesters of study:



1.1 Core curriculum

The core curriculum consists of six courses, normally taken during the first year of graduate study:

First year (Fall)

PHYS 70003 Mathematical Methods in Physics
PHYS 70005 Classical Mechanics
PHYS 70007 Quantum Mechanics I

First year (Spring)

PHYS 70006 Electrodynamics
PHYS 70008 Quantum Mechanics II
PHYS 70009 Statistical Mechanics

The department's "standard syllabi" for these courses, summarizing the expected topical coverage, may be found in Appendix A. These are 3-credit courses and must be taken for grade credit.

1.2 Research area courses

The research area courses address the more specialized knowledge and approaches of specific subdisciplines of physics (such as astrophysics, atomic physics, condensed matter physics, high energy physics, or nuclear physics). The general pattern is that, for each research area, one or more *introductory research area courses* (at the 60000-level) provide the fundamental concepts (Sec. 1.2.1). Then one or more *advanced research area courses* at the 80000/90000-level delve more deeply into this area (Sec. 1.2.2). Special topics courses are also often offered in the various research areas (Sec. 1.2.3).

Research area course requirement. You must take at least *three* research area courses, as three-credit graded courses. Of these, at least one must be a suitable *breadth* course and at least one must be a suitable *advanced* course. Let us now clarify what this means.

Any course listed below as an *introductory research area course* or *advanced research area course* may be counted towards the overall research area course requirement. Typically *special topics courses* may be counted towards the overall research area requirement as well, provided that they have sufficient physics content, but you should consult with the DGS in advance.

For the *breadth* requirement: This course may be at any level (60000-level or above), so long as the course's coverage is be sufficiently broad in nature to give you a solid introduction to some research area outside your own. Any course listed below as an *introductory research area course* or *advanced research area course* may be used to satisfy the the breadth requirement, provided it is outside of your research area. (While a *special topics course* might have a sufficiently broad nature to be suitable for satisfying the breadth requirement, this is not necessarily the case, so be sure to obtain prior approval from the DGS.) Furthermore, if your research is interdisciplinary, be sure to consult with the DGS to determine what constitutes "outside of your research area".

That said, one course outside of your research area is, arguably, the bare minimum of "breadth". You are certainly encouraged to take more than one course outside of your research area if you so desire.

For the *advanced* requirement: Any course listed below as an *advanced research area course* may be used to satisfy the advanced research area course requirement. Normally, an "advanced" course is one at the 80000 or 90000 level. You will normally take at least one advanced course in your own research area. (While a *special topics course* might possibly be sufficiently deep and comprehensive in its coverage to be suitable for satisfying the advanced research area course requirement, this will not typically be the case, so be sure to obtain prior approval from the DGS.)

Courses from outside the physics department may also occasionally be applied towards the research area course requirement, with prior approval from the DGS. The guiding principle is that they must contain sufficient physics content.

1.2.1 Introductory research area courses

The introductory research area courses (offered at the 60000 level) provide the fundamental concepts and methods of some area of physics. These courses are designed to be at a level such that they can be taken in the first year of graduate studies, before you have completed the core curriculum (they are meant to be accessible to advanced undergraduates as well).

You will typically take the introductory research area course within your own expected research area of specialization, as a prerequisite to the more advance courses. For instance, PHYS 60701 Introduction to Nuclear Physics is a prerequisite to PHYS 80701 Nuclear Physics. However, this may depend upon your research area (see Sec. 1.8).

Furthmore, an introductory research area course (outside your own research area) may be used to satisfy the out-of-area (or "breadth") requirement. However, you might be able to use an advanced research area course (Sec. 1.2.2) for this purpose, instead, if you satisfy the prerequisites to go directly into this course (for instance, PHYS 80003 Quantum Field Theory I or PHYS 80102 Networks, Information and Physics can be taken after just the standard core

courses, with no further prerequisites).

Note that several of these courses serve also as senior undergraduate electives, and are therefore cross-listed at both the 50000 (undergraduate) and 60000 (graduate) levels. As a graduate student, you should register for the 60000-level section.

Astrophysics

PHYS 60201 Physics of Astrophysics (fall, =PHYS 50201)
PHYS 60202 Relativity: Special and General (spring, =PHYS 50472)

Biophysics

PHYS 60401 The Physics of Cells (fall, =PHYS 50401)
PHYS 60410 Patterns of Life

Condensed Matter Physics

PHYS 60501 Introduction to Solid State Physics (fall, =PHYS 50501)

High Energy Physics

PHYS 60602 Particles and Cosmology (spring, =PHYS 50602)

Nuclear Physics

PHYS 60701 Introduction to Nuclear Physics (spring, =PHYS 50701)

1.2.2 Advanced research area courses

The advanced research area courses (offered at the 80000 or 90000 levels) typically require prerequisites from the core curriculum. They also typically build upon a prerequisite introductory (60000-level) research area course. You will typically take at least one advanced research area course within your research area of specialization, and most likely more (see Sec. 1.8).

Astrophysics

PHYS 80202 Astrophysics: Stars (spring, alt. years)
PHYS 80203 Astrophysics: Galaxies (spring, alt. years)
PHYS 80204 Cosmological Physics (on demand)

Atomic Physics

PHYS 80301 Atomic Physics (on demand)

Biophysics

PHYS 80401 Biophysics (on demand)

Condensed Matter Physics

PHYS 80501 Solid State Physics
PHYS 80502 Soft Condensed Matter Physics (on demand)
PHYS 90503 Quasiparticles in Condensed Matter Physics (on demand)

High Energy Physics

PHYS 80003 Quantum Field Theory I (fall)
PHYS 80004 Quantum Field Theory II (spring)

PHYS 80601 Elementary Particle Physics (spring)

Network Science

PHYS 80102 Networks, Information and Physics (on demand)

Nuclear Physics

PHYS 80701 Nuclear Physics (fall)
PHYS 90702 Nuclear Structure (alt. years)
PHYS 90703 Nuclear Astrophysics (alt. years, or more often as needed)
PHYS 90704 Nuclear Reactions (on demand)

1.2.3 Special topics courses

Special topics courses are also frequently offered on a one-time basis. Some of these are intended as "pilot" offerings, which might subsequently develop into regular courses. Recent examples include:

Astrophysics

PHYS 60204 Exoplanets (Fall 2021)

Condensed Matter Physics

PHYS 60510 Quantum Materials and Devices (Fall 2021)
PHYS 90507 Topology and Dirac Fermions in Condensed Matter (Fall 2018)

Since these courses typically are narrowly focused, and do not provide a thorough introduction to a given subdiscipline, they typically will not count towards the breadth requirement. However, they might still count towards the Research Area course requirements overall (please consult with the DGS).

1.3 Methods courses

The department offers various *methods courses*, in which you develop your knowledge of practical methods (experimental, observational, computational, statistical, *etc.*) used in physics research:

Experimental/Observational Methods

PHYS 60210 Modern Observational Techniques (fall, alt. years, =PHYS 50481)
PHYS 61701 Modern Methods for Experimental Nuclear Physics
PHYS 71010 Methods of Experimental Physics (spring, =PHYS 41442)

Computational/Numerical Methods

PHYS 50051 Numerical PDE Techniques for Scientists and Engineers
PHYS 60050 Computational Physics (fall, alt. years)
PHYS 60070 Computing and Data Analysis for Physicists (fall, alt. years)

Statistical Methods

PHYS 60203 Statistical Analysis Techniques for Modern Astronomy

Theoretical/Mathematical Methods

PHYS 90020 Advanced Continuum Mechanics (=AME 90620)

Since these courses focus on methods and tools, rather than on the physics of a given research area *per se*, these courses do *not* count towards the Research Area course requirement.

1.4 Professional development courses

The following courses focus specifically on professional skills:

PHYS 60061 Scientific Writing for Physicists (fall, 1.5 credits)
PHYS 95000 Physics Teaching Practicum (every semester, 1 credit)

These courses are graded on an S/U basis.

Scientific Writing for Physicists. Communication skills are essential for sharing your research with others and ultimately securing a job. Success as a scientist is inextricably tied to the ability to clearly describe complex ideas in writing, whether to communicate them to your colleagues through journal articles (or your thesis!), to your collaborators through internal working documents, or to funding evaluators in your fellowship and grant proposals. In this course, we will discuss the key ingredients involved in writing clearly, concisely, efficiently, and effectively. We will also address the effective visual presentation of information.

As a significant component of this class, you will plan, draft, and revise a substantial written work (such as a short paper) on your research. In doing so, you will make use of the writing principles we learn, and you will incorporate extensive feedback from the instructor and from your colleagues in the course. Thus, this course is intended primarily for graduate students in their second year and beyond, who are already engaged with research.

Physics Teaching Practicum. Physics Teaching Practicum is designed to offer supervised teaching experience to graduate students in physics who have completed the majority of their class work. Three lectures are planned, delivered and observed, and reflected upon. A teaching portfolio/notebook documents the experience. There is a mandatory orientation session that must be completed prior to the teaching experience. The practicum coordinator will match physics graduate students wishing to gain teaching experience with physics instructors who are willing to mentor qualified graduate students in teaching selected lectures in their course. This opportunity is limited to three lectures each per semester for both the faculty and the graduate students. Each lecture will be subject to the agreement of the course instructor and observer and arranged with the practicum coordinator at least a week in advance of the lecture. Instructors serving as mentors will be expected to work with the graduate student on the preparation of the lecture for the course. A faculty observer for the lecture will then be selected. The observer will provide one page of written feedback to the student and discuss the results with the student in a follow-up interview. A teaching portfolio/notebook documents the planning, observation, and student's reflection on the experience. The class, PHYS 95000, will be added to a student's transcript with the grade of "S" once three lectures and teaching portfolio are completed. The three lectures need not all be with the same instructor and may be spread over more than one semester.

This course is offered in collaboration with the Kaneb Center for Teaching and Learning.

Note: You should not *officially* register for this course until the term where you will be completing your third teaching experience. Alternatively, you can simply wait and register for credit "after the fact", once you have completed all requirements. Please consult with the instructor, who will provide you with permission to register for the course at the appropriate time.

1.5 Colloquium and seminars

The colloquium is where all members of our departmental community learn about each others' fields, at a broadly accessible level. The research seminars, for different research areas, are where more technical details are shared and where you can expect to learn the current status of your own research field.

Colloquium. Colloquium speakers will generally be guest lecturers from outside the department, presenting their research at a level accessible to physicists from all areas of research. Attendance at colloquia is an essential part of being a member of our departmental physics community. Colloquia are held weekly on Wednesdays at 12:30 PM. Special colloquia may also occasionally be held at other times during the week.

Every semester, all resident students are expected to register for Physics Colloquium:

PHYS 73000 Physics Colloquium

This is a zero-credit course, *i.e.*, no course credit is given, but it appears on your transcript.

Seminars. The research areas within the department sponsor weekly research seminars. Speakers at seminars may include visitors to the department and graduate students presenting their research. Seminar talks are generally at a higher (or at least more technical) level and go into greater depth than those given as a colloquium. Participation in a weekly seminar is an important part of a physicist's continued education.

All resident students past their first semester are required to register for one of the research seminar courses each semester:

PHYS 83200 Astrophysics Seminar
PHYS 83500 Condensed Matter Seminar
PHYS 83600 Elementary Particles Seminar
PHYS 83700 Nuclear Seminar

These seminars are offered as 2-credit S/U courses.

Generally, students from the smaller research areas without their own seminar series will take one of the four seminars listed above, *e.g.*, biophysics and network science students traditionally participate in the Condensed Matter Seminar.

Attendance of the regularly scheduled seminar is a requirement of all resident graduate students. Unexcused absences may result in an unsatisfactory grade. On occasion, research advisors may recommend for their students the substitution of a special talk for the weekly seminar. The research advisor will notify the seminar instructor of the substitution and will verify the student's attendance of that special talk.

Note that TA schedules are adjusted to allow students in each research area to attend the regularly scheduled seminar. In the unusual event of a class scheduling conflict with your regular seminar choice, *e.g.*, if you are taking a class outside the department, please consult with the DGS.

1.6 Research and dissertation courses

Starting in the spring semester of the first year, students will take at least one credit of research and dissertation per semester, registering under the section assigned to the student's research advisor.

PHYS 98699, Research and Dissertation, is the course most students should take. This is a variable credit course graded on an S/U basis. At the time of registration, the number of credits should be chosen to ensure that, in combination with any other courses being taken, the student maintains at least the 9-credit minimum full-time load.

PHYS 98700, Non-Resident Research and Dissertation, is the appropriate course for students not living near the University of Notre Dame (see ACGS, Sec. 3.3). Common examples include students stationed at CERN or national laboratories for their thesis research, or those who are "all but dissertation" (ABD) and finishing writing their thesis at a location other than Notre Dame. This also is a variable credit course graded on an S/U basis. Because being in PHYS 98700 means that the student is non-resident, the university will not allow the student to register for any other courses concurrent with PHYS 98700. You will therefore generally need to sign up for 9 credits, to maintain 9-credit minimum full-time load. If you plan to register for PHYS 98700, department approval must be requested by contacting the Graduate Program Coordinator.

PHYS 98200, Dissertation Completion, is only for graduate students past their eighth year of study. Departmental approval is required.

Summer registration for research courses. Unless you are receiving your degree and leaving in May, you need to register for PHYS 67890 Independent Summer Research. This is a zero-credit course. It will not show up on your transcript. It is there simply to allow you to sign up for a course to maintain your student status for administrative purposes. However, if you plan to receive a degree in August (either your master's or your Ph.D.), the Graduate School asks you to instead sign up for PHYS 98699 Research and Dissertation, so that you officially have a course listed on your transcript for your "final" term of enrollment. There is only one section of this course in the summer, with the DGS listed as the instructor. You should sign up for zero credits (see Sec. 9.6). There are also some instances where registration for nonzero credits is required for visa purposes (the Graduate Program Coordinator can help you with this, in coordination with ISSA).

1.7 Petition for course offering

Graduate students can petition the departmental Instructional & Course Offering Committee, through the DGS, for advanced electives (such as those listed above as "on demand") to be offered. The petition needs to be made in time for the committee to take it into account when the course schedule is being developed, typically early September for the upcoming spring

semester or January for the upcoming fall semester. The signers of the petition thus indicate their willingness to take the requested course if offered.

1.8 Recommended research area curricula

The faculty in the different research areas have also developed *recommended research area curricula* for their students. The following descriptions give general guidance. You should consult with your research advisor to more precisely determine the specific expectations from your research group, given your own particular research directions. The department also strongly encourages graduate students to take elective courses beyond the departmental or research group requirements.

1.8.1 Astrophysics

The following courses are recommended for all students:

PHYS 60201 Physics of Astrophysics
PHYS 60210 Modern Observational Techniques
PHYS 80202 Astrophysics: Stars
PHYS 80203 Astrophysics: Galaxies
PHYS 80204 Cosmological Physics

Additional electives include:

PHYS 60001 Relativity: Special and General

1.8.2 High energy physics

The following courses are normally taken in the second year:

PHYS 80003 Quantum Field Theory I
PHYS 80004 Quantum Field Theory II
PHYS 80601 Elementary Particle Physics

Students are welcome, but not required, to take PHYS 60602 Particles and Cosmology in their first year.

1.8.3 Nuclear physics

In the spring of your first year, you will develop a broad contextual understanding of nuclear physics phenomena, in PHYS 60701 Introduction to Nuclear Physics. Coming out of this course, the goal is that you should have a grasp of modern nuclear physics research, both in experiment and theory (*e.g.*, at a level sufficient to understand national physics community's *Long Range Plan*), and you should have the practical prerequisites (mass formulas, *etc.*) needed to pursue nuclear physics at a more rigorous level in subsequent courses, without being distracted by filling in basics.

Then, in the fall of your second year, you will move on to a rigorous introduction of the theory underlying nuclear structure, nuclear astrophysics, and nuclear reactions, in PHYS 80701 Nuclear Physics. This course makes full use of the first year core courses, such as Quantum Mechanics and Electrodynamics.

After completing the PHYS 60701/80701 sequence, it is recommended that you take the 90000-level courses (Nuclear Reactions, Nuclear Structure, and Nuclear Astrophysics), as appropriate and when available, to obtain a robust and comprehensive foundation in nuclear physics.

To summarize, the recommended curriculum consists of:

PHYS 60701 Introduction to Nuclear Physics (spring)
PHYS 80701 Nuclear Physics (fall)
PHYS 90702 Nuclear Structure (alt. years)
PHYS 90703 Nuclear Astrophysics (alt. years, or more frequently on demand)
PHYS 90704 Nuclear Reactions (on demand)

Additionally, students in experimental nuclear physics will normally take:

PHYS 60070 Computing and Data Analysis for Physicists (fall, alt. years)
PHYS 61701 Modern Methods for Experimental Nuclear Physics (spring)

Advising notes: PHYS 60701 is generally the gateway course and is a prerequisite to PHYS 80701. However, students who have previously taken a nuclear physics course at the level of PHYS 60701 elsewhere, *e.g.*, as an undergraduate, may petition for a waiver (Sec. 3) to place directly into PHYS 80701. Then PHYS 80701 is an essential prerequisite to both PHYS 90704 Nuclear Reactions and PHYS 90702 Nuclear Structure. However, especially for students from astrophysics who are seeking only a basic background in relevant aspects of nuclear physics, it is possible to proceed directly from PHYS 60701 to PHYS 90703 Nuclear Astrophysics (*i.e.*, PHYS 60701 may serve as the prerequisite).

1.9 Typical course schedule

First year (Fall)

Mathematical Methods of Physics	3 credits
Classical Mechanics	3 credits
Quantum Mechanics I	3 credits
Introductory research area course *(optional)*	0–3 credits
Colloquium	0 credits
	9–12 credits

First year (Spring)

Electrodynamics	3 credits
Quantum Mechanics II	3 credits
Statistical Thermodynamics	3 credits
Introductory research area course *(optional)*	0–3 credits
Colloquium	0 credits
Seminar	2 credits
Research and Dissertation	1 credit
	12–15 credits

Second year and beyond

Research area or methodscourses *(optional)*	0–9 credits
Scientific Writing for Physicists *(optional)*	0–1 credits
Physics Teaching Practicum *(optional)*	0–1 credits
Colloquium	0 credits
Seminar	2 credits
Research and Dissertation	1-9 credits
	9–15 credits

1.10 Review of Physics summer course

The Review of Physics summer course sequence is intended for incoming graduate students before their first semester at Notre Dame:

PHYS 67001 Review of Physics A: Mechanics & Thermodynamics
PHYS 67002 Review of Physics B: Electromagnetism
PHYS 67003 Review of Physics C: Quantum Mechanics

Participation is optional, but highly recommended. This "physics boot camp" for incoming graduate students is an opportunity for you to review the essential components of your upper-level undergraduate physics courses, including classical mechanics (with some thermodynamics), electromagnetism, and quantum mechanics. The goal is to ensure that you and your colleagues have a common conceptual core, mathematical foundation, and problem-solving proficiency as you embark on graduate studies.

It is important to realize that this is a "forward looking" review, designed to ease you into the mindset of your core graduate courses and allow you to hit the ground running in the fall. For instance, electromagnetism will focus on the application of Maxwell's equations and wave dynamics, while quantum mechanics will focus on properly understanding quantum mechanics in terms of state vectors and operators living in Hilbert spaces. We have chosen textbooks at an appropriate level to help you bridge this gap, and then, hopefully, to later serve you as resources in understanding the classic but notoriously dense graduate texts.

A significant emphasis will be placed on ensuring you are fully at ease with the necessary (but, as experience has shown, often spotty) mathematical background, such as vector analysis and linear algebra. There will also be an emphasis on critical problem solving approaches, or how to decide which approach to use and when to switch approaches, in order to help you with the transition from the simpler undergraduate-level problems you may be familiar with to the more challenging, open-ended problems you will find in your graduate courses.

The Preliminary Examination (Section 4) consists of three parts, on Mechanics & Thermodynamics, Electromagnetism, and Quantum Mechanics. Each review course attempts to at least touch on the major topics from the corresponding part of the Preliminary Examination. If you have mastered the basic concepts and proficiencies of undergraduate mechanics, thermodynamics, electromagnetism, and quantum mechanics, at the level reviewed in the summer course, the general expectation is that you should be able to pass the Preliminary Examination on your first attempt.

However, it is important to realize that it is *your responsibility* ensure that you have mastered the materials specified in the description of the Preliminary Examination (see Section 4), regardless of which specific topics might be selected for emphasis by the instructor when you take the review course. In the short time available, the review course can only *attempt* to review some substantial portion of undergraduate-level physics. It is up to you to study any materials which the review course might not have touched upon as deeply as you find you need (the specific areas in need of deeper review may be expected to differ from student to student depending on background). A variety of relevant textbooks, including the reference textbooks cited in the Preliminary Examination description, will be available on reserve in the Chemistry Physics Library.

Topics

Review of Physics A: Mechanics & Thermodynamics.

Statics (vector decomposition), central forces, rigid body motion, oscillatory motion and normal modes

Basics of Lagrangian/Hamiltonian formulation of classical mechanics

Laws of thermodynamics, ideal gas, state equation

Mathematical concepts reviewed include: Vector techniques and curvilinear coordinate systems; derivatives, chain rule, integration by parts; total differentials, directional derivatives, partial derivatives; basic ODE techniques (including exponential ansatz); Maxwell relations; *approaches for critically deciding among problem solving techniques and when to switch among them*

Review of Physics B: Electromagnetism.

Basic electrostatics from the perspective of the Laplace/Poisson equation (*e.g.*, Laplace/Poisson equation in simple geometries, image charges), multipole expansion, magnetostatics

Maxwell's equations, electromagnetic waves, physical optics

Mathematical concepts reviewed include: Vector calculus for electromagnetism (gradient, curl, Laplacian, vector derivative identities, vector integrals); basic linear PDEs (separation of variables, exponential ansatz $e^{i\vec{k}\cdot\vec{r}}$ & $e^{i\omega t}$)

Review of Physics C: Quantum Mechanics.

General formalism of quantum mechanics in terms of linear operators and Hilbert spaces, matrix representation of quantum problems, coordinate/momentum representations

Quantum harmonic oscillator (Dirac formulation), basic properties of angular momentum operators, central force problem, identical particles

Mathematical concepts reviewed include: Linear algebra (matrices, vector spaces, eigenproblems); eigenbases (including Fourier transform & series); linear operators (their representations in various bases, commutator relations)

2 Degree requirements

2.1 Summary of Ph.D. requirements

There are two sources of requirements for the degree: (1) requirements set by the department and (2) requirements set by the Graduate School (through the Graduate Bulletin of Information and the Academic Code of the Graduate School). The following description attempts to *summarize* these requirements. The details of the departmental requirements are explained elsewhere in the Guide for Graduate Students, while the definitive source for the Graduate School requirements is the Academic Code of the Graduate School (ACGS).

In the following summary, we focus on the degree requirements *per se*. There is also a required timeline for completing candidacy and then the doctoral degree requirements. Candidacy must normally be passed no later than your eighth semester of enrollment *i.e.*, spring of your fourth year [ACGS 6.2.7]. Then all doctoral degree requirements, including official submission of the dissertation, must be completed within eight years from the time of matriculation [ACGS 6.2.6]. It is possible to apply for an extension of up to two semesters beyond this time [ACGS 6.2.6.1].

2.1.1 Departmental Requirements

Coursework requirement. The coursework requirements consist of the *Core Curriculum Requirement* (a core curriculum of 6 courses) and the *Research Area Course Requirement* (at least 3 research area courses, including at least one *advanced* and one *breath* course). The courses which satisfy these requirements are defined in Sec. 1. Note that the Graduate School requires the coursework towards the degree to be completed with a cumulative G.P.A. of 3.0 or better [ACGS 4.5 & 6.2.8].

Experimental proficiency requirement. Students who have not previously taken an advanced undergraduate lab (or equivalent) are required to take an approved graduate experimental methods course (see Sec. 1 for a list of approved courses).

Preliminary examination. The Preliminary Examination is described in Sec. 4.

2.1.2 Graduate School requirements

Credit hours. At least 60 credit hours are required for the Ph.D. degree [ACGS 6.2.1]. For the Ph.D. in Physics, the Graduate Bulletin of Information moreover specifies that at least 27 of these credit hours must be graded credits. Note that, if you complete the standard required coursework as described above, you will automatically fulfill the 27-credit requirement.

At most 6 hours of the credit requirement can be satisfied with courses at the 40000-level or 50000-level, with permission, and none below those levels [ACGS 4.1]. Again, this is not of concern to you if you complete the standard required coursework as described above. However, if you waive any of the standard courses (Sec. 3.2), and are thus replacing the missing credits with electives, you need to make sure that you respect the Graduate School's limit on applying

50000-level credits towards your degree (only in very exceptional circumstances would 40000-level courses be considered for the Physics Ph.D.).

Residency requirement. The minimum residency requirement for the Ph.D. degree is normally full-time status for four consecutive semesters [ACGS 6.2.2].

Foreign language requirement. The Graduate School does not impose a foreign language requirement, but rather leaves this to the individual degree programs [ACGS 6.2.3]. The Physics Ph.D. does not have a foreign language requirement.

Responsible conduct of research and ethics training. All Ph.D. students must complete training modules for the Responsible Conduct of Research and Ethics requirement [ACGS 6.2.4].

Candidacy examination. The Graduate School requires both a written and oral candidacy examination [ACGS 6.2.7]. The format for the Physics Ph.D. candidacy examination is described in Sec. 7.

Admission to candidacy. Admission to candidacy is a prerequisite to receiving a doctoral degree. "To qualify for admission to doctoral candidacy, a student must: be in a doctoral program, complete the program coursework and language requirements with a cumulative G.P.A. of 3.0 or better, pass the written and oral parts of the doctoral candidacy examination, and have the dissertation proposal approved (if this is not part of the candidacy exam)." [ACGS 6.2.8] The Physics Ph.D. program procedures for candidacy are described in Sec. 7.

Dissertation, defense, and submitting the dissertation. The general Graduate School rules are defined in ACGS 6.2.9–6.2.11. The Physics Ph.D. program procedures for the dissertation and defense are described in Sec. 8.

2.2 Summary of M.S. requirements

The graduate program is primarily a doctoral program, leading to the Ph.D. degree. The department ordinarily will not accept students who intend to complete only the master's degree.

You will therefore most likely receive the M.S. in course to completing your Ph.D., upon completing candidacy for the Ph.D. degree. However, there is also an option for completing the M.S. purely through coursework and a Master's Comprehensive Examination. In practice, this option is taken by students who leave the Ph.D. program after completing coursework but before completing candidacy.

All requirements for the master's degree must be completed within five years [ACGS 6.1.4].

Coursework requirement. The Physics M.S. requires 8 courses, chosen from those taken as part of the Ph.D. curriculum, and selected with approval of the DGS.

Credit hours. At least 30 credit hours are required for the M.S. degree [ACGS 6.1.1]. For the M.S. in Physics, the Graduate Bulletin of Information moreover specifies that at least 24 of these credit hours must be graded credits.

Residency requirement. The minimum residency requirement for the master's degree is registration at full-time status for one semester during the academic year, or for one summer session [ACGS 6.1.2].

Foreign language requirement. The Physics M.S. does not have a foreign language requirement [ACGS 6.1.3].

Master's comprehensive examination. The master's comprehensive examination [ACGS 6.1.5] for the Physics M.S. is an oral test on material covered in the basic graduate courses. The examination panel consists of the research advisor of the student and two other faculty members. A majority vote of the three examiners decides the outcome. One retake is permitted if recommended by the panel. The student is immediately informed of the results of the examination.

Admission to candidacy. Admission to candidacy (candidacy for the M.S., that is, not to be confused with candidacy for the Ph.D. as described above) is a prerequisite to receiving the M.S. "To qualify for admission to candidacy, a student must be in a master's degree program. He or she must be registered and enrolled in the program and must maintain a minimum cumulative G.P.A. of 3.0 in approved coursework." [ACGS 6.1.6]

Thesis requirement. While some master's programs at Notre Dame have thesis requirements or thesis options [ACGS 6.1.7], there is no thesis option for the Physics M.S. (When you are reading the policies in the ACGS, note that a *research master's degree* refers to one with a thesis requirement. The Physics M.S. is, consequently, not classified as a research master's degree.)

Award of master's degree to doctoral students. The Graduate School allows students to substitute the Ph.D. Candidacy Exam in place of the Master's Comprehensive Exam, according to guidelines set by the department [ACGS 6.2.5]. A student in the Physics Ph.D. program may receive the physics M.S. without taking the Masters Comprehensive Examination, on the recommendation of the program, upon completion of the remaining M.S. requirements above and both the written and oral parts of the Ph.D. Candidacy Examination.

3 Transfer credit and waiver of a required course

Reference: ACGS, Sec. 4.6

The Department of Physics and Astronomy makes the following distinction between the transfer of credit and the waiver of a requirement:

Transfer credits are entered by the Registrar's Office onto a graduate student's University transcript. The awarding of transfer credits by the University is a formal acknowledgment that a student has previously taken graduate course(s) that can count in the place of Notre Dame graduate course(s). The awarding of transfer credit follows rules established by the Graduate School and the University. This is the normal and preferred mechanism to be used by the department to indicate the acceptance of a core course requirement taken elsewhere.

On occasion, and as an exception, a student may request that a requirement in the Physics core curriculum be waived. This will occur when the student believes that he or she has a course background equivalent to one of the Notre Dame core courses, but the course taken does not meet the requirements for transfer credit. In this case, the student may ask the department to waive the requirement of the course. If a waiver is granted, the record of this waiver is maintained by the DGS. No record of the waiver appears on the student's University transcript. The waiver therefore also does not count towards the credit requirement of 27 graded credits for the Physics Ph.D. (Sec. 2.1). Any missing credits will have to be replaced by taking some other elective course, chosen with permission of the DGS.

3.1 Transfer credit

The following applies to incoming graduate students to Physics who have already taken one or more graduate courses elsewhere.

For a course to be eligible for transfer:

- The student must have had graduate student status when he or she took the course;
- The course must have been completed within a five-year period prior to admission to the physics degree program;
- Grades of "B" or better must have been achieved;
- It must be a graduate level course.

Additionally:

- If student is transferring from an unfinished master's program, the student will not be allowed to transfer more than six semester credit hours into a Notre Dame Physics Ph.D. program;
- If student has completed a master's or Ph.D. program, the student will not be allowed to transfer more than 24 semester credit hours to the Notre Dame Physics Ph.D. program.

The above is a partial summary of the transfer-credit rules of the Graduate School and the University (see ACGS, Sec. 4.6, for more complete information).

The Department of Physics and Astronomy's role in transfer credit decisions is to make recommendations on the suitability of a graduate course as replacements for Notre Dame's physics core course requirements.

At the time of student's orientation to the department, an initial meeting will be scheduled with the DGS. Prior to that meeting, the DGS will have reviewed the student's transcript in order to generate the list of possible transfer courses.

The student and the DGS will decide together which courses should be reviewed for possible transfer credit. The student may decide to forgo the transfer credit and take the Notre Dame course.

The student then makes an appointment with a designated recent professor(s) of the course(s). A list of these professors will be made available at orientation. This "review panel of professors" is responsible for making recommendations for particular courses in the Notre Dame physics core. The review panel professor will evaluate the suitability of the course taken as replacement for one of the physics core requirements.

The professor will ask to examine material related to the course taken, e.g., the syllabus, textbook, and tests taken as part of the course. The professor may ask the student to answer orally basic questions on the material studied in the course. If the student is unable to answer these questions satisfactorily, then the course will not be transferred.

The professor will report his or her recommendations on transfer credit back to the DGS. Final decisions on courses to be taken in the fall and on courses to be transferred will be made by the DGS after a second discussion with the student. The DGS has the responsibility of making the department's recommendations on transfer credit to the Graduate School. At the end of the fall semester, the DGS forwards transfer credit recommendations to the Graduate School.

3.2 Waiver of required course

As described above, at the time of the student's arrival in the department, the DGS will have reviewed the student's previous transcripts looking for courses that are eligible for transfer credit. If the student believes that he or she has course background equivalent to one of the Notre Dame core courses, but the course taken does not meet the requirements for transfer credit, then the student may request that a requirement be waived.

After a discussion with the student, the DGS will send the student to the appropriate member of the review panel for transfer courses. The professor will evaluate the suitability of the course as a replacement for one of the Physics core requirements. If there appears to be a good match, then the professor will arrange to give a written exam comparable to past finals in the course. This final will be graded on a scale of pass/fail. There are no allowed retakes of this exam. A report of the grade and a recommendation on the waiver will be made by the professor to the DGS.

The student must discuss possible waivers of credit with the DGS before contacting any of the faculty on the review panel.

Written examinations on first-semester courses must be taken before the fourth class day, and graded before the sixth class day. Written examinations on all other core courses must be taken and graded before the end of the first semester.

The DGS maintains discretion on the number of courses that may be waived for a particular

student. Generally, for students following a Ph.D. program, no more than six courses will be waived. If a student following the Ph.D. program has a combination of waived and transferred courses, the total of the two categories generally will not exceed eight courses (or 24 credits).

Similar restrictions on waived and transferred courses exist for master's students. A student may not transfer more than six credits or two courses towards a Notre Dame MS degree. Additionally, for master's students, the combination of waived and transferred courses will not be allowed to exceed two courses (or 6 credits).

4 Preliminary Examination

4.1 Description

Through successful completion of the Preliminary Examination, students demonstrate proficiency in a core of upper-level (junior/senior) undergraduate physics subject matter, identified as essential to success in future studies and as a well-prepared physicist. The process of preparing for the examination provides an opportunity for a consolidation of knowledge, including the necessary prerequisite mathematical proficiencies, as well as development of problem-solving abilities.

The exam consists of three parts, each administered separately:

- Part A: Mechanics & Thermodynamics
- Part B: Electromagnetism
- Part C: Quantum Mechanics

Each part of the exam is passed independently. For instance, if a student passes Parts A and C, but not Part B, then only Part B need be retaken.

The exam problems test for *basic understanding* and the ability to solve standard undergraduate problems at a level that can reasonably be expected of all incoming graduate students.

Part A: Mechanics & Thermodynamics primarily emphasizes classical mechanics; basic principles of thermodynamics are also included, but not statistical mechanics. The text John R. Taylor, *Classical Mechanics* (Chapters 1–5, 7–8, 10–11 & 13), is representative of the level and orientation of the classical mechanics coverage of the exam. The text Daniel V. Schroeder, *An Introduction to Thermal Physics* (Chapters 1–4 & 5.1–3), is representative of the level and orientation of the thermodynamics coverage of the exam. The following topics are identified for emphasis in the exam:

- Statics (vector decomposition), central forces, rigid body motion, oscillatory motion and normal modes
- Basics of Lagrangian/Hamiltonian formulation of classical mechanics
- Laws of thermodynamics, ideal gas, state equation

Part B: Electromagnetism covers both electrostatics/magnetostatics and electrodynamics, with an emphasis on the Laplace/Poisson equation and Maxwell's equations as unifying foundations. The text J. R. Reitz, F. J. Milford, and R. W. Christy, *Foundations of Electromagnetic Theory* (Chapters 2–4, 6, 7.1–4, 8, 9.1–8, 11.1–3, 12.1–3, 16, 17.1–3, 18.1–5 & 20.1) is representative of the level and orientation of this part of the exam. The following topics are identified for emphasis in the exam:

- Basic electrostatics from the perspective of the Laplace/Poisson equation (*e.g.*, Laplace/Poisson equation in simple geometries, image charges), multipole expansion, magnetostatics
- Maxwell's equations, electromagnetic waves, physical optics

Part C: Quantum Mechanics emphasizes the Hilbert space formalism of quantum mechanics and its formulation in terms of linear operators and matrices, as a bridge to advanced treat-

ments of quantum mechanics. The text John S. Townsend, *A Modern Approach to Quantum Mechanics* (Chapters 1–3, 4.1–3, 5.1–3, 6, 7.1–7, 9.1–6 & 9.8–9, 10.1–2 &12.1) is representative of the level and orientation of this part of the exam. The following topics are identified for emphasis in the exam:

- General formalism of quantum mechanics in terms of linear operators and Hilbert spaces, matrix representation of quantum problems, coordinate/momentum representations
- Quantum harmonic oscillator (Dirac formulation), basic properties of angular momentum operators, central force problem, identical particles

4.2 Timeline

The exam schedule is designed to allow ample time and opportunity for students with deficiencies in their essential undergraduate physics background to make up these deficiencies, while also ensuring that any student who is unable to do so will know this and be in a position to move on within approximately a year of joining the program.

First administration. The first administration of the Preliminary Examination will be held on a series of three dates near the start of the fall semester (typically beginning between orientation and the start of classes). All students are expected to arrange to be on campus in time to take all exam parts. Failure to take the exam counts as failure of the exam (see "Special circumstances" below).

The exams will be graded within approximately one week's time, and before the start of classes. The results will be used diagnostically by the student and DGS for placement and advising purposes. Students may be given the option of taking junior/senior-level courses from the undergraduate physics major, as preparation for the graduate core courses, taking into account the exam results, performance in the summer class, and other circumstances.

Second administration. Students who need to retake any part of the exam will have a second opportunity to do so at the end of the spring semester of their first year of classes, in May. This administration will be after spring grades have been released (typically the week between final exams and commencement). Again, exams will be graded within approximately one week's time, to allow proper planning for the summer based on the results.

Any student who has not at this point passed all three segments of the exam is *required* to develop an appropriate summer study plan, in consultation with the DGS, and must allocate at least one month of study time over the summer. The department will not permit such a student to assume research commitments which would interfere with adequate exam preparation (in particular, the student cannot be on Research Assistantship support for more than 2 months over the summer). If the student *has not* already taken the corresponding part (or parts) of the Review of Physics summer course, the preceding summer, the student will be expected to do so now, and will be paid the same stipend as incoming students for doing so. Alternatively, if the student *has* already taken the corresponding part of the Review of Physics summer course, the preceding summer, the student is still welcome to optionally retake this part, but the student will *not* be paid to do so.

Third administration. Students who still need to retake any part of the exam will have a third and final opportunity to do so in August, before the fall of their second year in the program. That is, the student will sit for the same administration as the new class of incoming graduate students. Again, exams will be graded within approximately one week's time, to allow proper planning for the fall semester.

Students who have not successfully completed all parts of the exam after this third administration may either (1) opt to leave the university immediately or may (2) develop a plan for completion of the Master of Science degree in Physics, in consultation with the DGS. In this latter case, the student may remain registered for the fall semester, and the department will endeavor to provide continued teaching assistant support for this one semester. The student will be expected to complete all requirements of the Master of Science degree, including a Master's Comprehensive Exam, as detailed in Section 2.2.

4.3 Policies

4.3.1 Problem preparation

Each question will be written and approved by at least two members of the Preliminary Examination Committee. The most recent instructors of the corresponding segments of the Review of Physics summer course will also normally be called upon by the Preliminary Examination Committee to provide feedback on the exam questions, in order to help ensure that they are at the appropriate level and can reasonably be solved in the allotted time by students who have mastered undergraduate physics at the level defined above.

Complete written solutions will be prepared in advance of the exam administration and will be submitted to the department along with the exam itself. After the exam is administered, the exam and solutions will be made available electronically for inspection by the department faculty and current graduate students.

4.3.2 Administration and format

Each part of the Preliminary Examination will be administered as a 3-hour proctored written exam. The exact format of each part of the exam (*e.g.*, number of questions) may vary, to meet the goals of the exam subject to the given time constraints, and will be determined by the Preliminary Examination Committee. Students requiring special accommodations are encouraged to contact Sara Bea Accessibility Services as early as possible so that suitable arrangements can be coordinated with the department.

4.3.3 Grading

Each exam question will be graded independently by two faculty members from the Preliminary Examination Committee. Grading for each question will be on a scale of 0 to 4. The graders will independently grade a scanned copy of the student's solved exam.

The Preliminary Examination Committee chair will review the scores of both graders. If the committee chair judges that the scores differ significantly (*e.g.*, by more than 1 point) or otherwise require further review, the committee chair may convene the graders to review and

reevaluate the scores. If this does not resolve the concern, then a third grader will be called upon for that problem, and the three grades will be averaged. Grading will be blind, *i.e.*, identifying information will not be released to the Preliminary Examination Committee.

An overall score of 3 out of 4 on the exam counts as passing. The scores on the examination will be reported to the DGS, who then notifies students of their results.

If a student fails a part of the exam, the student's score for each problem (averaged over graders) will be provided to the student, and the student may request a scanned copy of the student's work on that part of the exam, to aid in future exam preparation. However, appeals of scores will not be considered by the department. The student's original work will be retained on file by the department for at least one year.

While the membership of the Preliminary Examination Committee will be public, the identities of the graders of each exam problem will not be released.

4.3.4 Extraordinary performance in coursework

The purpose of the Preliminary Examination — aside, of course, from its pedagogical purpose as motivation for a review of undergraduate physics and its use in placement and advising — is to certify that all students in the Ph.D. program have mastered a fundamental core of upper-level undergraduate physics proficiencies. This is related to, but distinct from, the proficiencies and level of accomplishment demonstrated by completing the graduate core courses.

However, students who demonstrate exceptional proficiency in a related graduate core course can be presumed to have obtained the required level of mastery of the prerequisite materials. Therefore, a demonstration of exceptional proficiency, as evidenced by a grade of A- or above, may count in place of the corresponding part of the exam. Credit for Part A: Mechanics & Thermodynamics requires an A- or above in *both* PHYS 70005 Classical Mechanics *and* PHYS 70009 Statistical Mechanics. Credit for Part B: Electromagnetism requires an A- or above in PHYS 70006 Electrodynamics. Credit for Part C: Quantum Mechanics requires an A- or above in PHYS 70007 Quantum Mechanics I.

If coursework is to be counted in place of a part of the exam, this coursework must be completed *before* the student's third attempt on that part of the exam.

Given the difficulty of comparing grading scales across institutions, transfer coursework from another institution cannot count for this purpose. (However, Notre Dame graduate coursework completed before attaining degree-seeking status in the Ph.D. program can still count.)

4.3.5 Special circumstances

It is important, for the good of both the student and the department, that the regular schedule of exams be adhered to, in order to ensure that all students complete (or learn of their failure to complete) the Preliminary Exam in a timely fashion. Failure to sit for any part of the exam will count as failure of that part of the exam, except under the following special circumstances.

Inability to take the exam due to illness/disability must be supported by medical documentation. (In the event of short-term illness, a formal medical excuse must be obtained from University Health Services. In other cases, the student will be referred to Sara Bea Accessibility Services for confidential evaluation of any documentation.) It is important to notify

the department, via the graduate administrator and/or DGS as soon as possible and, barring extreme emergencies, before the exam is administered.

Excused postponements for other extraordinary (nonmedical) circumstances, such as family crisis, should again be requested in advance of the exam and must likewise be supported by documentation. These cases must be considered and approved by a committee constituted and operating according to the department's formal Appeal Process (Section 11.2).

Note, however, that arrival on campus in time for the first August administration of the Preliminary Examination is the student's responsibility. Delayed arrival, regardless of reason, will not be considered grounds for an excused postponement of the exam.

Formal leave from the university for the fall term may be considered grounds for postponement of the August administration, and formal leave for the spring term may be considered grounds for postponement of the May administration. Similarly, a student who matriculates in the Ph.D. program on a nonstandard schedule, *e.g.*, starting in the spring semester, may be placed on a revised schedule for the Preliminary Exam, to be developed in consultation with the DGS.

The Preliminary Exam is limited to students who have degree-seeking status in the Ph.D. program. Thus, students who have non-degree status will not take the exam, even if they are being considered for matriculation as Ph.D. degree-seeking students at a later date.

Note that students are required to pass all parts of the Preliminary Examination before being considered for invitation to take the Ph.D. Candidacy Examination. However, given that the invitation to take the Ph.D. Candidacy Examination normally comes after the usual timescale for completion of the Preliminary Examination, this consideration will only be relevant in rare cases.

4.4 Exam-day guidelines

The Preliminary Examination Committee determines the resources you may bring with you to the exam. You may expect the following guidelines to apply, unless you are notified in advance of adjustments.

The exam is closed book. However, you will have use of the following resources:

(1) *Mathematical Handbook*. You will be expected to bring a copy of the *Mathematical Handbook of Formulas and Tables*. If you have not already obtained your own copy, the department maintains a few copies on reserve and available for you to check out through the Hesburgh Library reserves. It is strongly recommended that you familiarize yourself with the organization of information in the *Mathematical Handbook* in advance, so you can find information (identities, integrals and derivatives, special functions and polynomials) quickly, when needed.

(2) Reference sheet. You may bring one page of notes to the exam (in your own handwriting, and you can use both sides), containing definitions, relations, *etc.*

(3) Dictionary. If English is not your native language, you may bring a dictionary to use to clarify any unfamiliar English terms.

You may not bring any other materials. You may not use any electronic device (calculators are neither needed nor permitted).

Note that you will *not* be expected to have memorized any numerical constants.

Part II

Research, candidacy, and dissertation

5 Research advisors and co-advisors

Research advisors are chosen from the list of the regular "tenure and tenure track" (T&TT) faculty of the department, including "concurrent" T&TT faculty from other departments. A list of faculty is available on the department web site, and further information on prospective advisors who are currently seeking students is provided in conjunction with Research Orientation Seminars early in the fall semester.

It is expected that all students will make at least a tentative choice of a research advisor by the start of the second semester of graduate study. To facilitate the choice of a research advisor, in the fall semester, the DGS organizes a series of talks, the "research orientation seminars," in which professors in the department describe their research to the first-year class. Attendance of this program is mandatory. Students are also encouraged to talk individually to professors about research opportunities in the group and future opportunities for research assistant (RA) positions. Recognizing the importance of the research advising relationship, the department requires the student and the advisor to commit to each other by signing a research advisor contract (see at the end of this guide), which is given to the DGS for the department's record. For first-year students, no research advisor contract may be signed until after the presentation of all of the research orientation seminars.

An increasingly common option is for the student to select two research advisors, or "co-advisors." The two advisors may both be regular T&TT faculty in the department, or may include one T&TT faculty from the department plus a second researcher chosen from the physics research or emeritus faculty, from the faculty in another department or unit of the university, or a researcher chosen from outside the university. In the latter case, the external co-advisor must also be approved by the departmental Executive Committee on Advancement of Promotions (ECAP). The DGS will initiate the approval process by requesting a CV and passing it on to the ECAP. If a co-advisor is chosen, all parties (that is, both co-advisors and the student) must sign the research advisor contract.

Research advisor responsibilities include the suggestion of possible research problems and guidance and direction in the chosen problem. Research advisors will also advise the student on courses to supplement the required curriculum. They are expected to guide the student in professional development and to seek or provide the funding required to support the student (in the summer and also as soon as possible after the student's course work is complete). Research advisors give feedback to the student through regular research meetings and grades in the research and dissertation course. If the student has co-advisors, the co-advisors will determine a system for jointly grading the student (e.g., a joint decision on the research grade or perhaps alternation of research sections between the two research advisors).

A frequent question with co-advisors concerns the roles and responsibilities of the two advisors. The following terminology is introduced to discuss this. At least one of the two advisors must be on the T&TT faculty in the student's department; this advisor is denoted the "home-department advisor." The second advisor may also be a "home-department advisor," but if the second advisor is not on the T&TT faculty in the student's department, then this person will be called an "external advisor." A second designation, "primary advisor," is used to denote the advisor primarily responsible for the student's research. The primary advisor is generally the one who provides office or laboratory space and funding to the student. Primary advisors can be either home-department advisors or external advisors. There is no requirement that a primary

advisor be designated, that is, it can be the case that the co-advisors take near equal roles in supporting and mentoring the student. Questions of research attribution should follow normal standards in research, e.g., papers submitted to journals and presentations at conferences should only include those who were actually involved in the research work. The home-department advisor always assumes the role of making sure that academic requirements are completed by the student according to the rules of the department. An external advisor should clearly understand that the jointly shared student is a Physics graduate student, following the requirements and policies of the department as described in this guide, e.g., the student's required physics curriculum should be completed before electives are taken from the external advisor's department. Both co-advisors will be equal partners in the students written and oral candidacy exams and the Ph.D. defense, e.g., both ideally would contribute questions to the written candidacy exam. Both advisors will sign the final dissertation, so both will need to be in support of the work presented in the dissertation. And if there is a recognized primary external advisor, then the student's department chair may ask that advisor to assume responsibility for the support of the student, e.g., in the summer and after courses are complete. Clearly, both co-advisors should thoroughly discuss their roles before signing a co-advisor research contract.

The following are anticipated situations where the research contract may need to be re-negotiated or broken:

Voluntary change of research advisors or research area by the student. The initial choice of research area and an advisor by a student is considered to be somewhat tentative, requiring evaluation by all for an initial period of time. A six-month trial period is common; for theory students, the trial period might go through the end of the second year. If during this period, the student decides to change areas and/or advisors, common courtesy demands that the student first notify the current research advisor that they are thinking of a change. Changes of research advisor sometimes occur after the second year, but the new advisor and the student must both recognize that the student's "clock" does not restart after the change; a prime consideration should thus be how to accomplish the change without impacting greatly the student's time to degree. After the third year, if there is serious difficulty with a research advisor, a change can still be made, but a change of research groups will be problematic. It will be at the discretion of the DGS, chair, and new research advisor whether previous invitations to take candidacy or results of previous candidacy exams still hold for the new research situation. It is extremely important that funding opportunities be considered when making a change, since the department will not be obligated to provide support beyond what was promised when the student was first admitted. In all cases, after a new research advisor has been found, a new research advisor contract should be signed and filed with the DGS. The new research contract must include a releasing signature from the previous research advisor. This signature indicates that the change of research advisor has been discussed.

Termination of a research advisor contract by a research advisor. The research advisor contract implies significant responsibilities for the advisor, including mentoring in research and the securing of some sort of funding for that student (TA, RA, or fellowship). For the student, the research advisor contract implies a work commitment and a sacrifice of time and energy for the goal of obtaining research experience and an expected future Ph.D. So if there is a situation where the research advisor contemplates the termination of the student's contract, this must be

handled in a professional way. This includes a history of clear communication of expectations by the advisor to the student. If there is dissatisfaction with the student's research performance, the student must be told how to improve and be given time to improve. It is recommended that the research advisor document the warning in writing (see Sec. 5.5 of ACGS). If the student has not been performing adequately in research, the student's research grades should reflect this. (Two grades of U in a row in research will result in the graduate student being placed on probation; see Sec. 5.6.3 of ACGS.) If the advisor ultimately decides to terminate the student, a notification of the breaking of the research advisor contract must be given to the chair and the DGS so that the student's future in the department can be discussed.

The "divorce" of co-advisors. Either the student or the co-advisors may decide to terminate the co-advising contract. In the case that co-advisors decide to divorce, the first question to address is which co-advisor assumes sole responsibility for the student. Generally, this will be the primary advisor, but, of course, the student has a strong say in this. If the primary advisor is also external, a breaking of the research advisor contract would then leave the student without a home-department advisor. A solution to this dilemma is that the external advisor can request that either the DGS or the department chair assume the role of the home-department advisor. It is best if all "divorces" can be amicably solved, but if this is not possible, the organizational chart of the university and its reporting lines will be used to find an arbitrator for the problem (department chair, dean, or provost or perhaps an officer in the Office of Research).

6 Mentoring committees

6.1 Purpose and role of the mentoring committee

Your mentoring committee members contribute an "outside" perspective on your research progress and directions, and they are a valuable resource for professional advice and feedback. You will meet annually with your mentoring committee, or more often as needed, starting in the spring of your second year:

- Perhaps most important, the very act of periodically formulating and reassessing your research progress and goals, in preparation for the annual meeting, serves as an impetus to keep your research on track.
- The Mentoring Committee Meeting Report form (which you can find in Appendix D) then provides you with written feedback on this progress and on your goals. Note that this form also serves as your annual written feedback for purposes of maintaining good standing with the Graduate School (see Sec. 10).
- Finally, keeping in regular contact with the committee members allows them to be informed readers of your thesis when the time comes, and it helps to ensure that any problems are discovered and resolved in advance of your defense.

For that matter, it also certainly does not hurt to have a ready-made set letter writers available who have followed your work over your entire graduate career. This same committee will normally also serve as your Candidacy Exam committee and as your Doctoral Committee, *i.e.*, for your defense.

There are several reasons for establishing an advising relationship with your committee as early as your second year. This makes it possible for the committee members to shape your research and provide you with professional development resources at an early stage. The mentoring committee meeting will also encourage you to begin having conversations about your long-term research goals and professional development opportunities by your second year. The committee is then already in place so that you can proceed to candidacy as soon as these ideas solidify into a concrete thesis proposal. An important consideration in forming a mentoring committee by your second year is to ensure that you have a chance to become acquainted with your committee *before* your Candidacy Exam. If your first meeting is at an exam, it is natural to view the committee as an "inquisition panel", but, this way, your initial relationship with the mentoring committee is formed in the context of mentoring.

6.2 Assembling the mentoring committee

Your committee will normally consist — other than your advisor(s) — of three faculty members, including at least one from outside your area. This out-of-area member will also normally serve as chair of the mentoring committee meetings. The DGS is responsible for asking faculty to serve on this committee (that is not your task). However, the DGS will first solicit your input on potential members.

For the committee members from your own research area: Be sure to provide *several* recommendations for acceptable committee members in your field, not just two. Some faculty

may have conflicts you are not aware of, and some faculty are already on so many committees that it is not reasonable to ask them to take on any more at this time. Therefore, it is important that the DGS have some freedom in assembling the committees. Of course, you can express your preferred choices and reasons why these faculty might be most suitable. But please also be sure to name some alternates. (If you do not suggest alternates yourself, beware that the DGS will likely have to choose substitutes arbitrarily.)

For the out-of-area member: Departmental policy is that the DGS should give primary consideration here to balancing research committee loads among the faculty and spreading membership among the various research areas. Therefore, you are not normally expected to make suggestions. That said, if there is an interdisciplinary connection with some particular faculty member outside of your area which you think might be relevant, feel free to let the DGS know, and this information will be taken into consideration along with the other factors.

Exclusion of faculty members: Please think carefully, and consult with your advisor, about any faculty members with whom you believe it would be impossible to work effectively, either within your area or outside your area. The department policy is that students, in consultation with their research advisor(s), are allowed to exclude three faculty from consideration, similar to what is done with journals and the choice of referees.

Eligible faculty: Committee members are normally chosen from among the T&TT faculty of the university. For interdisciplinary thesis research projects, it may be appropriate for faculty from other departments to serve on the committee.

While non-T&TT faculty (such as research faculty) can serve on committees, this requires the DGS to bring your request to the departmental Executive Committee on Appointments and Promotions (ECAP) for approval. Typically, the ECAP will approve this individual to serve as an *additional* member of your committee, above the usual complement of three T&TT faculty.

A researcher from outside the university may also be chosen to serve on the mentoring committee, again with approval of the ECAP. The DGS will initiate the process by requesting a CV and a brief explanation of the individual's suitability to serve on the committee.

6.3 Scheduling the mentoring committee meeting

Your annual mentoring committee meeting should happen as early as possible in the spring semester. In any case, it should take place by the middle of the spring semester.

The DGS will send out a reminder about scheduling mentoring committee meetings at the start of the spring semester, together with an up-to-date listing of the mentoring committees. A half-hour timeslot should more than suffice.

Once you have found a time which works for your committee, contact the departmental Graduate Program Coordinator with the proposed date. If you are having difficulty finding a time which works for your committee, please let the Graduate Program Coordinator know, since the department may be able to help. The department will also assist with reserving a room, if needed.

If the Graduate Program Coordinator does not hear from you with a meeting date, the DGS will follow up with you and your advisor. Hopefully this should not be necessary.

There are circumstances where it is appropriate to hold a special research committee meeting, outside of the regular early-spring timeframe:

(1) You are expected to meet with your committee once the research, analysis, and interpretation for your thesis are substantially in place and when you have a relatively clear conception of the anticipated contents of the thesis itself (typically about three to six months before your defense). The purpose of this meeting is to discuss the planned outline and contents, so that your committee can determine if they expect this will lead to a defensible thesis. It is much better to uncover any issues in advance and thus to avoid surprises at the defense. If your committee is satisfied, they will indicate so in the appropriate place on the form ("Committee grants the student permission to schedule thesis defense"). Scheduling of the defense can only proceed once this permission has been granted.

(2) Your mentoring committee may indicate that a meeting should be scheduled sooner than the next annual meeting if there has been insufficient progress.

(3) You and your advisor might decide to call a meeting under other special circumstances, *e.g.*, if a major change in research direction is being considered.

FAQ #1 *I will be taking my oral Candidacy Exam this spring (or I have just taken it this fall). Should I still meet with my committee?*

Yes! A Candidacy Exam is no substitute for a mentoring committee meeting (it is, in fact, almost orthogonal to a mentoring committee meeting).

The mentoring committee meeting has mentoring as its primary purpose. It is where you can get guidance on professional development and discuss long term plans, rather than specifically defending a thesis topic. It is also where you get concrete written feedback on all aspects of your progress (something which does not happen in the Candidacy Exam), as required by the Graduate School to remain in good standing (see Sec. 10). And, realistically, you are able to talk freely about a variety of concerns and problems in an informal meeting which you would be unlikely to venture into in a formal examination setting. Therefore, you are expected to have a research committee meeting each spring regardless of where that may fall relative to a Candidacy Exam.

However, you have a variety of choices as to how you might wish to coordinate scheduling of the Candidacy Exam and the mentoring committee meeting. It is certainly possible (though less than ideal) to reserve time for a research committee meeting immediately after the 2.5-hour exam timeslot. However, this is strongly discouraged, as you are likely to be exhausted after the exam and thus to have a less-than-optimally-productive meeting. A more sensible approach may be to meet with the committee several weeks in advance of the exam, so that you can identify any major issues which might come up during the exam, *before* you finalize the thesis proposal. Or you might wish to meet a few weeks after the exam, so that you can follow up on any issues which arose during the exam.

FAQ #2 *One or more of my committee members will be away, or I will be away on research, for an extended period of time. What should I do about scheduling the meeting?*

It is important that all committee members be able to participate in the conversation "live", but this does not mean they need to be physically present. Remote participation by teleconference (or by speaker phone) is perfectly acceptable.

However, if some committee member is genuinely unavailable, even for remote participation, then you should simply meet with the remaining available committee members.

6.4 Preparing for the mentoring committee meeting

You are expected to update your professional CV and provide this to the departmental Graduate Program Coordinator in advance of the meeting. Be sure to list any publications or external fellowships, as the department will be tracking these.

You will need to complete portions of the Annual Mentoring Committee Meeting Form in advance. Please see the guidelines and procedures on the first page of the Annual Mentoring Committee Meeting Form (Appendix D).

Then the department will prepare an electronic packet for your committee with information on your academic progress, and share it with you and the committee in an electronic folder. The packet will include: the CV you provided, and a summary of your progress towards completing your degree requirements, and the Annual Mentoring Committee Meeting Form.

6.5 Mentoring committee meeting

The meeting itself is generally brief and informal. A designated member of your committee, who is *not* the advisor, will serve as chair of the research committee meeting. This designated chair, who is normally the out-of-area member, will be indicated on the mentoring committee listing. (Another member may substitute if the designated chair is unavailable.) Another committee member will generally serve as "scribe", completing the remaining fields in the Annual Mentoring Committee Meeting Form on behalf of the committe. (This member will typically be from within your research area and thus more readily able to take notes involving the terminology of your field.)

Please see the first page of the Annual Mentoring Committee Meeting Form (Appendix D) for further details of the meeting procedure.

It is important to note some things which your research commitee meeting is *not*:

Your mentoring committee meeting is not an exam!

Your mentoring committee meeting is not a seminar presentation!

And it is not something for which you should prepare a massive report!

Overpreparation for mentoring committee meetings may be done with the best of intentions, but it starts to became a deterrent to the meetings happening at all. Let us therefore specifically emphasize that you should *not* give any sort of formal presentation (you can save that for group meetings or your research area's official seminar). If you think it will be helpful to prepare some notes for your committee (*e.g.*, on your progress, or plans, or any unexpected challenges and delays), this is okay, but any notes should be limited to the bare minimum needed to guide the conversation. Keep them down to a page or so, at the very most!

7 Candidacy

Candidacy should be completed before the end of the eighth semester (*i.e.*, spring of the fourth academic year). Students who delay taking the candidacy examination without good cause may find themselves without stipend or tuition support.

Please also refer to the Graduate School web site for a summary of current policies on candidacy and the Candidacy Examination.

7.1 Invitation to take the Candidacy Examination

Students must be invited by the department to take the candidacy examination. This invitation is initiated by the research advisor, who informs the DGS of a student's readiness for candidacy and gives a summary of the student's accomplishments. The DGS reviews the advisor's request and ensures the student has completed the appropriate requirements (listed below). After concurring with the advisor's recommendation, the DGS formally invites the student to candidacy.

The department requires that: (1) The student has a positive recommendation from the research advisor. (2) The student has passed all parts of the Preliminary Examination; (3) The student has completed the Ph.D. course requirements (a student who has completed almost all requirements, except for taking a breadth course, will still be considered for invitation to take the candidacy exam, but candidacy will be contingent on completion of the breadth requirement); and (4) The student has a grade point average (GPA) of at least 3.000.

7.2 The written Candidacy Examination

The Ph.D. candidacy examination consists of two parts: written and oral. The written examination is given first. This examination, which is four hours in length, is confined to the student's area of specialization. Once the candidate has completed the written examination, copies of the questions should be given to the department. These will be made available in electronic form to all faculty members and to interested graduate students. A notebook of the examinations is made available to students through the department office. Each exam question is graded independently by two members of the T&TT faculty on a scale of 0.0-4.0, with 3.0 being a Ph.D. pass. When complete, a report summarizing the procedures used and the grades on the exam should be sent by email to the DGS, for the department's records. Results of the written examination are reported to the student by the research advisor.

Note: the department recommends that the written exam be given no later than 6 months after the invitation to take candidacy.

7.3 The research proposal

Part of the preparation for the oral candidacy examination is the creation of the research proposal describing the student's proposed thesis research. Preparation of this document is viewed as an important part of the "professionalization" of the graduate student. Advisors and students should work together to make sure that the research proposal reflects the student's readiness to become a candidate for the Ph.D. degree.

The student and research advisor must mutually agree upon the contents of the research proposal. The research proposal should clearly and concisely state the research problem, the research methods to be applied for its resolution, anticipated difficulties (and techniques for coping with these). It should include an introduction to the general research topic as well as citations to the relevant research literature. Since the fall 2003, copies of research proposals have been filed in a notebook available to students and the department through the department office.

Sufficient time must be given to oral exam committee members to review the research proposal in advance of the oral candidacy exam. In the Department of Physics and Astronomy, this time period is 5 business days. (This is defined as the days when the office is staffed, that is, typically Monday through Friday excluding any official staff holidays such as Christmas break, Good Friday, etc.) Students should give an electronic copy of the proposal to the department at the same time that committee members receive their copy. The office will then publicly post a copy of the research proposal on the department's bulletin board.

7.4 Scheduling the oral Candidacy Examination

Normally, the membership of the student's oral candidacy committee and is the same as the student's mentoring committee. After you have successfully passed your written exam, you will work with your committee to find an appropriate time for your oral exam. The department recommends that the oral examination be given no later than 6 months after the written exam is passed.

You will need to allow 2.5 hours for the exam. Graduate School rules specify that the oral exam should last a minimum of 1.5 hours and a maximum of 2.5 hours.

Due to the active professional travel schedules of many of the physics faculty, it can be difficult to schedule the oral candidacy exam. The following are rules agreed to by the faculty.

The primary responsibility for scheduling a tentative date for an oral-candidacy exam lies with the graduate student. The tentative date should take into account the 5 business-day period for readers of the research proposal. There are various ways to schedule a tentative date. The student may do this through individual conversations or emails with the advisor(s) and committee. Another suggestion is to use an on-line poll to suggest dates to the advisor and committee. (The student should first exclude all officially scheduled teaching times, seminars, and colloquium, and then construct a poll that can be finished quickly by all participants.) A third option is to ask office staff to assist in scheduling.

The faculty have agreed that a one-week period is a reasonable time for a request for scheduling information from a student to a faculty member. Polite reminders of the request may be sent within this week, but if no information is forth-coming in the week on scheduling availability, then the student should involve his/her research advisor. The research advisor is then asked to contact committee members about their availability for an exam.

It is unreasonable to ask faculty to tie up their schedules for candidacy-exam dates too far in advance. A month in advance is reasonable. It is not reasonable to request to schedule multiple dates for an exam.

When a tentative time is agreed upon, the time, date, and place should be recorded with the graduate student coordinator. The date the proposal is due to committee members and the office is determined at that time.

The office is responsible for scheduling the oral candidacy exam with the Graduate School at least three business days ahead of time.

Other rules agreed to by the faculty:

If at all possible, candidacy exams should be scheduled during the academic year. And while occasionally candidacy exams may occur during the summer, students must understand that this requires agreement and cooperation of all committee members. If a summer candidacy exam appears to be a necessity for a student, then the constraint of faculty availability should be taken into consideration at the time of assignment of the student's mentoring committee.

If a faculty member commits to a particular date, it takes extraordinary circumstances to renege on this commitment. Examples include illness or family emergencies. In other circumstances, e.g., a forgotten or new conflict, the faculty member will need to arrange his/her own substitute from the T&TT faculty. The DGS should be informed of the substitution.

Finally, oral candidacy exams should occur before the end of the fourth year. Note: This is a Graduate School rule. Failure to comply may result in termination of any funding from the Graduate School.

7.5 The oral Candidacy Examination

The oral examination takes approximately two hours (not less than 1.5 hours and not more than 2.5 hours). It starts with a 30-minute presentation by the student of the research proposal. The student or research advisor may invite guests to this presentation, but the guests are excused from the examination before questions from the mentoring committee begin. The examining committee will first ask questions of the student that focus on the research laid out in the research proposal. A second round of questions is typical and may include more general physics questions in addition to further questions focused on the student's research proposal.

The purpose of the oral candidacy examination is to certify that the student has sufficient command of background material and techniques to ensure successful completion of the proposed dissertation. While most questions will typically focus on the student's research area, more general questions probing the student's physics background may also be asked. The examining committee votes on the oral examination (pass/fail) immediately after the examination, with three passing votes required to pass the examination. If the committee has five members (e.g., including the co-advisor), four votes are required to pass. Successfully passing this examination constitutes approval of the dissertation proposal. After the exam is over, the committee's votes are reported to the Graduate School on an electronic Reporting Form. (Each committee member must enter a Pass/Fail vote.)

In case of failure in either or both parts of the doctoral candidacy examination, the department chair, on the recommendation of a majority of the examiners, may authorize a retake of the examination. The Graduate School must approve any such authorization. Failing the candidacy exam a second time results in forfeiture of degree eligibility and is recorded on the candidate's permanent record.

7.6 Admission to candidacy

Once the student has satisfactorily completed all course requirements, and passed the written and oral candidacy examinations, the student is admitted to candidacy. A student who has not

completed the physics breadth requirement before taking the candidacy examinations will not be formally admitted to candidacy until this requirement is complete.

Admission to candidacy for a physics graduate student implies that all formal requirements for the Ph.D. have been completed with exception of the dissertation.

Admission to candidacy is a prerequisite to receiving any graduate degree. To qualify for admission to doctoral candidacy, the student must: Have provided proof of the conferral of an undergraduate degree; be in a doctoral program; have been continuously enrolled in the program; be in good standing; have passed the written and oral parts of the doctoral candidacy examination.

There is an electronic form for applying for admission to candidacy for the Ph.D. degree. The department office prepares this form for the Graduate School after the oral candidacy examination has been passed.

A Ph.D. student who wishes to receive a MS degree, after their oral candidacy examination has been passed, must also apply for admission to master's degree candidacy. The department office can prepare this electronic form after the oral candidacy examination has been passed. [The same form is used for those students who wish to terminate with the MS degree (Sec. 2.2).]

8 Doctoral dissertation and defense

Please also refer to the Graduate School web site for a summary of current policies on the dissertation and defence.

8.1 Doctoral committee

The DGS will appoint a dissertation committee consisting of the dissertation director (a.k.a., the research advisor) and three readers. Normally, the committee is drawn from the membership of the student's oral candidacy committee and is the same as the student's mentoring committee.

In the event that the candidate's dissertation director departs the University, an additional co-director (co-advisor) from among the regular teaching and research faculty will be appointed to the dissertation committee. In exceptional circumstances, the department, by faculty vote, may recommend to the Graduate School that the former faculty member remain the sole advisor. Note: Co-directors cannot serve as readers, so if there are co-directors, the student's committee's size is increased by one in number.

8.2 The reading of the dissertation

The physics faculty have agreed that readers need sufficient time to read the thesis. The following has been agreed to by the faculty.

The dissertation is one of the most important documents that a Ph.D. physicist ever writes. The copy that is submitted to the readers should be a near final copy of the work. Specifically, readers are not expected to be editors of the thesis, so the copy that they review should have already been edited for spelling and grammatical mistakes. The research advisor(s) should also have approved the release of the dissertation to the readers.

Reading a dissertation is a serious responsibility for the faculty reader, taking a significant amount of time. The Graduate School suggests that readers be given a two- to four-week period to read and approve/reject a dissertation. The physics faculty discussed this requirement and agreed that the time period for physics should be set to 15 business days. (This is defined as the days when the office is staffed, that is, typically Monday through Friday excluding any official staff holidays such as Christmas break, Good Friday, etc.)

The office is responsible for setting the clock on the 15 business-day reading period. To clarify, suppose a student delivers a dissertation to readers on a Wednesday. The count starts on the next day, Thursday. If there are no official holidays in the time period, then the readers have through the Wednesday three weeks later to read the dissertation and decide whether it is approved or rejected. Readers should all be given a copy of the dissertation on the same day, in the format that each prefers (electronic or hard copy). For purposes of setting the clock, the office needs to receive an electronic copy on the same day.

Readers should not be given multiple drafts of the dissertation during the reading period. A reader has the right to ask the 15 business-day clock to be reset to 0 if students present a new draft or chapter(s). An insufficiently edited dissertation may also be returned to the student, again resetting the 15 business-day clock for the readers.

8.3 Scheduling the defense

You will work with your dissertation committee to find an appropriate time for your defense. You will need to allow 2.5 hours for the defense. Graduate School rules specify that the defense should last a minimum of 1.5 hours and a maximum of 2.5 hours.

Due to the active professional travel schedules of many of the physics faculty, it can be difficult to schedule the defense. The following rules have been agreed to by the faculty and are similar to those for the oral candidacy exam.

The primary responsibility for scheduling a tentative date for a defense lies with the graduate students. The tentative date is based on the 15 business-day reading period plus the three business-day for scheduling with the Graduate School. There are various ways to schedule a tentative date. The student may do this through individual conversations or emails with the advisor(s) and committee. Another suggestion is to use an on-line poll to suggest dates to the advisor and committee. (The student should first exclude all officially scheduled teaching times, seminars, and colloquium, and then construct a poll that can be finished quickly by all participants.) A third option is to ask office staff to assist in scheduling.

The faculty have agreed that a one-week period is a reasonable time for a request for scheduling information from a student to a faculty member. Polite reminders of the request may be sent within this week, but if no information is forthcoming in the week on scheduling availability, then the student should involve his/her research advisor. The research advisor is then asked to contact committee members about their availability for the defense.

When a tentative time is agreed upon, the time, date, place, and title of the dissertation should be recorded with the graduate student coordinator. The deparment should also be provided with an electronic copy of the dissertation. The coordinator will not schedule the defense with the Graduate School until all signed readers' reports have been received. Readers must make a decision on whether they sign the form by 15 business days after receipt of the dissertation.

Also agreed upon by the physics faculty were the following policies regarding defense scheduling:

Many of the physics faculty are involved in research both off-campus and abroad. The summer time is the prime season for scheduling off-campus experiments and conferences. It is also the time when faculty takes vacation. Students should not expect that faculty will be able to commit to a student defense during the summer. It is fine to try to schedule a defense in the summer, but it will take far more flexibility on the part of all committee members than during the academic year.

The department expects that the committee assigned at the time of oral candidacy will continue to track the student's progress through the defense. Thus, every scheduling effort should involve attempting to schedule a defense at a time convenient to all advisors and members of the committee.

Exceptions to this policy can exist, e.g., the illness or unavailability (e.g., due to sabbatical) of someone on the committee or a particularly awkward convergence of conflicts in proposed times of the defense. First, the student should explore conducting the defense with one faculty member present by "virtual link." If this does not work, then the student may request the replacement of someone on sabbatical. During the academic year, the responsibility for a sabbatical replacement lies with the DGS. During the summer, the responsibility for organizing

a replacement lies with the student and research advisor, in consultation with the DGS. Every attempt should be made to keep the substitutes to just one.

If a faculty member commits to a particular date, it takes extraordinary circumstances to renege on this commitment. Examples include illness or family emergencies. In other circumstances, e.g., a forgotten or new conflict, the faculty member will need to arrange his/her own substitute from the T&TT faculty. The DGS should be informed of the substitution.

8.4 Doctoral defense

In defending the dissertation, the student supports its claims, procedures and results. The defense is the traditional instrument that enables the doctoral candidate to explore with the dissertation committee the dissertation's substantive and methodological force. In this way, the candidate and the committee confirm the candidate's scholarly grasp of the chosen research area.

The format of the defense is determined by the department with the Graduate School's approval. At the defense, the student starts by giving a 30 minute presentation of his or her research. The time and location of the first 30 minutes of the defense will be advertised, with the talk open to all interested parties. Guests are excused from the defense once the questions begin. The student will be questioned on the research by the dissertation committee. A dissertation defense must last at least 1.5 hours and end before 2.5 hours. After the examination is completed, the chair calls for a discussion followed by a vote of the dissertation committee. At least three votes out of four will be required to pass a candidate, and four votes on a five-person committee. After the defense is over, the committee's votes are reported to the Graduate School on an electronic Reporting Form. (Each committee member must enter a Pass/Fail vote.)

In the case of failure of the defense, on the recommendation of a majority of the examiners, another opportunity to defend may be authorized. An authorization for a second defense must be approved by the Graduate School. A second failure results in forfeiture of degree eligibility and is recorded on the candidate's permanent record.

8.5 Submission of the doctoral dissertation

Before a Ph.D. student can submit his or her dissertation to the Graduate School office, he or she must have successfully defended it. Even though the dissertation has been approved for defense, revisions may be required. If defects in the dissertation come to light at the defense, the student may be asked to revise the dissertation before it is accepted by the Graduate School and the degree is conferred. In that case, it will be the responsibility of the research advisor(s), or such person as the defense committee may appoint, to report to the Graduate School that such revisions have been completed satisfactorily.

Formatting and submission instructions, forms and links are available via the Current Students page at `http://graduateschool.nd.edu`.

Part III

Administrative policies

9 Registration Policies

9.1 Registration and Enrollment

Reference: ACGS, Sec. 3.1

Students must register and complete ND Roll Call ("enrollment") before each semester and summer session at the time and locations announced by the University Registrar.

When registering for classes each semester, students are expected to indicate if they plan to graduate. You will by default only see an option to add yourself to the Ph.D. graduation list. If you wish to put yourself on the M.S. graduation list, contact the departmental Graduate Program Coordinator to have this option manually added. Also, if you did not indicate during Rollcall that you wish to put yourself on the graduation list, but later wish to be added to the list, contact the departmental Graduate Program Coordinator to be added.

9.2 Maximal Registration

Reference: ACGS, Sec. 3.7

During the academic year, a graduate student may not register for more than 15 credit hours of graded graduate courses each semester, i.e., 60000-, 70000-, 80000- and 90000-level courses. (In Summer Session that limit is 10 credit hours.) Exceptions to maximal registration must be approved by the DGS and by the Graduate School.

9.3 Auditing a Class

Reference: ACGS, Sec. 4.3

With the permission of the instructor and the DGS, the student may also audit courses. (A form to request that a course be marked as audited is available through the Graduate School web site.) Normally, graduate students are limited to auditing two courses per semester. A recorded audit is graded V. Incomplete audits are not recorded. The audit grade of V cannot be changed to a credit grade. In the academic year, full-time graduate students may audit courses without charge. In the summer session, there are no free audited courses. Any course taken or audited in the summer session will be charged at the full price.

9.4 Changes in Class Schedule

Reference: ACGS, Sec. 4.2

Once the semester begins, students may add courses only during the first six class days of the semester. After this time, students may add courses only on the recommendation of the department and with approval of the Graduate School.

Students may drop courses during the first six class days of the semester. To drop a course after this period and up to the mid-semester point (see the Graduate School Calendar for the exact date), students must have the approval of the department offering the course, the physics

DGS, and the Graduate School. A course may be dropped after the mid-semester point only in cases of serious physical or mental illness. Courses dropped after this date will be posted on the student's permanent record with the grade of "W." It is expected that students receiving a stipend will maintain a full-time schedule.

Warning: The consequences of dropping and adding a course in the first six days of the semester may be serious. Students should consult with the DGS to discuss any changes in schedules.

9.5 Grades

Reference: ACGS, Secs. 3.5 and 4.5

For an explanation of the grading scale, see ACGS, Secs. 4.3 and 4.5.

Note: There are rules about the assignment of the grade "incomplete" and the time frame for completion of the work by the student: See ACGS, Sec. 4.4. The student has 30 days from when grades were due to complete the coursework. If coursework is not completed by that date, the grade of "I" is changed permanently to the grade of "F."

9.6 Summer Session

Unless you are receiving your degree and leaving in May, you need to register for the summer term. The main reason is to ensure that you maintain your student status for tax purposes. Otherwise, FICA taxes will be deducted from your summer stipend. You should be sure to register early, *e.g.*, by the end of the spring semester, to make sure you are classified correctly in the first summer pay period.

Normally, you need to register for PHYS 67890 Independent Summer Research. This is a zero-credit course. It will not show up on your transcript. It is there precisely for the purpose of letting you sign up for a course to keep your student status.

However, if you plan to receive a degree in August (either your master's or your Ph.D.), the grad school asks you to instead sign up for PHYS 98699 Research and Dissertation. The difference is that this course *will* show up on your transcript, and the grad school seems to care that you are registered for such a course in your final term of enrollment. There will only be one section (98699-01), with the DGS listed as instructor, and it will count for zero credits. You will need to request permission from the department to register. Also, in this case, be sure to indicate that you are "graduating" (receiving a degree), when you complete the registration.

If you have any courses (that is, real courses, as opposed to zero-credit administrative niceties like the above!) that you want to take over the summer, be sure to see the departmental Graduate Program Coordinator. There is a tuition waiver form you will need to complete (otherwise you *will* be charged!).

You will also need to complete the summer "roll call".

10 Good Standing, Progress, and Assessment

10.1 Annual Advising Meetings and Written Assessment

The Graduate School requires that all students receive annual written feedback from the program (see Sec. 5.5 of the ACGS). It is expected that this feedback will call attention to any problems that might lead to the student not being in good standing.

Near the end of your first year, either in late spring or over the summer, you will schedule a first-year advising meeting with the DGS. The First Year Advising Report (see Appendix C) is completed partly by the DGS during this advising meeting (for academic progress) and partly by your research advisor in a separate discussion (for research progress).

In subsequent years, you will have an annual spring Research Committee meeting (Sec. 6.5), and your Research Committee Meeting Report (see Appendix D) will be completed during the meeting.

10.2 Satisfactory Progress and Maintaining Good Standing

The Graduate School has established two status definitions for graduate students (see Sec. 5.6 of the ACGS): *in good standing* or *on probation*. In summary, a student is in good standing if enrolled and making satisfactory progress towards their degree. To remain in good standing, you must meet certain basic criteria applied by the Graduate School, plus you must meet the department's own specific criteria.

As described in Sec. 5.6.3 of the ACGS, a student will lose good standing based on failure to meet the Graduate School's requirements under the following circumstances:

(1) A cumulative grade point average below 3.0 in any two semesters;

(2) A failure to pass candidacy exams by the end of the eighth semester; or

(3) Earning a grade of U in research for two consecutive semesters.

The department furthermore applies the following more specific standards at the end of each academic year to judge satisfactory progress:

Academic progress. By the end of your *first year*, you must have completed at least 5 of the 6 Core course requirements. You must also complete the Preliminary Exam according to the schedule and policies described in Sec. 4. By the end of your *second year*, you must have completed the Core course requirements and at least 2 of the 3 required Research Area course requirements. By the end of your *third year*, you must have completed all course requirements, including the Experimental Proficiency Requirement (Sec. 1). You may satisfy these requirements either by completing the course at Notre Dame or by waiver or transfer (Sec. 3). Exceptions to this schedule must be approved in advance, in writing, by the DGS.

Research progress. By the end of your *first year*, you must have identified a tentative advisor, signed an advising contract with this advisor, and successfully completed at least one credit of Research and Dissertation with this advisor. In *subsequent years*, you must maintain enrollment in Research and Dissertation each semester.

Annual written assessment. At the end of your *first year*, you must complete your First Year Advising Meeting (Sec. 10.1), as evidenced by submission of the signed report form to the department. In *subsequent years*, you must complete your annual spring Research Committee meeting (Sec. 6.5), as evidenced by submission of the signed report form to the department.

Service. You are also expected to satisfactorily perform any assigned TA duties. Failure to do so may result in loss of good standing according to the procedure defined in Sec. 12.1.

The student and research advisor should both be aware of the "clock" of time elapsed: you need to pass candidacy by the end of the fourth academic year, there is no possibility of receiving a graduate assistantship stipend (that is, TA support) past the end of the sixth academic year, and Ph.D. eligibility can be lost at the end of the eighth academic year. The department will also attempt to remind students and advisors of the approach of these time limits.

Students will be informed of concerns about their progress to degree by a warning letter (described in Sec. 5.5 of the ACGS).

10.3 Probationary Status and Dismissal

As described in Sec. 5.6 of the ACGS, either the department or the Graduate School may place a student on probationary status. Probation is intended to offer the student a final opportunity to correct deficiencies. Normally, a student will be on probation for one, or at most, two semesters. Students on probation are ineligible for financial support from the Graduate School (see Sec. 5.6.2 of the ACGS for details).

A student may be dismissed from the physics program for failure to complete requirements by the established timeframe for them (see Sec. 5.7 of the ACGS). Students will be notified in writing of the decision to dismiss them. The student may appeal the decision (as described in Sec. 5.8 of the ACGS).

11 Resolving problems

11.1 Departmental support structure

The advisor and mentoring committee are primary sources of advice and support for the graduate student. It is important to establish and maintain good communication with both the advisor and the committee to provide a space for discussion of expectations, goals and concerns.

Students are welcome to contact the DGS in the event that they experience difficulty in coping with the course work or other aspects of graduate student life. Any issues regarding the relationship between the student and their advisor and/or mentoring committee should be brought up to the DGS. Likewise, others in the department (students, postdocs, faculty, and staff) are urged to contact the DGS if they observe that a graduate student is having difficulties.

The DGS will help the student explore options for the resolution of these difficulties. In the event that the student has a conflict or problem with the DGS, he or she should bring the concern to the attention of the department chair.

In addition to the traditional advising/support structure, the Department provides services of an ombudsperson. The department ombudsperson provides a safe forum for the graduate students, undergraduates and junior faculty to present complaints or discuss issues. The ombudsperson can provide advice on how to proceed when a conflict arises and where to report an issue if necessary. The ombudsperson is required to follow the Title IX reporting guidelines. The contact information for the current ombudsperson is provided here:

`https://physics.nd.edu/about/resources/`

If you would like to discuss your concerns with a person outside of the Department, the Graduate School also provides an ombudsperson:

`https://graduateschool.nd.edu/policies-forms/graduate-school-ombudsperson-speak-up/`

11.2 Department Grievance Procedures and Appeal Process

Reference: (ACGS, Sec. 5.8)

The Graduate School has developed a Grievance and Appeal Procedure to give students the opportunity to resolve complaints dealing with academic issues such as dismissal, being placed on probation, denial of readmission, and any other program decisions that terminate or impede progress to degree. The Graduate School also requires each program to have a formal grievance program approved by them.

In the event that a student has an unresolved complaint or grievance with the department, he or she may appeal in writing to the department chair and/or the DGS. The department chair (or DGS) will then appoint an ad hoc appeals committee of three faculty members to investigate the complaint. All faculty members on this committee must be unconnected factually with the case or reasons for appeal. This committee may include the DGS or department chair, unless the DGS/department chair has been involved in the case.

The student's written statement should include details of the nature of the problem, the date(s) the problem occurred, the grounds upon which the appeal is based, background information that the student considers important, and the relief requested.

The appeals committee will promptly and thoroughly investigate the appeal to determine whether the relief requested is warranted. The investigation may include interviews and/or written statements from the student, any student witnesses, faculty or staff members who may be able to provide pertinent information about the facts, as well as a review of pertinent documents. In most situations, the appeals committee will complete the investigation in 30 business days (Note: Business days do not include weekends or employee holidays as recognized by the University.) There may be some reports that cannot be investigated within 30 business days. In such cases, the chair of the appeals committee will communicate to the student that the investigation is going to take longer than 30 business days and will also include a statement indicating when the committee anticipates completing the investigation. The DGS/department chair will notify the student in writing of his/her decision. If the DGS/department chair has been involved in the case, the notification will be from the designated chair of the appeals committee.

11.3 Conflicts in Responsibilities

Graduate students are frequently in positions where they hold multiple responsibilities, often reporting to multiple people, e.g., TA supervisors and research advisor(s). If there are issues that result in conflicts of responsibility, the student should consult with the DGS or department chair for advice on how to resolve that conflict. In situations involving course work, teaching, and research, generally course work takes priority over teaching (e.g., a student should not be asked to grade exams during the time when a class is held) and teaching over research (e.g., the student should not be asked to attend a group meeting that conflicts with a teaching assignment).

11.4 Statement on Mentoring

The University of Notre Dame and the Physics graduate program recognize that, to be a good advisor to graduate students, one must be a good mentor. We believe that advisors should provide engaging, constructive, and supportive environments for the graduate students they oversee and serve. The advisor-graduate student relationship should be one of open communication and transparency, personal and professional development, and respect. Advisors should prepare graduate students to facilitate a thriving learning community and serve as leaders in their future careers. *[Adopted December 10, 2021.]*

12 Financial Support

In order to be eligible for University funding, the student must be enrolled full-time, seeking a graduate degree at Notre Dame, and be in academic good standing (defined below).

Financial support allotted by the Graduate School for distribution by the department includes academic year tuition scholarships, graduate assistantships, health insurance subsidies, and departmental fellowships, as well as summer session tuition scholarships and University fellowships.

All entering graduate students and some continuing students in good academic standing are awarded graduate assistantships (or fellowships) from the University. In physics, all graduate assistantships (GAs) are teaching assistantships (TAs) and have duties and responsibilities as discussed below.

Students are expected to transition to research assistantship (RA) funding once they are fully engaged in research, as soon as their research advisor's funding permits. This transition should occur no later than the end of the student's second year, except in unusual circumstances. For research advisors without external financial support, the department has typically committed GA support through the student's fifth year.

12.1 Teaching Assistantships

Teaching assistants (TAs) typically assist in undergraduate and graduate laboratories, tutorial sessions, or with grading problems or examinations. The time required for these duties is normally 15 hours per week. Detailed TA information is posted on the department web site.

Before teaching assignments are made, the supervisor of teaching assistants will ask the faculty their needs and preferences for TAs and also ask the TAs for their preferences for teaching duties. Preferences are considered, and honored when possible, subject to the constraint of meeting the department's needs. Minimal revisions to assignments are made during the first week of classes when scheduling conflicts occur. Problems with the teaching assignments, the supervisor, the TA, or the TA's teaching load should be called to the immediate attention of the DGS.

At the end of each semester, every teaching assistant is rated by the faculty on the manner in which he or she has performed these duties. The student will receive periodically or on request a summary of those ratings. A student who has performed his or her assigned duties poorly will receive a letter of warning. If his or her performance has not improved by the end of the period specified, then that person risks being not in good standing with the department on the basis of service and will either lose the TA stipend or have the TA stipend reduced.

12.2 Research Assistantships

Post-candidacy students may be supported by research grants made to their research advisor from agencies outside the University. The duties required for such grants are defined by the research director and the continuation of such support is subject to the availability of funds and the advisor's discretion. Not all professors have such grants.

12.3 University and External Fellowships

The department and University also award fellowships to a number of highly qualified graduate students. Notification is by letter.

Information on fellowships available from inside and outside of the University is shared periodically with the students and advisors via the department e-mail list-servs. Students and advisors are also urged to do their own searching for academic-year and summer fellowship opportunities. Information is also posted on the Graduate School and the department websites.

12.4 Loss of Graduate Assistantship Stipend

A student placed on probation will lose financial support from the Graduate School (stipend, full tuition, health subsidy, and professional development funds) except for a tuition scholarship that covers eight of the nine credit hours required to maintain full-time status (see ACGs, Sec. 5.6.2).

It is Graduate School policy that students beyond six years of enrollment are ineligible to receive a GA stipend.

The department through its admission letter guarantees five years of academic-year support for those students in good standing. This support will be removed if the student has a history of performing his or her assigned TA duties poorly; in those cases the student will be designated as being not in good standing in the department on the basis of service and may lose their financial support.

12.5 General Rules

Assistants and fellows who receive a full stipend should not be employed elsewhere either on or off campus. Graduate students are provided stipends so that they can devote full time to their studies. Therefore, they are discouraged from taking part-time employment. If students have a personal or professional reason to claim exception, part-time work must be approved by the graduate advisors (the DGS and research advisor), the primary employer, and the Graduate School.

Assistants and fellows who receive a full stipend should also take a full-time academic schedule, defined to be at least 9 credit hours per semester. Details of courses appropriate for this schedule are given earlier in this guide.

Recipients of federal financial aid must comply with the standards of progress set by their respective departments for their particular programs of study. The director of financial aid will notify students in writing when failure to maintain progress will result in the loss of financial aid. Appeals indicating mitigating circumstances must be made in writing to the director of financial aid.

12.6 Tuition Scholarships

All entering graduate students and all continuing students in good academic standing and on stipend support are awarded academic year tuition scholarships. These cover full-time schedules (9 credits or more) for students in years one to eight. A graduate student cannot receive

more than eight academic years of tuition support from the Graduate School or from funds allotted by the Graduate School to departments.

After the eighth year of graduate study, the student will require both a Graduate School approval for continued Ph.D. eligibility (ACGS, Sec. 6.2.6) and will need non-graduate school funds for tuition for courses. The minimal registration to remain a graduate student is 1 credit during the academic year (part-time). Students completing graduation requirements early in the semester and those completing their degree away from campus may save on tuition by being non-resident (see ACGS, Sec. 3.3). Students needing campus facilities (e.g., laboratories, computers) to complete their research work should retain resident status.

12.7 Summer Funding

Summer funding is provided primarily through external funding obtained by the research advisors. A limited number of TA positions and fellowships exist for summer. The department develops a list of those graduate students desiring summer TA support. In consultation with the chair, the DGS then makes the summer TA assignments.

12.8 Student Health Insurance Subsidy

The cost for a single student for health insurance will be completely covered by the University for students who are fully funded. Doctoral students must be in their first 8 years of study to be eligible for a health subsidy.

Students who plan to graduate in January have the option to enroll in insurance for the fall term only. This allows those transitioning to a job to enroll in their employer's plan starting January 1.

It is possible to waive the student insurance plan under certain circumstances. The deadline for doing this is September 15.

Informational e-mails with current details will be sent out by the departmental Graduate Program Coordinator at the start of each semester.

13 Communication

13.1 Formal Communication

The department communicates important decisions to students via letters. The actual offer of admission comes to the student from the Graduate School, but is always associated with a letter of intent, sent first by the department to the student. Fellowship notifications are also sent by letter.

Generally, results of examinations are sent to students by letter. Preliminary examination results are sent by the DGS to the students. The result of written candidacy examinations is communicated to the student by the research advisor. The result of oral candidacy examinations, the master's comprehensive examination, and the Ph.D. defense is sent to the student by the Graduate School.

For students who are not in good standing, or for those in danger of losing good standing, warning letters are sent by the Graduate School and/or the department.

13.2 Support Notification

For the first-year of graduate studies, support notification occurs through the student's admission letter. After the first year, the student is required to have a research advisor. It is the responsibility of the research advisor to communicate support commitments for a given year (e.g., RA or TA) directly to his or her students.

Due to the cyclical nature of external funding, support arrangements can change for a student through the course of a year. If an advisor gains a source of new external support, the appropriate time to change the student from TA to RA is before the next semester begins. The department assumes that the advisor discusses this change in funding directly with the student. Questions on support status should be brought to the Business Manager, the research advisor, the DGS, or the chair, as appropriate.

13.3 General Communication

Much of the department's day-to-day communication is done by electronic mail sent to the student's Notre Dame email address. Students are expected to check their Notre Dame email on a daily basis during the academic year.

The department maintains a list-serv of all of its graduate students. Regular messages will be sent using this list-serv by the department chair, the Business Manager, Graduate Student Coordinator, and the DGS. These emails will include reminders of deadlines and special opportunities for graduate students.

A request for the distribution of a list-serv message to the graduate students can be made by sending a message directly to the list-serv. The message will be distributed if it is judged to be in the best academic interests of the students.

Occasionally, students do not receive email due to mistakes in email configuration or forwarding. It is the student's responsibility to ensure that the department's email can be received.

Important messages to graduate students will also be distributed in written form to graduate student mailboxes in the Department of Physics and Astronomy. Students should also check

their mailboxes on a daily basis during the academic year.

The chair and DGS will periodically hold "town hall" meetings with the graduate students. General questions and concerns of graduate students should be discussed at these meetings. Additionally, students are urged to bring individual questions and concerns directly to the attention of the DGS or chair.

There is a bulletin board outside the main Physics Office that is exclusively for graduate students. Please refer to the bulletin board for information on job opportunities, career training opportunities, course information, upcoming events, etc.

13.4 Department Web Site

The department will maintain a copy of this guide on its web site, `http://physics.nd.edu/`. The DGS will work with the department on maintaining up-to-date information in that location for graduate students. Suggestions for new topics to be posted there can be brought to the DGS.

13.5 Calendars

The Academic Calendar for the university is maintained on the Registrar's web site. Also found in that location is the schedule for department examinations and final examinations.

The GSU and the Graduate School also maintain calendars of events for graduate students. Also maintained on the Graduate School web site is a calendar of important deadlines for graduate students.

Schedules of the department's research seminars and colloquia are maintained on the department's web site.

14 Miscellaneous policies

14.1 Leaves and Related Options

Students considering a leave of absence should see ACGS, Sec. 5.1.

Students needing a temporary interruption of the physics graduate program should see graduate school policy on medical separation from academic duties, ACGS, Sec. 5.2

The childbirth and adoption accommodation policy can be found in ACGS, Sec. 5.3.

Withdrawal policy is described under ACGS, Sec. 5.4.

The DGS is available to discuss the meaning of these different options with any interested student.

14.2 Family Support

The Graduate School's statement on family support:

> *"A Catholic University, Notre Dame is committed to fostering a family-friendly environment for its graduate students, one that makes it possible for those students to balance successfully their parenting responsibilities and their academic pursuits. To that end, the Graduate School at the University of Notre Dame offers the following policies and initiatives..."* (See the family support section of the Graduate School's web site).

Faculty and graduate students are in particular directed to the Childbirth Accommodation Policy (see ACGS, Sec. 5.3).

New mothers associated with the department are welcome to use the Nieuwland Lactation Lounge, located in Room 236 Nieuwland. See the Graduate Program Coordinator for help.

Note that the spouses and children of graduate/professional students are eligible to use the Notre Dame Wellness Center. This center includes pediatric care.

The department does not have written policy on visits to the department of family members. Generally, family members are welcome to visit offices within Nieuwland Science Hall. Visitors are not allowed in teaching and research labs without the permission of the lab director and/or anyone else responsible for laboratory safety.

Also of interest is the reference on the Graduate School's web site to information on how to create a family-friendly department.

14.3 Policy for Pregnant Graduate Students in Labs

The following is the Graduate School's policy for pregnant students working in lab settings:

> *"Exposure to certain chemicals, biological agents and radiation has proven harmful to fetuses, especially in the first three months. For those pregnant graduate students whose research requires them to be present in laboratories where there is a potential biological, chemical or radiation risk to her unborn child, the Graduate School strongly recommends that they immediately inform their advisers of their*

pregnancy, and then contact the Office of Risk Management. This Office is dedicated to providing professional advice in the areas of safety, occupational health, environmental protection and risk management. Safety professionals can advise the student (and the adviser) about the effects of harmful materials on the development of the fetus, particularly in the critical first three months, and recommend that the woman avoid the laboratory for a certain period of time."

14.4 When a Student is Ill

When a student is ill, he/she should seek any needed medical attention and notify anyone in the department who may be affected by the student's absence from campus. For illnesses of short duration, the student's TA supervisors, instructors and research advisor(s) should be notified, as appropriate. If possible, TAs should attempt to find their own substitutes for their TA duties, and then notify the supervisor of the arrangement. For classes, instructors will be able to help students in various ways, e.g., by giving extensions of homework deadlines. If the illness is of long duration, the student should consult with the DGS on whether a leave or another option is appropriate (see part II).

14.5 Problems

Students should feel welcome to contact the DGS in the event that they experience difficulty in coping with the course work or other aspects of graduate student life. Likewise, instructors in graduate courses, research advisors, and mentoring committees are urged to contact the DGS if they observe that a graduate student is having difficulties.

The DGS will help the student explore options for the resolution of these difficulties. In the event that the student has a conflict or problem with the DGS, he or she should bring the concern to the attention of the department chair.

14.6 Professional Travel

If a student is travelling professionally, e.g., to a workshop or meeting or to do research, then a Memorandum of Proposed Travel form must be filed with the department office in advance of that travel. There are sometimes occasions when students still in classes will need to travel professionally; in those cases, instructors should be consulted on whether arrangements can be made for making up the work missed. If a student is on TA, then TA responsibilities take priority over research responsibilities. Thus if a TA is considering professional travel, he/she will need to make acceptable arrangements with his/her supervisors for covering his/her duties before committing to the trip.

Travel reimbursements are processed through the Physics Department Office. At the time that the Memorandum of Proposed Travel form is submitted you will also need to submit the Student Business Travel Certificate form. This form is required by Accounts Payable in order to be reimbursed. Both forms are available through the Physics Department Office.

The Graduate School has dedicated travel funds to help support the professional development of graduate students (for research, conferences, summer schools, *etc.*). Please refer to the

Graduate School web site section on Graduate Professional Development Awards for deadlines and for the application details.

The Graduate Student Union's Conference Presentation Grant also may be used, more specifically, to support students traveling to present their research. Information on this award is likewise available on the Graduate School web site.

14.7 Vacations

Note: The department does not have written policy on vacation scheduling by graduate students (or by the faculty). For students on TA support, it is expected that the students will be present on campus during the time when classes and finals are held. The breaks between semesters are generally viewed as research time; it is assumed that graduate students will consult with their research advisors on any plans to take time off during those breaks (this excludes university scheduled holidays). Similarly, students on RA or fellowship support are expected to consult with their research advisor(s) on their work schedules during the time period for which they are paid.

14.8 International Students

Notre Dame sponsors most international graduate students for the purposes of their visa applications, providing the appropriate visa application documents, e.g., the I-20 for the F-1 visa and the DS-2019 for the J-1 visa. International students should be aware that there are academic circumstances where they may need to consult with the local Immigration Services Office (ISO) in order to remain in lawful immigration status.

The department is required to notify ISO when a graduate student changes his/her degree level or status. Situations included in this are additions of new degree programs, a change from a Ph.D. program to a MS program, or a change of academic program. Additionally, the department is required to report to ISO within two days of occurrence when any F-1 or J-1 visa holders: Are suspended, dismissed, or terminated from the program; terminate their programs early for any reason at all (withdrawal, leave of absence, etc.); engage in research or study abroad; engage in research at another location in the United States outside of Notre Dame; will complete their degrees from outside the United States.

International students may occasionally run into difficulty with visa issues when travelling outside the United States. Occasionally, a physics student receives a visa check. If the visa check occurs between semesters, the student may be delayed returning to campus to either take or teach classes. Students in such situations should notify the department immediately of their status so that contingency plans can be made.

14.9 Academic Integrity Policy

Please see Secs. 5.9 and 5.10 of the ACGS for the university's policy on academic integrity and on falsification of academic credentials.

14.10 Other Graduate School and University Policies

Physics graduate students are students in the Department of Physics and Astronomy, in the Graduate School, and also in the University. Students are bound by a series of codes, rules, and policies which regulate student life at Notre Dame. Some of these are rules and policies created by the Department of Physics and Astronomy. Others are rules and policies of the Graduate School. And others are rules of the University itself.

Students are bound throughout their stay by the version of these regulations in effect at the time they were first admitted for graduate work. However, if a new regulation is adopted which is less stringent than the one previously in effect, the new regulation applies also to the graduate students currently enrolled in the department. If, in unusual circumstances, a student's program or status is at variance with these regulations so that an exception must be made, such an exception must be approved by the physics faculty upon the recommendation of the DGS.

This guide is the primary source of information for rules and policies specific to graduate students in the Department of Physics and Astronomy.

A primary source of information for Graduate School rules and regulations is the Academic Code of the Graduate School (ACGS) (included at the end of this guide) and other information posted on their web site. If there is any contradiction in policy between this guide and the ACGS, then the ACGS's statement of the rule takes precedence.

A primary source of information for the University's rules is du Lac, which is available through the web site of the Office of Residence Life and Housing. If there is any contradiction in policy between this guide and the Grad Handbook, then the Grad Handbook's statement of the rule takes precedence.

Graduate students should refer first to the section of du Lac entitled "University Standards of Conduct." This section describes a number of university policies, including those for sexual harassment, sexual misconduct, smoking, and use of alcohol and controlled substances. Students should become familiar with this entire section of du Lac. Unless otherwise noted, the policies and procedures of du Lac apply to all students, undergraduate, graduate, or professional, on or off campus. In reading these sections, please remember that these policies are in place for the benefit of the University community as a whole. For example, harassment policies list types of behaviors that could get a graduate student into trouble (e.g., when acting as a teaching assistant) and also provide steps to follow if he or she believes that he or she is the victim of either discriminatory or sexual harassment.

Finally, there are many helpful sections in du Lac describing university services that are available to graduate students.

15 Other Resources

Graduate students will find helpful information through the Graduate School web site (`http://graduateschool.nd.edu/`). Worth visiting is the section entitled the "Graduate Student Life," which includes references to family support, health and spiritual resources, recreational and athletic opportunities.

The section of the Graduate School web site entitled "Professional Development" is organized according to four components: Research, teaching, ethics, and career. Many interesting workshops are organized by the Graduate School; it is possible to synchronize a student's google calendar to the Graduate School's schedule of events. All new graduate students will be required to attend an ethics training workshop. This workshop will be held in January, at a time and place to be announced.

The Department of Physics and Astronomy typically has two student representatives to the Graduate Student Union (GSU) (`http://gsu.nd.edu/`). GSU meetings are generally open for all interested graduate students.

Within the department, the Graduate Physics Students (GPS) organization provides help and support to graduate students.

A Standard syllabi for the core courses

PHYS 70003: **Mathematical Methods in Physics**

- Linear vector spaces
- Matrices
- Group theory
- Complex variable theory
- Infinite series
- Special functions
- Differential equations

Text: K. F. Riley, M. P. Hobson, and S. J. Bence, *Mathematical Methods for Physics and Engineering: A Comprehensive Guide*, 3ed.

PHYS 70005: **Classical Mechanics**

- Lagrangian formulation of classical mechanics
- Hamiltonian formulation of classical mechanics
- Mechanics of a particle
- Systems of particles
- Rigid bodies
- Theory of small oscillations
- Central force motion and harmonic oscillators
- Special Relativity

Optional topics:

- Continuum mechanics
- Non-linear dynamics and chaos
- Hamilton-Jacobi theory

Text: Herbert Goldstein, Charles P. Poole, and John L. Safko, *Classical Mechanics*, 3ed.

PHYS 70006: **Electrodynamics**

- Electromagnetic fields: Maxwell equations, potentials, gauge freedom, and conservation laws
- Waves in vacuum
- Covariant formulation of electromagnetism; Lagrangian and Hamiltonian methods
- Properties of conducting, dielectric, and magnetic matter
- Electrostatics and magnetostatics: multipole expansion and Green functions
- Waves in matter, dispersion, guided and confined waves
- Retardation and radiation
- Scattering and diffraction

Optional topics:

– Fields from moving charges: Bremsstrahlung, synchrotron, and Cherenkov radiation

Text: A. Zangwill, *Modern Electrodynamics*.

PHYS 70007: **Quantum Mechanics I**

– General Hilbert Space formulation of Quantum Mechanics
– Schrödinger *vs.* Heisenberg picture
– Harmonic oscillator
– Coulomb problem
– Bohm-Aharonov effect
– Theory of angular momentum
– EPR correlations and Bell's inequality
– Symmetries and conservation laws

Text: J. J. Sakurai and J. J. Napolitano, *Modern Quantum Mechanics*, 2ed.

PHYS 70008: **Quantum Mechanics II**

– Bose-Einstein and Fermi-Dirac statistics
– Elementary approximation methods
– Scattering theory
– Realistic hydrogen atom
– Advanced approximation methods
– Partial wave expansions
– Optical theorem
– Introduction of Feynman rules
– Relativistic quantum mechanics, Dirac equation, and the Klein-Gordon theorem

Text: J. J. Sakurai and J. J. Napolitano, *Modern Quantum Mechanics*, 2ed.

PHYS 70009: **Statistical Mechanics**

Statistical Basis of Thermodynamics

Ensemble theory; Microcanonical ensemble

– Canonical ensemble
– Grand canonical ensemble
– Quantum statistics
– Simple gases
– Bose statistics
– Fermi statistics

Text: P. K. Pathria and P. D. Beale, *Statistical Mechanics*, 3ed.

B Physics Ph.D. program guidelines for the International Doctoral Program in Science

The International Doctoral Program in Science is a dual degree program, established under a four-way agreement between Katholieke Universiteit Leuven (Leuven, Belgium), Pontifica Universidad Catolica de Chile (Santiago, Chile), Università Cattolica del Sacro Cuore (Milan, Italy), and Notre Dame. It allows for students from any one of these institutions to pursue a jointly-advised Ph.D. at any of the other instututions, and then receive Ph.D.'s from both institutions.

The following guidelines govern the interpretation of the University of Notre Dame Physics Ph.D. degree requirements for students who come to Notre Dame, as their "host university", from one of the other partner universities.

Note that the general administrative requirements for such students will typically be set by the governing agreement for the International Doctoral Program in Science (*Agreement for an International Doctoral Program in Science*, May 12, 2016). There may also be a supplementary bilateral agreement between the Notre Dame Graduate School and a specific partner university. Finally, for each individual program participant, an "Individual Annex" (*i.e.*, appendix), will be prepared, containing information, agreements, and requirements specific to that student. The present "Physics Ph.D. Program Guidelines for the International Doctoral Program in Science" should be referenced in the Indiviudal Annex.

Recognition of coursework. Prior coursework may be recognized as satisfying the Notre Dame physics Core and Research Area course requirements according to the following review procedure:

(1) The student will provide the DGS with transcripts and all relevant information and materials (e.g., the course descriptions, syllabi, textbooks, and, to the extent available, completed exams or coursework). The DGS will review the student's transcript in order to generate a list of possible courses for recognition.

(2) The DGS will appoint a Review Panel of faculty from the department. The review panel will evaluate the suitability of the courses taken for recognition in satisfaction of the Notre Dame physics course requirements. Course numbering and grading systems differ internationally, and these differences must be taken into account when evaluating prior coursework. When deciding whether or not to recognize prior coursework, the Review Panel will apply the criteria that: (a) the course content should be sufficiently advanced as to be considered at the graduate level, and (b) that the student's scores should reflect a level of mastery commensurate with B-level or higher work at Notre Dame. The courses need not be in one-to-one correspondence with Notre Dame courses but must, in aggregate, be determined to satisfy the Notre Dame physics course requirements.

(3) The Review Panel may ask the student to answer orally (*e.g.*, via teleconference) basic questions on the material studied in the course. If the student is unable to answer these questions satisfactorily, then the course will not be recognized.

(4) Final decisions on prior coursework to be recognized and on any remaining courses to be taken at Notre Dame will be made by the DGS after a second discussion with the student.

Experimental proficiency requirement. Recognition of prior advanced undergraduate laboratory coursework (or equivalent) towards this requirement will be determined by the DGS, following the usual procedures.

Recognition of examinations. The Review Panel will evaluate the academic requirements and examinations satisfied by the student at the partner institution and will make a recommendation on recognition of these in place of the Preliminary Examination and the written and/or oral parts of the Candidacy Examination. Final decisions on recognition and on any remaining examinations to be taken at Notre Dame will be made by the DGS.

Enrollment expectations. For any term during which the student is in residence at Notre Dame, the student will be expected to enroll in and successfully complete at least 9 credit hours of coursework. These must include (as usually expected for students in residence): a research area seminar, Colloquium, and at least one hour of Research & Dissertation credit.

Credit hours. No overall credit requirements will be imposed by the Physics Ph.D. program unless otherwise specified in the governing agreement.

Residency requirement. The Graduate School's residency requirement is set in the governing agreement for the International Doctoral Program in Science. The Physics Ph.D. program moreover stipulates that the student must be enrolled in residence at Notre Dame for at least two full semester terms, during which time the student must satisfy the "Enrollment expectations" above.

Responsible conduct of research and ethics training. This requirement must be satisfied according to the usual Graduate School guidelines.

Research committee. A local Notre Dame Research Committee shall be established, for advising and mentoring purposes, no later than the student's first term of enrollment at Notre Dame. Formation of the committee shall follow the usual departmental procedures for forming a Research Committee. The Notre Dame supervisor will serve on the committee in the role of the advisor, and the home university supervisor will be invited to participate in meetings in the role of coadvisor. This committee shall continue to meet at least annually (by teleconference, if necessary), or more frequently if needed, until completion of the degree program.

Admission to candidacy. Procedures for possible recognition of the coursework and the Candidacy Examination requirements are detailed above. If any coursework requirements are completed at Notre Dame, these must be completed with a cumulative G.P.A. of 3.0 or better.

Regardless of whether or not a Candidacy Exam is taken at Notre Dame, in order to attain candidacy, the Notre Dame supervisor will be expected to formally request an invitation to candidacy from the department, and the student will be expected to: (1) provide the department with a copy of his or her written research proposal and (2) give an open presentation to the department of his or her planned thesis work. This presentation may be given as part of a formal seminar series or as a specially posted presentation.

Dissertation, defense, and submitting the dissertation. The procedures for the dissertation, defense, and submission of the dissertation are set by the governing agreements.

The Physics Ph.D. program moreover stipulates that the doctoral examination board must include at least two Notre Dame physics faculty: the Notre Dame thesis supervisor and at least one other Notre Dame faculty member (this faculty member will typically also serve on the Notre Dame Research Committee).

C First-year advising meeting form

A form similar to the following will be completed electronically by you, your advisor, and the DGS in the advising meeting at the end of your first year.

First-Year Advising Meeting

Department of Physics and Astronomy
University of Notre Dame

Student

Advisor(s)

Summary of Academic Progress

The Summary of Academic progress is to be completed in a meeting with the DGS. All other sections are to be completed in a meeting with the student's Advisor(s).

Summary of Initial Research Involvement

Research Plans

Are there potential research directions and a tentative plan for research work to be conducted over the next year?

Professional Development

Are there professional development opportunities (e.g., conferences and schools in the next year)?

Are there relevant fellowship opportunities to pursue in the next year?

Recommendations and Comments

Signatures

Advisor

Coadvisor

Student

Director of Graduate Studies

D Annual mentoring committee meeting form

A fillable version of the Annual Mentoring Committee Meeting Form may be downloaded from the department web site:

`https://physics.nd.edu/graduate/current-students/`

UNIVERSITY OF NOTRE DAME

DEPARTMENT OF PHYSICS

Annual mentoring committee meeting

Guidelines for the Mentoring Committee Meeting

The committee members meet with the student and their advisor(s) annually to provide guidance and assistance to the student on their path towards becoming a professional researcher. The purpose of the meeting is to establish a relationship and to encourage regular communication between the student and the committee members.

The meeting should be an opportunity for the student to share their research accomplishments, receive feedback on the progress they have made and guidance for their future steps towards completion of their dissertation and long-term career goals. It should not be considered an exam.

Students should not be required or encouraged to prepare any additional documentation for the meeting except for pre-filling some section of the meeting form and updating their CV. The meeting should be formulated as a discussion with the student and not a one-sided student report to the committee members.

The form completed during the meeting serves as an annual written feedback for the graduate student as required by the Graduate School.

Procedures for the Mentoring Committee Meeting

1. The out-of-field committee member should lead the discussion as the committee chair, while one of the in-field committee members acts as a scribe and fills out the form. On the form, the name of the chair should be indicated with an asterisk (*) and the name of the scribe – with a hash symbol (#).
2. **Fields marked with a black border** are primarily informational and contain information that can be obtained from the previous year's form or student's CV. These should be filled out prior to the meeting by the student in consultation with their advisor(s).
3. **Fields marked with a red border** are meant for discussion that should summarized by the scribe during the meeting.
4. The student should email the pre-filled form and their current CV to the Graduate Administrator, who will share these documents with the committee via Google Drive. As part of the feedback to the student, the committee should verify that the CV reflects student's accomplishments and provide a comments on its form and content.
5. The meeting should conclude with a **discussion between the student and committee without the advisor(s) present**. The discussion should remain confidential, unless reporting in accordance with Title IX is required, or the student requests that the discussion be shared with others (e.g., with the advisor(s) or the DGS). The purpose of the discussion is to address topics not covered by the form, e.g., relationships within the student's research group, ease of communication with the advisor, or general sense of progress in the student's research project.
6. After the meeting, the **scribe should electronically sign** the form on behalf of the whole group and email it to the student, advisor(s), committee members and the Graduate Administrator.
7. The completed form will be added to a Google Drive folder, where it will be available to the student, advisor(s), and committee members for future reference.

UNIVERSITY OF NOTRE DAME

DEPARTMENT OF PHYSICS

Summary of the annual mentoring meeting

Date:

Student:

Advisor(s):

Committee members (indicate the scribe with # and the chair with *):

Student's status:

Year in the program:

What is the source of the student's funding? ☐TA ☐RA ☐ External Fellowship ☐None

If not RA or External Fellowship, are there resources available for future RA support for the student?

Has the required coursework been completed? ☐Yes ☐No

If not, what is the expected time frame for completion of the coursework?

Has the candidacy exam been completed? ☐Yes ☐No

If not, what is the expected time frame for the **candidacy exam**?

If yes, what is the expected time frame for the **defense**?

Research plans:

Briefly describe your research project. *If post-candidacy*, how has your dissertation project evolved since the previous meeting? Have there been any major changes to the project?

Feedback from the committee members:

Does the thesis provide a contribution that advances human knowledge? How does this thesis advance the research field? (Update as appropriate as the thesis project develops.)

Research goals:

What are the **primary tasks** towards completing your thesis that you set for yourself **in the previous year**? (These should be transferred from the previous year's form for discussion.)

What progress have you made towards accomplishing these tasks?

What do you think were the most important aspects of your research progress in the past year? If you were involved in projects that are not part of your thesis work, discuss those as well.

What are the **primary tasks** towards completing your thesis that you are setting for yourself **in the coming year**? (These will be transferred to next year's form for discussion.)

Are all necessary resources available to you to reach your planned goals and maintain progress towards completion of your thesis? Please comment on the items below and discuss any additional resources that are relevant to your research project:
- One-on-one discussions with the advisor,
- Advising from other faculty,
- Communication with external collaborators/experts,
- Equipment and/or software, access to research facilities,
- Textbooks/publications, external data,
- Funding for research-related travel / conferences,
- Healthy work environment (office space, personal interactions, etc.),
- Other (please specify).

List **publications** that you coauthored that have been submitted/accepted to a **scientific journal** since the last meeting. What are the plans for you to publish in the future?

Feedback from the committee members:
Pre-candicacy: Is sufficient progress being made toward defining research directions and formulating a plan for dissertation work?
Post-candidacy: In light of the progress so far, does the student have a clear plan for dissertation work going forward?

What can the advisor/committee members/DGS/department do to improve/maintain the student's progress?

Would an additional mentoring meeting in the fall semester be needed? ☐Yes ☐No
If yes, please explain why. A follow up meeting will be scheduled for the upcoming semester.

Professional development:

What **long-term career goals** are you considering (e.g., academic/industry/lab position)? How do your professional development and research project align with this goal?

In the past year, did you have a chance to **present** your research at a **conference/meeting**? Are there plans for you to attend one in the next year?

In what **schools** did you participate in the last year? Are there any schools that might be of interest to you in the near future?

What **fellowships** did you pursue in the last year? What is the status of your application(s)? Are there any fellowships that might be of interest to you in the near future?

Feedback from the committee members:
Does the mentoring committee have any recommendations for professional development opportunities that are relevant to the student's long-term goals?

Student's CV
Is the student's professional development accurately reflected in their CV? Is the CV appropriate for student's long-term career goals?

Other comments and recommendations:

Final discussion without the advisor(s) present

What else would you like to share/discuss with the committee members?
The meeting without the advisor(s) present was held: ☐Yes

Signature of the scribe

(On behalf of the student, advisor(s) and all the committee members)

E Teaching assistant rights, responsibilities, and procedures

TEACHING ASSISTANT RIGHTS, RESPONSIBILITIES, AND PROCEDURES
UNIVERSITY OF NOTRE DAME, DEPARTMENT OF PHYSICS AND ASTRONOMY

I. Purpose

Undergraduate teaching is an essential and important part of a graduate education in the United States, and at Notre Dame in particular. Teaching assistantships fulfill many important needs: (1) They pay the bills, allowing you to have fun studying physics and get paid for it! (2) They are a transition from your role as student to your role as teacher and researcher. (3) They provide valuable experience in front of a classroom, training which is useful if you plan to teach after graduation, or if you ever plan to give research presentations to colleagues.

There are four primary kinds of teaching assistantships which are available in the physics department, and you will probably gain experience with all four:

Teaching tutorials or help sessions: Some of the lower level undergraduate courses meet for an hour each week in small groups (called "tutorials") with a graduate student. Others have "help sessions" in the evenings for students who need assistance in understanding the material. TAs are responsible for getting up in front of the tutorial or help session and leading it. The specific task varies by course, but may include providing homework help, working sample problems, organizing group learning exercises, or giving advice about how to do physics problems.

Grading problem sets: Most undergraduate and graduate courses have weekly problem sets which are assigned by the professor, completed by the students, and graded by a TA. Each week you will get a pile of homeworks to grade and you will be expected to return them to the professor graded within a few days. You may or may not be given solutions to the problems by the professor, but if you aren't then you will also have to complete the homework assignment yourself.

Grading exams: Almost all of our courses assess their students through exams. Our courses offer 1–4 exams during a semester. In many cases the exams are graded in part by TAs. Assignments involving exam grading require TAs be available to grade exams promptly. In the case of our large introductory physics courses, this can mean being available the day of an exam for grading. For smaller courses, this may mean being available to grade the exams within a few days or a week of the exam date. It is important to discuss the expectations for exam grading with the professor at the beginning of the semester.

Assisting in labs: Most lower level undergraduate courses also meet for 2–3 hours per week for a laboratory experience. While the lab will usually be organized by a faculty member or senior graduate student, TAs attend the labs and are responsible for helping students complete the labs and for grading the student lab reports.

More experienced TAs may be asked to actually run the lab sessions for a particular course, or to run the undergraduate Help Center. These jobs carry extra responsibilities beyond those discussed below.

II. Responsibilities

Each course will be organized differently and your responsibilities will be determined primarily by the professor in charge of the course, but here are some general rules:

1. At the beginning of each semester, find out your TA assignments, make sure that they are consistent with your background and abilities (*e.g.* experimental solid state students shouldn't be asked to TA courses in particle theory), and make sure they do not interfere with your own class meetings. Then contact the professor for each course. You and the professor should meet to discuss his/her expectations of you as early as possible. For large courses, it is normal to have a group meeting for all TAs — attendance at this is mandatory.

2. **Be prepared!**

   - For teaching tutorials: Know the material which has been covered in that week's lecture, look over the homework assignment which the professor has given them. If there are special problems that are to be worked in tutorial, make sure you have prepared them.
   - For teaching labs: The head TA or professor will organize a weekly session for you to practice on the laboratory equipment and do the lab yourself. It is very important that you attend this! You need to familiarize yourself with the lab setup, the computers and software, and the goals for each lab.

3. **Stay on top your job.**

   - For tutorials, don't let students' work pile on your desk. Make sure all collected assignments are quickly passed on to the professor or the graders.
   - For graders, complete your grading on time and return to the professor without delay. Don't let grading pile up from one week to the next – students need quick feedback on their assignments to help them judge their own progress and understanding.
   - For labs, complete grading them so they are ready to be returned the next time the lab meets.

4. **Complete your duties**. There will be occasions when a time conflict will prevent you from completing one of your duties. *It is your responsibility to find another graduate student to stand in for you!* It is common practice among the grad students to trade favors. If you can't attend your own tutorial, you must find someone else to do it for you. (Under no circumstance can you cancel or reschedule a lab or tutorial without permission from the professor!) Any arrangements you make need to be explained to and cleared by the course professor.

5. **Stay in communication with the professor.** If an issue arises in tutorial, in lab, or in grading that you think the professor should know about, tell him/her. If you notice the students are having particular problems with a certain concept, say something. If a student is falling behind or is frequently absent, report it. You are the first line of contact

with the students and you will often see problems weeks before the professor does. The sooner you let the professor know, the more likely it is that a solution can be found. In a lecture of several hundred students, it is too easy for the professor to not notice one student falling behind – it is your job to help keep that from happening. *Special note:* if a student misses a lab, report it immediately to the course professor!

6. **Stay in communication with the students**. Lab TAs are expected to have office hours each week to help students with the lab reports. Tutorial TAs may or may not be expected to have office hours, though it is always a good idea. (Graders are almost never expected to hold office hours.)

7. **Give useful feedback to the students**. At all times, strive to help the students without doing their work for them. When grading, clearly mark where points were subtracted and, where appropriate, give a short explanation of why the student's work was incorrect. If possible, try to pinpoint their error.

8. **Keep careful records**. Graders should keep copies of all assignment grades for the duration of the semester. If attendance is taken in tutorials or group projects are completed, TAs should keep copies or originals of these documents. Lab TAs will keep grades on special 3×5 cards which are to be held until the end of the semester then turned over to the professor.

9. **Know the Honor Code**. The undergraduates at Notre Dame are bound by an Honor Code that disallows cheating and lays out clear penalties. You should find out from the professor how the Honor Code applies to each course (*e.g.* are the students allowed to work together? Can they turn in group homework assignments? etc.) and report to him/her any suspected violations. *It is not your job to deal with violations*, just to report them to the course professor.

10. **Don't act as paid tutor to students in your courses**. Graduate students often make extra cash by tutoring students one-on-one. This is allowed only if the student being tutored is not enrolled in the course for which you are a TA. So a TA in Physics 30210 may be a paid tutor for students in Physics 10320, but *may not* tutor students in 30210. (Grad students running the Help Center should talk to the department about what rules apply to them.)

11. **Auxiliary duties.** From time to time, TAs may be asked to complete other duties which are auxiliary but still a necessary part of their position. These may include maintaining a database of homework grades, helping to set up and run lecture demonstrations, and setting up for/proctoring/grading exams. For large courses, it is the usual practice to set aside a block of several hours for grading exams. All graders, and sometimes all tutors, are expected to come to the grading session and help. Graders may also be asked to write up solutions to the homeworks for distribution to the students.

III. Rights

There are some things which are specifically **not** the responsibilities of teaching assistants. Some you may be willing to do, or even want to do, but you don't have to if you don't want to.

And some are simply inappropriate for you to do even if you want to. (If for some reason you are the primary instructor for a course, these won't apply to you.) You *don't* have to:

1. Work more than 12 – 16 hours a week on your TA assignments. This time limit is for all your TA assignments combined, not for a single course. Some weeks may be more than 16 hours, but then that should be averaged out with weeks with fewer hours.

2. Lecture for the professor. If the professor cannot lecture, he/she is supposed to find another faculty member to take the lecture. The department does not want graduate students teaching lectures, except in special circumstances which require permission from the department. Similarly you should not, on more than the rare occassion, have to hold office hours for the professor.

3. Buy the course textbook. If you need a textbook for the course (usually this applies only to tutorials), the department will provide one to you. Please ask!

4. Photocopy course material. It is not your job to photocopy exams, homework assignments, etc for the course. That job belongs to the faculty and the clerical staff.

5. Write exams. You may be asked to suggest problems for exams, but the exam itself is the responsibility of the professor.

6. Assign midterm or course grades. Although you will often be asked to grade individual assignments, and you may even be asked to record and total students' grades in a spreadsheet, it is the responsibility of the course professor to assign a letter grade to each student and to record that letter grade for the registrar. This is true both for final course grades and also for midterm course grades (which are given in the lower level courses).

Again, some things on this list you may want to do for the experience, such as lecturing. And it is generally consider acceptable for you to give a couple lectures, usually in upper level courses. If you want more experience than that, or want to lecture in lower level courses, talk to the course professor and a representative of the department about what kinds of opportunities may be available.

If you feel that you are being asked to do things which are outside the realm of your responsibilties, or if your TA load is too heavy, talk to the course professors, the faculty member in charge of coordinating TA duties, and/or the Director of Graduate Studies.

IV. Advice

Students often struggle with one of two temptations: either to let their TA responsibilities consume all their time, or conversely, to ignore their TA responsibilities. Both are very bad ideas. Being a TA is an important part of your graduate education, but it is only a part. You need to strike a balance among teaching, research and coursework, just as the faculty do.

There are distinct advantages to being a good TA. First off, there are yearly university awards for the best TAs, awards that are very valuable on a professional resume (and sometimes come with cash!). Good TAs also tend to get the choice teaching assignments from semester to semester (while bad TAs get stuck with the worst). And TAs who are particularly irresponsible risk losing their assistantships completely, which means loss of income and a big tuition bill!

Set aside a time slot each week for completing your TA assignments. And look far ahead for conflicts in your schedule (travel, exams, etc) that will prevent you from doing your job. The sooner you make other arrangements, the smoother it will go.

Finally, try to have fun. The students here at Notre Dame are actually a smart group of kids and when you get to know them and talk to them, it can be a very rewarding experience. And perhaps for the first time in your life, you are on the other side of the desk — it's your turn to explain the mysteries of the universe to a group of students anxious to learn them. What could be better!

F Physics graduate course numbering

You may be curious as to what the numbers for physics graduate courses represent. Here is the detailed description. (For historical reasons, there may be some exceptions to the following scheme.)

University numbering system. The Registrar provides some general guidelines on the meaning of the first two digits of a course number, which we quote here.

> First rule: The first digit in the 5-digit course number indicates the level of the course:
>
> **0**XXXX = Pre-College course
> **1**XXXX = Freshmen Level course
> **2**XXXX = Sophomore Level course
> **3**XXXX = Junior Level course
> **4**XXXX = Senior Level course
> **5**XXXX = 5th Year Senior / Advanced Undergraduate course
> **6**XXXX = 1st Year Graduate Level course
> **7**XXXX = 2nd Year Graduate Level course (MBA / LAW)
> **8**XXXX = 3rd Year Graduate Level course (MBA / LAW)
> **9**XXXX = Upper Graduate Level course
>
> Second rule: The second digit in the 5-digit course number indicates the category of the course:
>
> X**0**XXX = Regular classroom course
> X**1**XXX = Lab / Drill / Studio
> X**2**XXX = Tutorial / Discussion Group
> X**3**XXX = Seminar
> X**4**XXX = Study Abroad / Off Campus
> X**5**XXX = Internship / Field Work
> X**6**XXX = Directed Readings
> X**7**XXX = Special Studies
> X**8**XXX = Thesis / Research / Dissertation
> X**9**XXX = Transfer course articulation
>
> The last three digits of the course number are used by each academic department to meet their own curriculum structuring needs.

Note that courses at the 5xxxx level or below are classified by the university as "Undergraduate Division" courses. The Academic Code of the Graduate School limits how many credits of these may be applied towards graduate degree requirements:

> The advanced undergraduate courses numbered 40000 – 59999 may be taken to satisfy up to six hours of graduate credit requirements. Grades in these courses will count towards the student's G.P.A. Programs may place additional constraints on the use of 40000 – 59999 level courses to meet their degree requirements. For purposes of progress within a graduate department or program of study or admission to degree candidacy, no graduate credit is allowed for courses below the 40000 level. (ACGS Sec. 4.1)

Physics graduate course numbering. Within the physics graduate program, the first digit, representing the course level, has the following more specific interpretation:

6 = Graduate course accessible without graduate-level prerequisites
7 = First-year graduate core course
8 = Advanced graduate course (typically with 7xxxx-level core courses as prerequisites)
9 = Advanced graduate course (occasionally used for more advanced topics)

Note that the introductory research area courses serve both as advanced undergraduate electives and as graduate courses and are cross-listed at the 5xxxx and 6xxxx levels.

Within the physics graduate program, the third digit is used to represent the course's research area:

0 = Interdisciplinary
1 = Network science
2 = Astrophysics
3 = Atomic physics
4 = Biophysics
5 = Condensed matter physics
6 = High energy physics
7 = Nuclear physics