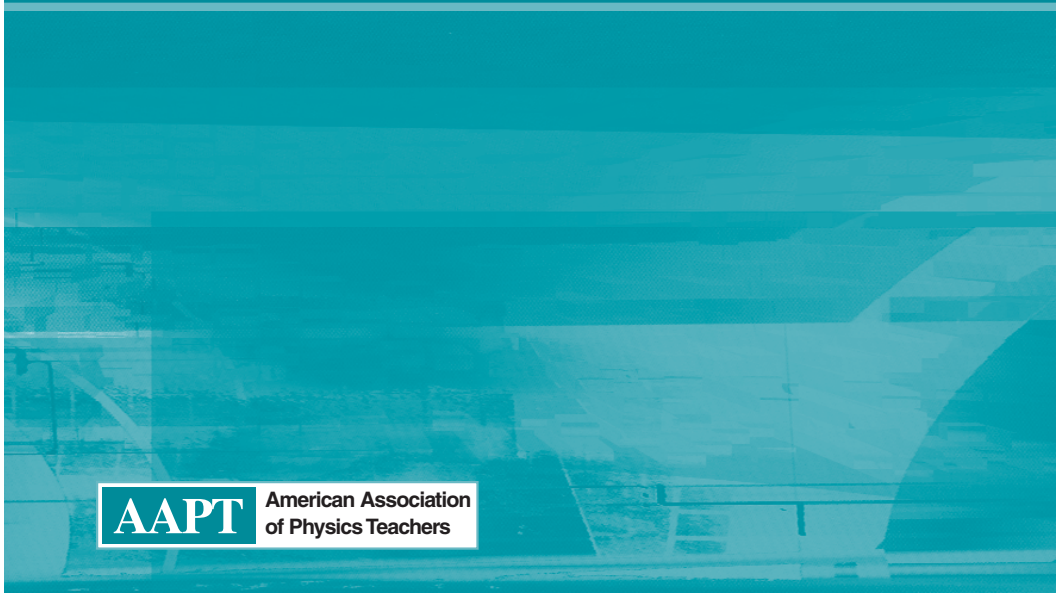
careers research advanced degrees decisions education

Planning for Graduate Studies in Physics and Related Fields



AAPT American Association of Physics Teachers

Planning for Graduate Studies in Physics and Related Fields

Editor

Dennis C. Henry
Gustavus Adolphus College
St. Peter, MN

Planning for Graduate Studies in Physics and Related Fields

American Association of Physics Teachers
One Physics Ellipse
College Park, MD 20740-3845
www.aapt.org

Cover design by Kim Wolford.

A publication of the
American Association of Physics Teachers

Editor's Note

This brochure is a complete revision of the 1994 edition, which was a project of the Committee on Graduate Education in Physics of the American Association of Physics Teachers. That edition contained some material drawn by permission from the pamphlet *Planning for Graduate Studies in Physics*, first published by the American Institute of Physics in 1980.

This revision has been informed by numerous changes in information technology, student demographics, and career opportunities that are having a significant impact on students making the transition from undergraduate to graduate education in physics and many other fields. I wish to thank the following colleagues at other institutions for their suggestions in reviewing this edition: Richard Jacob (Arizona State University), Kenneth Krane (Oregon State University), and Robert Ehrlich (George Mason University).

Dennis C. Henry
Gustavus Adolphus College
April 4, 2001

Planning for Graduate Studies in Physics and Related Fields

Table of Contents

Introduction

This brochure is written for students considering graduate work in physics or related fields such as astronomy, biophysics, and applied physics. It also provides some information for physics undergraduates who plan on pursuing post-baccalaureate studies in the fields of engineering, medicine, law, and other professions that attract significant numbers of physics B.A./B.S. graduates. It will help each student decide whether to pursue a graduate degree and, if so, how to prepare for this path while still an undergraduate. It addresses the mechanics of the application process, the types of financial aid, and the final selection of a graduate school. It concludes with a discussion about what a student might expect during the first few weeks of graduate school, and an example of a personal timetable.

Throughout the brochure are specific references and links to websites where students may find useful information and carry out steps in the various processes. A great deal may be learned through the services of professional organizations, government agencies, national laboratories, and some commercial entities. Virtually all of these organizations maintain comprehensive websites, many of which address education, careers, programs, scholarships, publications, memberships, and issues of national importance. Universities and many of their departments are similarly represented, and an increasing number accept online applications. We list below some of the organizations and online resources that will be cited in the remaining sections.

American Institute of Physics (with links to member societies): www.aip.org
American Physical Society: www.aps.org
American Association of Physics Teachers: www.aapt.org
Physical Sciences Resource Center: www.psrc-online.org
National Science Foundation: www.nsf.gov
U.S. Department of Energy (education page): www.energy.gov/scitech
Fermi National Laboratory (education page): www-ed.fnal.gov
Los Alamos National Laboratory (education page): www.lanl.gov/worldview/education/
Lawrence Livermore National Laboratory: www.llnl.gov
Associated Western Universities, Inc.: www.awu.org
American Association for the Advancement of Science: www.aaas.org
Council for Undergraduate Research: www.cur.org/physastron.html
Sigma Xi, The Scientific Research Society: www.sigmaxi.org
American Astronomical Society: www.aas.org
Institute of Electrical and Electronics Engineers, Inc.: www.ieee.org
Materials Research Society: www.mrs.org
American Society of Mechanical Engineers: www.asme.org
American Society of Civil Engineers: www.asce.org
American Medical Association: www.ama-assn.org

American Bar Association: www.abanet.org
Graduate Record Examinations: www.gre.org

Because the accuracy and timeliness of some web addresses inevitably deteriorate, most links given here are to domain-name homepages only. Students should not overlook the paper medium, and they are encouraged to become familiar with the practice and literature of their prospective field through such journals as *Physics Today*, *American Journal of Physics*, *Physical Review*, *The Physics Teacher*, *Science*, *Nature*, *Sky and Telescope*, and *IEEE Spectrum.*

A few other disclaimers are necessary. This commentary cannot speak to every situation; obviously, you must consider these remarks in light of your own case. It is also beyond the scope of this brochure to predict future employment opportunities for persons with graduate degrees in physics or related fields, although this is certainly relevant to the decisions you will make before and during graduate education. For insights into these questions, students are urged to talk with their advisers and those in careers of interest.

Graduate study is not a simple extension of undergraduate work. Success as an undergraduate does not necessarily imply success in graduate school. You must objectively appraise your talents and capacities and consider them in relation to those required for success in graduate work. It is difficult to define the combination of qualities that ensures success in graduate school. Imagination, ingenuity, and intelligence are definitely important, but maturity, motivation, and effort are just as important. Success in graduate study demands intense dedication to the task at hand, perseverance, optimism, and resilience. Most people who have been successful in graduate work and in their subsequent careers have found that graduate study demanded more hard work, commitment, and concentrated effort than any previous undertaking. Many also have found graduate study exciting, exhilarating, and a very satisfying capstone to their formal education. If you have already experienced the thrill of discovery on any scale, or of suddenly reaching a new level of understanding in science, you can expect even more such experiences in graduate study and research.

You may find it difficult to evaluate whether you are suited for graduate study. You are strongly encouraged to consult with a qualified adviser as well as a friend or acquaintance who has had experience in graduate work in your general field of interest, before deciding whether to continue to graduate study.

Why Graduate School?

The first question for you to consider before investigating graduate schools is, "Why do I want to do graduate work in physics or a related field?" If you have not formulated a direct answer to that question, consider it carefully before proceeding. If you do not find the intellectural encounter with a scientific problem and the accompanying hard work satisfying and rewarding, it may be that graduate study is not for you. The goal of a professional degree that leads directly to particular employment and an envisioned career is a powerful motivator. However, given the high probability that you will have a succession of careers, or distinct changes in responsibility and emphasis over your working lifetime, you should view graduate education, in some sense, as part of your general education.

What about the degrees themselves? The Ph.D. degree is primarily a research degree. It may lead to research work in industry, universities, public or private nonprofit laboratories, government agencies, or to a teaching position at the college or university level. It may also lead to jobs in management and administration in all areas. For some individuals, completion of the doctorate in a basic or applied science allows that person to later develop a new specialization or switch fields altogether.

The master's degree is less often the terminal objective of graduate studies in physics than is the case in engineering and interdisciplinary fields of study. Indeed, the M.S. in all the engineering fields, and in other fields such as architecture, is rapidly becoming the expected professional or practitioner's degree. In what follows, we shall be concerned mainly with questions that arise in planning for work toward the Ph.D. degree, with some suggestions for students with other graduate objectives. This is in no way to minimize the importance and value of other degree options, many of which rely on the same preparation and application steps.

The Ph.D. is generally awarded for original research during graduate studies. Such research is carried out under the supervision of the research advisor or major professor, and it will often be part of a group collaboration. There is no similar uniformity about the meaning of the master's degree. Some departments of graduate study require completion of a research or project thesis for the M.S. degree. Others require a library thesis, and still others require only that the candidate do satisfactory work in a number of graduate courses and on written and/or oral examinations. The M.S. degree is not usually a prerequisite for the Ph.D. degree, and many students find it feasible to pursue the Ph.D. degree directly, without fulfilling the requirements for a master's degree. Indeed, within physics a distinction is often made between master's degrees that are earned in the course of Ph.D. studies and those that are "terminal" at that institution. Some graduate departments will not admit students in anything but the Ph.D. track. Nevertheless, the M.S. degree in physics has a place in the overall picture of graduate education and will be sought by some graduate students not training specifically for college-level teaching or basic research. In particular, for individuals teaching at the secondary or community-college level, the M.S. in physics is often the preferred degree. A number of strong master's degree programs exist at universities where that is the highest degree offered. There are an increasing number of professional master's degree programs, many of which integrate physics with other fields. As previously mentioned, in engineering or professions with specialized certification or registration requirements, the M.S. is often the professional degree of choice. In many fields, students may wish to pursue the M.S. degree first to determine better their interest in and aptitude for research before committing themselves to a Ph.D. program.

Preparation for Graduate School

Studies show that most people who become scientists or engineers begin their college careers with this goal already firmly in mind. Certainly, there are some who first become interested in a career in the physical sciences during their undergraduate days. Students beginning their college physics studies should be aware that graduate education will be necessary for them to advance as physicists. Students earning a bachelor's degree in physics generally are not employed as physicists, whereas a student with a bachelor's degree in engineering can be employed as an engineer.

One of the greatest benefits of studying physics, mathematics, and chemistry at the undergraduate level is that they all prepare students to pursue advanced physics or engineering degrees, as well as contribute to their general liberal education. While the option to pursue graduate studies in physics can be closed off early by failure to take the necessary courses, the final decision to pursue physics or some other field of graduate study can be postponed right up to graduation. Indeed, one of the strengths of the core component of physics graduate study is that the graduate courses in classical mechanics, electrodynamics, statistical and thermal physics, quantum mechanics, and mathematical methods are common preparation for both the M.S. and Ph.D. in experimental, computational, or theoretical physics. Thus, the specialization decision can be left open even into graduate studies.

There is no better path to prepare yourself for graduate studies than a firm foundation in physics as an undergraduate, through courses required for the physics major and electives recommended by the faculty. If an interdisciplinary area, such as medical physics, becomes a goal, you will have to prepare yourself more broadly in chemistry and biology, although typically only at the introductory level.

Many undergraduate science departments include a research experience, perhaps as part of an honors track, senior thesis, or requirement for the major. The Council on Undergraduate Research (www.cur.org) has long championed this component of the undergraduate experience and publishes the *CUR Quarterly*. Many physics departments offer research opportunities throughout the academic year, while others do so primarily during the summer, such as through the National Science Foundation's REU (Research Experience for Undergraduates) program. Taking part in undergraduate research has merit even for students who are unsure of their postbaccalaureate plans. Students considering graduate work should make the most of local research opportunities, as well as summer programs at other universities, national laboratories, and in industry. Sponsored summer research appointments typically carry a worthwhile stipend, and often include allowances for room, meals, and travel. Such experiences can be very helpful in informing your decisions about graduate studies, fields of possible specialization, and careers. Students interested in learning more about summer research opportunities should make use of the posting system at their own department, and search the NSF-REU, Department of Education, and national laboratory websites. Application deadlines vary, but usually are concentrated in early February of each year.

Part of your preparation for graduate work must come from your own reading, beyond classroom assignments and projects. In graduate work and during your subsequent career, you will find it necessary to keep abreast of some fraction of the current scientific or technical literature. During your senior year, if not earlier, begin to acquaint yourself with the major physics or related journals and websites. Also, begin to build your personal scientific library and folders of electronic bookmarks. Watch for reviews of new books in your field of interest, and become acquainted with classic textbooks, monographs, and collections of physics problem solutions. You should already know how to search online resources and library indexes, but you should extend these skills.

Attending departmental colloquia, guest lectures, Society of Physics Students activities, and regional and national meetings of the American Physical Society, American Association of Physics Teachers, American Astronomical Society, and other professional societies is also an important way of broadening your education and graduate school preparation. Calendars of events are often posted on websites, and students may request to be added to e-mail lists. The Statistical Research Center of the American Institute of Physics (www.aip.org/statistics/) publishes annual reports on physics enrollments at both the undergraduate and graduate levels, degrees awarded, initial employment, and other data from each year's physics graduates. Many of these reports are sent automatically to physics department chairs on a scheduled basis. There is no better source of information on physics demographics, and every student should become familiar with these facts and trends. Here is an example from AIP's *1998 Graduate Student Report:* "First-year student enrollments have declined 26% since the early 1990's. This drop has been especially pronounced among U.S. citizens. As a result, foreign students comprised half of all students entering physics and astronomy departments in 1997–98. Subsequently, the number of U.S. students enrolling in physics and astronomy departments is the lowest it has been since the Institute started collecting data on citizenship about three decades ago."

Admission to Graduate School

It is useful to know the factors that graduate departments consider in making admission and financial aid decisions. The principal factors are:

- the quality of the undergraduate preparation,
- faculty evaluations in letters of recommendation,
- performance on the Graduate Record Examination, and
- experience in undergraduate research and projects.

Of course, a distinguished undergraduate record in a department known to maintain high standards and to prepare students well for graduate degree work is of the utmost value in being admitted to a graduate school and in winning financial support. Greatest weight usually is given to the quality of course work in physics and mathematics; however, evidence that you are literate and can express yourself well is also important. Letters of recommendation from people well acquainted with your work may be as important as your scholastic record. This is particularly so if you have an unimpressive transcript or GPA but you proved to be qualified for graduate work during your undergraduate career. Especially valuable are specific examples cited in letters of recommendation from professors or supervisors describing your experience in and aptitude for research work, e.g., on an undergraduate research problem, senior or honors thesis, special project, or summer employment.

Graduate Record Examination (GRE) scores are required for admission to many graduate schools and recommended for many others. The GRE General Test is the minimum such requirement, independent of the field of study. Approximately half of the graduate physics departments require test scores on the GRE Subject Test for Physics. Making a good showing on the GRE Subject Test for Physics is often a prerequisite for consideration at the most selective physics departments. A high score on the Subject Test is also essential for winning a graduate research fellowship from the National Science Foundation (NSF), particularly in physics. Doing well on the Subject Test may strengthen an application to graduate departments other than physics, but it is not required. In general, undergraduate physics majors will not have sufficient preparation for the other GRE Subject Tests unless they have taken extensive course work in the subjects of that exam. (Such Subject Tests were discontinued for engineering, geology, economics, and music in 2001.) For foreign students, an English-language test is often required, particularly for teaching assistantships. Each graduate school will furnish details on its requirements and recommendations regarding the GRE exams.

All of the standardized exams are now administered electronically, and there have been parallel changes to the applications and reporting process. Students should become familiar with the GRE website (www.gre.org) and the deadlines, applications procedures, forwarding of scores, and practice materials available.

A Word About Deadlines

Since the deadline for receipt of test scores by many graduate schools often falls in February, it is usually necessary to take the GRE during the previous fall term. The deadlines for national fellowships, such as the NSF Graduate Research Fellowship (www.nsf.gov/grfp), require similar advance planning.

Many students find it less stressful and more productive to take the General Test in the summer or early fall, and the Subject Tests in December. Some undergraduate physics departments offer practice sessions or review courses to help students prepare for the Subject Test for Physics. Application forms, sample test questions, and time and location of examinations can often be obtained from your school's registrar or placement office, or directly from GRE-ETS, P.O. Box 6000, Princeton, NJ 08541-6000. *Students planning on taking any of the GRE tests should make up a checklist of deadlines for applications early in the summer of the senior year.*

Choice of Graduate School

It may first appear that the process of choosing a graduate program is very similar to picking the right college after high school. While there are certainly similarities, they can be deceptive. You would be the first to acknowledge that you are a more mature, informed, and skilled person than when you planned that first transition. However, a successful outcome requires a close match between your interests and goals and the qualities of a particular university program offering specialized fields of advanced study. To use a physics analogy, one might say that the postbaccalaureate resonance is inherently much narrower.

The way in which the objectives of graduate training are achieved is not the same in any two departments. It may even differ widely for two graduate students in the same subfield in the same department. The core of all training is the graduate student's association with the person or persons directing the thesis work. In studying a scientific problem of mutual interest, this association will be important in shaping points of view and developing insight and skills. The experience should provide inspiration and stimulation for both student and teacher. Beyond this special role of the research supervisor/major professor, the entire department contributes to the education of graduate students in formal courses, seminars, apprentice teaching, and in consultations and discussions with individual staff members, postdoctoral research associates, and other students. The department plays an important role in the intellectual growth of graduate students by helping them appreciate and understand the significance of work outside their own subfield of interest and by helping them grow from a practitioner of specialized skills into a scientist. Points of view gained through general contacts not relating to a student's immediate research area can have a profound influence on shaping careers. Thus, you should consider both how well your particular subfield of interest is represented in the research taking place and the vitality and intellectual climate of the department as a whole.

In recent years, pressures to minimize the graduate curriculum and speed students into research and getting their Ph.D.s have created more variation among departments in the graduate courses students are expected to take. There is also considerable variation in the backgrounds of physics graduate students entering from the international pool that is characteristic of U.S. universities. Prospective students, particularly those still undecided about their field of specialization and those considering careers in academic physics, should look for graduate programs that support a strong core curriculum. Ideally, the department's course offerings should permit flexible entry points for students of different backgrounds and previous course experience.

Resources for Students

The annual American Institute of Physics (AIP) book, *Graduate Programs in Physics, Astronomy, and Related Fields* (www.aip.org/catalog/books/graduate.html), gives detailed information on most Ph.D.-granting physics departments and many master's-degree-only physics departments in the United States, Canada, and Mexico. In the fall of 2001, this was joined by a new electronic venture of AIP, GradschoolShopper.com. "The site provides both a graduate recruitment forum for graduate schools and a one-stop graduate-school shopping place for graduate-school-bound students. Supplementary content involves such features as:

- *Resources for students*: general advice on exams, admission process, tips on how to survive and prosper in graduate school, funding, graduate research resources, jobs and career information, etc.
- *Resources for academics*: recruitment tools, funding, jobs, education and employment data, latest trends, etc."

The resources cited above will allow you to judge the current research interests and areas of specialization of individual faculty members at each institution. They also show the numbers of degrees granted in the various areas in recent years. A copy of AIP's *Graduate Programs* is sent to the chairperson of every department offering at least a B.S. or B.A. degree in physics. It is probably available in the library or departmental office of your school. It lists institutions by state and alphabetically within each state. Programs at the schools that in aggregate award 99% of the Ph.D.s and 95% of the master's degrees in physics are described in detail. Tables in the appendix give subfields for all graduate programs in physics as well as in astronomy and some related fields. Peterson's online Grad Channel (www.petersons.com) can be helpful in locating graduate programs in engineering and interdisciplinary fields.

Other Factors

Most well-qualified students are supported financially during their graduate study in physics. The extent of financial support should not greatly influence your decision about where to apply, since the actual financial support is roughly the same at institutions of similar quality and living costs. Financial aid in the form of teaching assistantships, research assistantships, and fellowships is aimed at helping you attain your professional goals. This aid is not intended as income beyond the actual necessities of room, board, tuition, and required books. The taxable status of this aid varies by type and state, but the impact of taxes is generally small given the amount of aid.

If you have well-developed interests in a particular subfield of physics, you will have less difficulty in narrowing down the choice of graduate schools at which to apply. A careful study of *Graduate Programs* and

GradschoolShopper.com will help you identify the institutions that are active in your subfield. From the current scientific journals and from your professors, you can also learn who is active in your subfield of interest. Your professors can supply valuable information from their own experience and that of previous students at particular schools. All of this information can be used in weighing one institution against another.

If your interests are not well developed by the time you decide to go to graduate school, you may wish to rely on the advice of teachers or friends. First, seriously study *Graduate Programs* and GradschoolShopper.com to find some basis for limiting the possibilities and then consult with your teachers and friends. It is not unusual for students to begin with only geographic preferences and perhaps a preference for the size of university or city.

The level of activity of the department as a whole and the strength of the individual specialties can be partly measured by the numbers of recent degrees granted. The publication records of the research groups and individual staff members are also a matter of interest. For instance: Is the research work of the students published within a reasonable time after completion? How many recent papers have been published by faculty in your subfield of interest?

Many students enter graduate school with the intention of eventually teaching physics at the college level. Some departments, in addition to their research programs, offer courses and programs to prepare students for teaching careers. The definitive review of the issues, programs, and resources in this area is E. Leonard Jossem's "Resource Letter EPGA-1: The education of physics graduate assistants," published in the June 2000 issue of the *American Journal of Physics*. Students considering teaching physics in any capacity should become familiar with this Resource Letter and some of the many references it cites.

You may be attracted to a department by the work of a particular person or research group, but you must also realize that your plans to study with this individual or group may not materialize. The faculty member may find it impossible to take on an additional student during your research phase. External funding may fluctuate, facilities may be closed, and key people may move on or retire. Or, as often happens, you may change your interests as your training advances. Thus, do not limit your attention to one professor or his or her immediate group. Investigate the research activities of other members of the department. Also, assess the department as a whole as to breadth and depth of interests, flexibility of formal requirements, the freedom to move between different research groups, opportunity for interdisciplinary research, and general productivity. Women and minority students may want to gain additional information on the composition of the graduate student population and the faculty, as well as general perceptions about the intellectual and social climate in the department.

Information about such practical but important matters as the availability of specialized equipment and services sometimes can be gleaned by reading a cross section of the papers published by the department. A specific request for information directed to the department will usually result in data on special facilities and equipment, cooperative programs, and new faculty appointments. Such factors as the reputation of the university as a whole and of certain departments in which you may be particularly interested, the job experience of graduates of the department, and the university's location will inevitably enter into your decision. Married students and those with other relationships will want to investigate opportunities for their partners. A number of the questions just raised can only be satisfactorily explored by visiting the department, before or especially after an offer has been received. We will emphasize the importance of campus visits in the section on making your decision (p. 22).

If the institution where you are doing your undergraduate work also offers the M.S. and/or Ph.D. degree, you may wonder whether to continue there or to go elsewhere for graduate study. Students sometimes feel that because they are familiar with an undergraduate department it will be easier and less time-consuming to continue in the same institution. Such a course of action defeats, to some extent, the purpose of graduate study. In going to a graduate school, you have an ideal opportunity to enter a new environment and benefit from the stimulation of new points of view. In deciding whether or not to do graduate work at your undergraduate school, consider these factors seriously and weigh them against the possible advantages of continuity — particularly for students who have done substantial graduate-level work as undergraduates. Also, often a department will discourage all but the best of its own four-year graduates from continuing their graduate studies at the same school, at least in the same department.

You may minimize the number of applications you need to make if you have the proper qualifications for graduate work and if you can match your talents to the challenges particular departments seem to provide. However, in compiling your final list of schools, it is often wise to adopt a two- or even three-tier strategy. Your list should include:

- some schools that represent your top choices but are highly selective and competitive;
- a majority of schools that you and your advisers have identified as very good matches based on all the available information; and
- one or two less-competitive schools with solid programs, from which you would readily expect a graduate appointment.

How to Apply

Your undergraduate department may have a system in place for helping junior and senior majors with the mechanics of and strategies for applying to graduate and professional schools. If so, many of the topics in this and following sections will be part of such systems. It will be helpful for students to construct a timetable that lists the various steps. An example of such a timetable appears at the end of this booklet.

Graduate information and application addresses for each department are published in *Graduate Programs* and at GradschoolShopper.com. To obtain the most current information on your target schools, you should request information about the opportunities for graduate study in the department and the procedure for applying for admission and financial support. Your undergraduate department may maintain bulletin boards and a file of announcements, posters, brochures, and catalogs that can help at the information-gathering stage. It is generally unnecessary to request the graduate catalog from institutions, since the essential information is usually routed through the department offering graduate study. With the increase of information on the web, all manner of application materials and graduate catalogs are often online.

The departmental information you receive usually will include bulletins that describe the graduate curriculum in detail, an outline of the system of examinations, applications forms, and faculty-reference forms to be submitted on your behalf. Some institutions require separate applications for admission to the graduate school (or college) and for departmental admission and financial aid. Some departments or universities charge an application fee, but others postpone any fee until an offer of admission or appointment is extended. If the offer is accepted, then the fee must be paid. Those schools that accept online applications sometimes require application fees that can be paid online.

A question that frequently arises in filling out application forms is what degree objective to state (or box to check off). Most students going on in physics will check the Ph.D., or M.S. followed by Ph.D., if applying to one of the 180-odd departments that offer the doctorate. Students who are less certain about their talents or doctoral aspirations may be tempted to list only the M.S., even if the Ph.D. is their goal. Some Ph.D.-granting physics departments give preference for financial aid to students who specify the doctorate as their objective, although many make no distinction for entering graduate students. Thus, state the M.S. or M.A. objective by itself only if that is really the case. This is obviously not an issue for those universities offering only the M.S. or M.A. degree in physics or in the related program of interest.

In completing a graduate school or fellowship application, you are not only providing essential information but also making a case for yourself. Many applications require a personal statement, and this should receive your careful attention. You should ask the faculty member who knows you best and who will be writing one of your letters of recommendation to read your draft statement, and to make suggestions for its improvement.

Applications typically call for letters of recommendation from three people who personally know your aptitudes, work habits, and potential for graduate study. Physics faculty obviously should be represented in your selection, but you may also want to consider a professor in a closely related discipline if that person is in a position to make an informed evaluation. If you have worked closely on research projects or internships with a supervisor who can write an informed description of your work, you should solicit a letter from that individual. If you have done other supervised work that bears directly on your qualities as a potential teaching assistant, be sure that at least one of your recommenders can address those strengths.

In approaching a faculty member to write a letter of support for your application, you should make an appointment that will allow enough time for you to discuss your plans and to ask and answer questions. Both of you should feel comfortable discussing frankly the strength of the recommendations that can be written to different programs. For example, faculty may be able to support strongly a student's application to one university, while having some reservations about endorsing that student's application to a very selective program.

You should provide your recommenders with a summary of your past work and graduate school plans, in much the same form as you plan to submit with your application. Copies of your vita or resume, transcript, and personal statement will go a long way in supplementing conversations. To the maximum extent, you should assist your letter writers by completing as much of the paperwork and envelopes as they request. Lastly, give them plenty of time to work your letters (and often many others) into their schedules. Be explicit about due dates, with attached notes or a checklist. If you are concerned that one of your references may need a reminder about an approaching due date, make a polite follow-up a week or so in advance.

When to Apply

It is never too early to start thinking about graduate school. You should begin compiling information on individual graduate departments no later than the first term of your senior year. Applications for admission in the fall of a particular year are acted on during January–April of that year. Offers of all types may be made quite early in this period. Some engineering graduate programs are now requiring that applications be completed before Christmas.

If you will graduate in mid-year, you need not delay applying for admission until you are in phase with the group entering in the fall. Nevertheless, there are usually advantages associated with beginning in the fall as one of a new class of entering students. Departments operate differently with respect to mid-year admissions and financial aid. Direct correspondence is the best means to determine the practice of a specific school in this regard.

Applications are processed by department and university staff and are usually reviewed by a committee of faculty. It is a labor-intensive task to bring together all the applications forms, letters of reference, transcripts, GRE scores, and TOEFL (Test of English as a Foreign Language) scores for the international applicant pool. Some departments acknowledge the receipt of applications and supporting materials, while many do not. Similarly, some departments will notify students when materials are lacking from their files as time for evaluation approaches. Students may wish to confirm by telephone or e-mail that their files in a particular department are complete, but such inquiries should be kept to a minimum.

Financial Support

Financial support provided through a department for graduate study in physics may be in the form of a teaching assistantship, a research assistantship, a fellowship, or a combination. Most commonly, students apply for all of these types of financial aid at the same time and often on the same form.

In addition, the National Science Foundation, Department of Defense, and other government agencies, professional societies, and private foundations award fellowships on the basis of national competitions. Some fellowships are limited to U.S. citizens or underrepresented groups. Almost all such awards include tuition allowances and a modest stipend to defray the cost of living. We advise you to apply for such fellowship awards if you are qualified, even though your choice of graduate school is not definite when the fellowship application is made. Browse the websites of the sponsoring organizations for current information, and talk to your departmental advisor about your likely competitiveness. On some campuses there is a coordinated nomination and selection process for the most prestigious awards, such as the Rhodes Scholarship. In addition to those organizations listed at the beginning of this brochure, we call your attention to the following for their fellowship programs:

- *Fannie and John Hertz Foundation*: www.hertzfndn.org
- *National Physical Science Consortium*: www.npsc.org
- *Marshall Scholarship*: www.marshallscholarship.org
- *Fulbright Program*: www.iie.org/fulbright/us
- *GEM Fellowship* (minorities): www.nd.edu/~gem

Incoming physics graduate students are usually awarded teaching assistantships, fellowships, or (much less frequently) research assistantships. If you have accepted a teaching assistantship from a department and later learn that you have also been awarded a fellowship, usually you can choose which one to accept without prejudicing your admission to the department. Graduate schools differ greatly on the waiving of tuition and fees for students receiving assistantships or other financial support. Some schools offer full waivers of both tuition and fees, while others charge for either one, both, or some fraction. A relatively high assistantship or fellowship stipend can be substantially offset by the lack of such waivers or reductions.

Students should also find out whether their assistantship includes any medical benefits, such as health or major medical insurance. Such benefits are becoming common, and they can represent relief from a potential financial hardship.

Teaching assistantships provide an opportunity for working with students, for exercising a knowledge and understanding of physics, and for associating with

experienced teachers as well as other graduate students who are also in the process of learning. Initial teaching assistantship experience usually involves teaching and supervising students in laboratory sections in general physics as well as individual nonlaboratory and nonclassroom instruction. In subsequent years (and sometimes in the first year), it may involve teaching students in recitation and problem-solving sections. The benefits are so definite and valuable that we recommend a period of service as a teaching assistant for *all* graduate students. Many departments require those who win fellowship support also to serve for a time as teaching assistants.

The teaching assistant (T.A.) is expected to take his or her responsibilities seriously and to discharge them conscientiously. For many, this is the first step in the transition from pupil to teacher. For those who plan on an academic career at colleges where undergraduate education is the primary focus, successful experience as a T.A. will be particularly important. The experience is valuable even if you will not be a teacher. For example, many graduate departments require all new graduate students to take a written examination covering undergraduate physics early in their residence. Many students find that their T.A. experience helps them master concepts that appear on these exams.

Practices with respect to research assistantships are not uniform among the various academic departments. In many physics departments, only teaching assistantship (or fellowship) appointments are made to first-year students; research assistantships are reserved for subsequent years. In contrast, in engineering departments, teaching assistantships play a relatively minor role for first-year students and those on M.S.-degree tracks, and research assistantships support most students. In general, graduates with a physics major have not had undergraduate courses in engineering or other sciences that would be the normal teaching assignment for a beginning teaching assistant in those departments. Common exceptions to this statement include such courses as circuits and electronics, some parts of mechanics, mathematical methods, electromagnetic theory, statistical physics, and computers. Students with such special skills or lab-assistant experience should emphasize them on their applications, and they should be supported in faculty letters of reference.

The stipend for a research assistantship usually comes from funds available to a particular faculty member under a research contract or grant. All departments recognize that it is important that financial considerations do not compromise a graduate student's choice for his or her research problem and sponsor. Departments adopt different measures to ensure this.

Making Your Decision

Some graduate departments will begin mailing out offers to top candidates in January, with a "first round" completed in mid-March. Just as students apply to more than one graduate school, departments generally make more offers than they have openings. Thus, offers of admission and financial support depend on a sequence of decisions by several parties. Most universities have an April 15 deadline for students to accept or decline appointments. Such a deadline is necessary and should be respected so that departments can meet their teaching obligations and so other qualified candidates may receive offers. A student who accepts an offer of a graduate appointment at an early date may resign without prejudice before April 15.

One cannot overstate the importance of visiting those institutions that you are considering seriously. You may be spending five or more years at one of them. Thus, there is no substitute for a tour of the facilities and, more importantly, interviews with faculty and graduate students. Informal conversations with graduate students during your visit can provide valuable information on their perceptions of the department, as well as insights into the workings of different research groups. Spring break is a common time for seniors to visit prospective schools, particularly those from which they have received or expect to receive offers. Visits earlier in the year can be even more useful if they are part of a systematic information-gathering process.

Some graduate departments offer open houses or otherwise arrange visits for groups or individuals. Some will even contribute toward travel expenses or arrange for overnight housing. Students should feel free to inquire about such support, but should be prepared to make visits at their own expense. Before making your travel plans, speak with a member of the graduate faculty or senior department assistant who can assure that you will have a productive visit. You should mention at that time any specific faculty or research groups you would like to meet during your visit.

Ideally, you should have received two or more offers by the prescribed deadline and be in a position to make an informed decision. If you are not satisfied at that point with your choices, there are often still many graduate appointments that become available as candidates turn down multiple offers, and offers continue to be made through the spring. Here, again, you can benefit from discussing any questions with your principal undergraduate adviser. He or she can sometimes help you determine the likelihood that you will receive an offer from a particular school late in the application season.

At the decision stage, the size of the financial aid offer should play little or no role in your choice. Keep in mind that graduate study is a preparation for a creative, productive, adaptable, and enjoyable professional life. What you hope to accomplish in this phase of your education, rather than the temporary financial advantage of one offer over another, should govern your choice.

What to Expect

Once you have chosen a graduate school, you will need to consider such practical matters as:

- What is the academic calendar?
- What advance arrangements can be made about housing?
- What are the health insurance options for graduate students and families?
- Does the department give placement examinations prior to registration?
- What specific duties go with my assistantship or other appointment?
- Who will be my academic advisor during my first year?

Many common questions will be answered in mailings for incoming students sent by the department and university. While you may have gathered some information during campus visits before your decision, it is wise to start fresh and confirm what you may have learned then. Older graduate students can be very helpful in explaining requirements and recommending courses and instructors, but you should keep an open mind. Degree requirements and course offerings change, and important information of this sort is still best verified through official channels. In many departments, there are key staff people whose duties include helping incoming graduate students learn the ropes of a new department, institution, and city. It will be in your best interest to find out early who they are and to introduce yourself.

Most departments conduct a series of orientation events before the start of classes in the fall. These typically include social mixers, training sessions for new teaching assistants, interviews with faculty advisors, and "nuts-and-bolts" talks and tours covering offices, mail, paychecks, computers, keys, shops, and the like. The faculty who serve as departmental officers (i.e., head/chair, the associate and assistant head or chair, and graduate studies advisors) will have specific responsibilities for incoming graduate students. These faculty will highlight the department's schedule of events that new graduate students should put on their calendars. These events often include presentations by various research groups, department colloquia and seminars, and required written examinations. The department officers will tell students how they should move through course work and develop relationships with a particular research group and professor.

Choosing Courses

One of your most important early decisions will be the selection of first-semester (or first-quarter) courses. While certain courses and combinations are common for first-year students, the specific choices will depend primarily on the strength of the student's undergraduate preparation and, to a lesser extent, possible field of specialization. At many schools, a schedule of three courses is considered a full load for a graduate student with a half-time teaching assistantship. Students with fellowships or other appointments without specific time commitments usually will take an additional course. First-year students may be automatically enrolled in small fractional courses or seminars that are part of the orientation or teaching-assistant preparation outlined above.

If you have a strong preparation in undergraduate mechanics, electromagnetic theory, mathematical methods, quantum mechanics, and statistical and thermal physics, then you may be advised to sign up for the "standard" graduate core in these areas. However, in some departments there has been a contraction in the number of graduate courses expected of students before they begin research, sometimes down to a single year of courses. In such departments, where a significant number of entering students come in with the equivalent of the U.S. master's degree of coursework, the expectations for the graduate theory courses may be very high. Looking at the required textbook may help answer the question of course level, but since graduate faculty often draw only loosely on textbooks (mainly as references and sources of problems), impressions may be misleading. Students should critically explore with their graduate advisor, and with older students from similar institutions, whether they should begin with a mix of senior undergraduate/first-year graduate courses and upper-level courses in a specific field. It is to be expected that there will be a degree of overlap in content between strong upper-level undergraduate courses and an appropriate set of beginning graduate courses. However, students may confuse textbook familiarity with the kind of solid understanding that comes with multiple exposures at different levels. It is to no one's benefit for students to enroll in courses for which they have inadequate preparation. At the other extreme, it makes little sense for students to take intermediate courses that do not significantly advance their expertise and knowledge. Students should use every advising resource to help them determine where they are relative to the expectations of the available courses.

Graduate school years can be a time for making a lasting investment in yourself and in preparing yourself for a satisfying and enjoyable career progression. They coincide with a period of new freedoms and choices for recent college graduates. It has been the goal of this publication to help you prepare to make the most of this investment.

Timetable Example

Junior year

- ✓ Begin or continue discussions with faculty about graduate studies and focus on summer internships and research opportunities on and off campus. From November through mid-January, collect and complete applications for programs of interest. Follow up with these and other opportunities to secure a summer appointment.
- ✓ Draft your own timetable for the applications-related tasks for the summer and following academic year. (See below.)

Summer between junior and senior year

- ✓ Decide when you will take the GRE and complete online applications for fall testing dates. Obtain practice exams.
- ✓ Become familiar with the online resources for graduate study and national fellowships, and start building your list of bookmarks and e-mail folders.

Fall semester

- ✓ Collect information on graduate programs of particular interest, both from online resources and by talking with faculty and recent graduates. Set a target (e.g., mid-November) for having all applications materials in hand.
- ✓ Review for the GRE. Take the GRE Subject Test no later than the December offering. Have scores sent to candidate schools.
- ✓ Complete applications and forms for your references and meet with each of them before the end of the academic term. Request that your college transcript be sent to schools to which you are applying. Send completed applications by deadlines, some of which may arrive before Christmas.

Spring semester

- ✓ Watch for confirmations that your application materials have been received. Follow up on any missing materials, such as transcripts, letters of recommendation, and GRE scores. Contact any schools that you have not heard from to be sure that your file is coming together properly.
- ✓ Make preliminary plans to visit the most likely schools on your list. As acceptances and rejections come in, make arrangements as necessary. Keep your academic advisor informed of responses from schools, as well as your impressions from your visits.
- ✓ Final decision, mid-April. There are still many openings at good schools after this artificial deadline, so if you are not happy with your choices, start checking around and enlist the help of your advisor in making calls.

graduate school

discovery

opportunities

learning

physics