GRADUATE HANDBOOK

FOR PENN STATE'S

DEPARTMENT OF PHYSICS

Department of Physics
The Pennsylvania State University
104 Davey Laboratory
University Park, PA 16802
U.S.A.

August 2014

1 Introduction

This handbook is for the use of current and future graduate students in the Physics Department of the Pennsylvania State University (Penn State), University Park campus. Although designed as a reference, graduate students are encouraged to familiarize themselves with the contents of the *entire* handbook. Sections 2, 3 and 4 provide comprehensive information on the graduate program in Physics. University course administrative procedures and guidelines for teaching assistants appear in Sections 5 and 6. Section 8.6, and the appendices, should be consulted when necessary on departmental and university policy matters. This handbook outlines the department and university's expectations of a graduate student, the students' rights and responsibilities, and explains the procedures to be followed in various situations. **All incoming students should read carefully the information for new students in Section 2 and, especially for Ph.D. candidates, the description of the Ph.D. program in Physics in Section 3.2.**

This handbook is also for the use of the faculty who have responsibility for guiding and advising students, and for fairly and consistently administering the graduate program in Physics at Penn State. The handbook can only give a brief summary of the relevant university rules and policies. But it is the definitive statement of Physics Department rules and procedures.

The department strongly values student feedback on possible improvements to the graduate program. Students are encouraged to communicate openly with their peers and the faculty, both on physics, and on issues of common concern to the graduate program. Such issues may include TA workloads, graduate student benefits, computing and office facilities, departmental degree requirements, advanced course offerings, or future job opportunities. Announcements of interest to graduate students are routinely sent out by e-mail. Women and minority graduate students are encouraged to meet together regularly, as needed, providing an opportunity for informal peer support.

1.1 Exceptions to Rules

Nearly all of the rules in this handbook have had and will continue to have exceptions in **rare cases**. Although one should not count on this possibility, students should not be discouraged from applying for an exception if their circumstances are unusual. In such circumstances, the graduate student should immediately bring the matter to the attention of their adviser (if they have one), or to the Director of Graduate Studies. However, unnecessary requests for exemptions are liable to make the faculty unreceptive to future requests. A request for an exemption from any rule should be made **in writing** to the **Director of Graduate Studies**, who will consult with other faculty as needed.

1.2 Guiding Principles

The Physics Department adheres to the following “Guiding Principles for Good Practice in Graduate Education” as adopted from a statement of principles endorsed by the Graduate Council on May 8, 1996:

Working relationships between faculty, staff, and students are an important component of graduate education at Penn State. The quality of these relationships can make or break the graduate school experience. The development of a positive learning environment depends on a shared vision of educational values, objective, and expectations. It is the joint responsibility of faculty, staff, and students to work together to nurture this vision, and to encourage freedom of inquiry, demonstrate personal and professional integrity, and insure a climate of mutual respect. The following six principles are essential elements in a productive environment for graduate education at Penn State:

- ***Understanding the work environment.*** *Faculty, staff, and students must each take the initiative to learn the policies, rules, regulations, and practices that affect them, their work, and the units in which they work. Graduate program handbooks, pertinent University publications, funding agency references, and other resources can typically be obtained from graduate program officers, the Internet, registered student organizations, department faculty, other students, faculty advisers, and thesis committee chairs.*

- ***Academic honesty, professional integrity, and confidentiality.*** *These qualities are the responsibility of all faculty, staff and students. Each member of the graduate community must endeavor to adhere to the highest level of these ideals in all their personal and professional activities.*

- ***A clear course of study****. The student and his/her faculty adviser should develop and agree upon a clear plan of academic study and the responsibilities associated with it. Careful planning and discussion throughout a graduate program are the best way to avoid later misunderstandings and problems.*

- ***An atmosphere of openness.*** *Students and faculty must work to establish and maintain an environment that is open, sensitive, and encourages free discussion between members of the graduate community. Clear, two-way communication is a critical ingredient in a successful graduate experience.*

- ***Acknowledgment of intellectual rights and property.*** *Students and faculty should discuss issues associated with academic freedom, intellectual property, authorship, and publication as part of the student's academic plan.*

Resolution of these issues early in the graduate program is often the best way to avoid later disputes.

- ***Opportunities for evaluation.*** *Evaluation, reflection, and feedback are integral parts of the academic process. These items should be a regular part of every graduate program. Early, frequent, and constructive feedback helps to prevent small differences from becoming serious problems.*

While these six guiding principles are not exhaustive, they do reflect a spirit that can make the graduate education process at Penn State more rewarding and productive for everyone.

1.3 Eberly College of Science Code of Mutual Respect and Cooperation

The Eberly College of Science has adopted a Code of Mutual Respect and Cooperation designed "to embody the values that we hope our faculty, staff, and students possess, consistent with the aspirational goals expressed in the Penn State Principles. The University is strongly committed to freedom of expression, and consequently, the Code does not constitute University or College policy, and is not intended to interfere in any way with an individual's academic or personal freedoms. We hope, however, that individuals will voluntarily endorse the 12 principles set forth in the Code, thereby helping us make the Eberly College of Science a place where every individual feels respected and valued, as well as challenged and rewarded."

The 12 Principles of the Code are:

1. Treat everyone equally and with respect
2. Be courteous
3. Be ready to communicate
4. Encourage others and share your expertise with them
5. Give and accept constructive criticism
6. Be receptive to change
7. Be a team player
8. Get involved
9. Have a positive attitude
10. Be honest and accept responsibility
11. Recognize other people's priorities
12. Strive to do your best

1.4 Aims

The principal goals of the Penn State Physics Department are

- effective and conscientious education of students at all levels;

- performance of creative, high quality research at the frontiers of physics;

- provision of resources to the community, government, university, and industry in areas relevant to physics.

Our programs and rules are designed to achieve these aims, but the ultimate success depends on energetic, imaginative, and cooperative efforts of our students, faculty, and staff.

Specific goals of the graduate students in physics include: learning physics, developing research skills, and becoming prepared for future employment. The faculty and staff are devoted to helping students in all the many ways appropriate to these goals. Students should feel free to discuss these informally at any time.

Virtually all students are here because they aspire to careers involving physics in some way. Hence it is important to understand various facts concerning employment in such careers. The first fact is that only about 20% of Penn State Ph.D. recipients end up in academic careers; most of the rest work in the industrial sector. A rather higher proportion starts out in temporary postdoctoral positions. Frequently, the ultimate career does not directly involve the research area of the Ph.D. but does use the skills acquired during the graduate education.

What are the skills sought by these various employers? There is an emphasis, of course, on scientific ability. Very important also is the ability to communicate clearly. It is important for students in the job market to possess these capabilities. It is prudent for students to develop such skills by presenting seminars, which are critically assessed, by writing reports and papers, and by discussing science with colleagues.

It should be noted that employers regard publications favorably. However, the specific number of papers tends not to be a critical variable. (This is true for colleges and universities as well as industrial employers.) Much more important, in general, are the assessments in reference letters of the individual's contributions to research in their subfield.

2 New Student Information

2.1 Before You Arrive

Most of your questions about the graduate program in Physics at Penn State will be answered in this handbook. Prospective graduate students are advised to write to the Department of Physics, 104 Davey Laboratory, The Pennsylvania State University, University Park, PA 16802 or call (814) 863-0118 for assistantship applications, semester schedules and other information beyond what is found in this Handbook. Up-to-date descriptions of the research programs of the current faculty in Physics at Penn State can be found at http://www.phys.psu.edu. The Physics Department may also be contacted by e-mail at *graduate-program@phys.psu.edu*.

The University's publishes the *Graduate Degree Programs Bulletin;* it is available on-line at http://www.psu.edu/bulletins/whitebook/. The University also publishes a *Schedule of Courses* for each semester, available at http://schedule.psu.edu.

When you contact the graduate coordinator with enquiries (by writing, calling, or by e-mail at *graduate-program@phys.psu.edu)*, it helps to be specific about the questions, such as temporary housing need, orientation schedule, etc. For housing arrangements before your arrival, contact the graduate coordinator or the offices listed in Section 2.5.

2.1.1 How to Contact the Physics Department

Physics Department
Penn State
104 Davey Laboratory
University Park, PA 16802-6300
U.S.A.
+1 (814) 865-7533
(866) 649-0590 (toll-free within USA)
Fax: +1 (814) 865-0978
E-mail: *graduate-admissions@phys.psu.edu*
World-Wide-Web: http://www.phys.psu.edu/

The graduate coordinator (+1 (814) 863-0118) can be found in 108 Davey Lab. The graduate coordinator takes care of the administration of the graduate program. Questions regarding admissions, requirements, etc. should be directed to him/her. E-mail enquiries should be sent to *graduate-admissions@phys.psu.edu*.

2.1.2 Advising and Mentoring

Once a student begins research, this will be under the supervision of a faculty member, who is the student's official academic adviser. (It is possible to be co-advised by more than one faculty member.) The academic adviser is the primary person who will provide guidance on a course of study, etc. Before a student starts research, the advising function is taken on by the Director of Graduate Studies. He meets with the advised students at least once a semester. Students can also consult with other faculty members; for example, if they are interested in a particular research area, it may be useful to discuss appropriate plans of coursework, etc, with a professor who specializes in that research area..

Overall responsibility for the Graduate Program in Physics lies with the **Director of Graduate Studies**. Questions that have not been answered by the graduate handbook, your adviser, and/or the graduate coordinator, should be directed to him/her. The Director of Graduate Studies is always open to suggestions and concerns you may have about any aspect of the graduate program.

2.1.3 Who's who

In addition to the advisers and Director of Graduate Studies, there are a number of individual faculty members and committees within the Physics Department that have official responsibility for different aspects of the graduate program. They are frequently referred to in this handbook.

Department Head: Professor Nitin Samarth.

Director of Graduate Studies: Professor Richard W. Robinett, *rick@phys.psu.edu*. He is in charge of the graduate program in the department.

Graduate Coordinator: Carol Deering *cld33@psu.edu*

Graduate Program Committee: A committee of physics department faculty that makes the overall policy. Chair: Professor Marcos Rigol, *mrigol@phys.psu.edu*.

Candidacy Committee: A committee of physics department faculty that evaluates students for admission to Ph.D. candidacy. This includes administering the candidacy exam. Chair: Professor Marcos Rigol, *mrigol@phys.psu.edu*.

Adviser: Advanced students have an individual faculty member as adviser who is responsible for guiding their research. For students who have passed the comprehensive examination, the research adviser may continue as thesis adviser. Prior to finding an official research or thesis adviser, the role of adviser for a student is typically played by the Director of Graduate Studies.

2.1.4 Travel to Penn State

Penn State University (University Park campus) is located in the town of State College, Pennsylvania. You can find State College on road maps of the region. Maps of the campus and other information can be found at http://www.geog.psu.edu/print-campus-maps. Note that although the postal address for the campus is University Park PA, the actual town is named State College. The town can be reached by public transport (by air and by bus). For more travel information, both for getting to State College and within the area, see http://global.psu.edu/info/global-campus-community/life-state-college/transportation.

Air transport: The local airport is State College, Pennsylvania, (code SCE) with daily connections to Chicago, Detroit, Philadelphia, and Washington D.C. The closest major international airport is Philadelphia, PA. Getting from the airport to anywhere in the town can be done by a taxi or a shuttle.

Long distance buses: Express bus service to several cities, including New York City, is offered by Megabus, http://us.megabus.com/. (Note that in State College, the Megabus arrives in the Walmart Parking Lot at North Atherton Place, and that baggage is limited. Taxis are available for transportation within State College.) Greyhound bus has connections to the New York, Pittsburgh, and Washington D.C. areas, among others from the State College bus terminal on North Atherton Street, next to the university campus.

Train: Trying to get to State College by train is not normally recommended. The closest Amtrak station is in Lewistown, PA, approximately a half hour drive from State College, without public transport available to get to State College.

2.1.5 Housing

It is important to seek housing as soon as possible and before your arrival here. Full-time graduate students are not required to live on campus. Graduate students may apply to live in the on-campus White Course Apartments, which offer housing for singles, couples, and families. More information regarding housing can be found at http://www.hfs.psu.edu/housing/housing/graduate-and-family-housing/index.cfm.

2.2 Summary of Campus Services Addresses

Main Penn State phone number
+1 (814) 865-4700

Physics Department Address:
Physics Department
Penn State
104 Davey Laboratory
University Park, PA 16802
U.S.A.
Phone: +1 (814) 865-7533
Fax: +1 (814) 865-0978
E-mail: *graduate-program@phys.psu.edu*
World-Wide-Web: http://www.phys.psu.edu/

Thesis Office: 115 Kern Bldg., 865-5448.
http://www.gradschool.psu.edu/index.cfm/current-students/etd/

Student Affairs: 206 Old Main, 865-0909
http://studentaffairs.psu.edu/

Graduate School
114 Kern Bldg., 865-1795
http://www.gradschool.psu.edu/

Graduate Student Association Office
315 HUB-Robeson Center, 865-4211
http://gsa.psu.edu/

International Student Services
410 Boucke Bldg., 865-6348
http://global.psu.edu/info/internationals-psu/students

University Health Services
Student Health Center See Section 2.5.3.
http://studentaffairs.psu.edu/health/

University Health Services Student Insurance Office
302 Student Health Center, 865-7467
http://studentaffairs.psu.edu/health/services/insurance/

Center for Counseling and Psychological Services
501 Student Health Center, 863-0395
http://studentaffairs.psu.edu/counseling/

Affirmative Action Office
328 Boucke Building 863-0471
http://www.psu.edu/dept/aaoffice/

Office of Human Resources
James M. Elliott Building 4th Floor, 865-8216
http://www.ohr.psu.edu/

2.3 Graduate Degree Program Information

The university publishes a *Graduate Degree Programs Bulletin*, which can be found on-line at: http://www.psu.edu/bulletins/whitebook/. The bulletin contains comprehensive information on the graduate programs at Penn State and should be consulted as the primary source of information on university guidelines and regulations for the graduate program. In addition, there is an online booklet *General Polices, Rules, and Procedures* (http://www.sa.psu.edu/ja/procedures.shtml, click on the link "Student Guide to Policies and Rules") published by the Office of Student Conduct, (814) 863-0342. This is a compendium of university rules and regulations.

Every semester, the university publishes a *Schedule of Courses* for the next semester which is available online at http://schedule.psu.edu. Final examination times and places are sent to each student and faculty member via e-lion (http://www.elion.psu.edu).

Upon arrival on campus, you will be able to access the on-line information above on any of the public-use terminals available on campus, as in the Libraries and the Student Center (Hetzel Union Building (HUB)). You should also obtain a university computer account ("Access Account") as soon as possible (see Sec. 8.1); this will give you access to many otherwise restricted on-line resources.

2.4 Campus Services Information

Much information is available by the World-Wide-Web. Notable addresses are: Penn State's home page at http://www.psu.edu/, and the Physics Department's home page at http://www.phys.psu.edu/. General Academic information for Penn State is accessible on the WWW at http://www.psu.edu/academics.

2.5 After You Arrive

Upon arrival on campus, incoming students should make every effort to introduce themselves to the graduate coordinator. The graduate coordinator can be found in 108 Davey Lab. You may need to stay at a local motel for the first few days until you find housing.

Upon arrival, you will also want to find out about various orientation schedules. Information on orientation schedules is always available from the graduate coordinator. Upon arrival on campus, other resources will be available to you. International students will need to contact the Office of International Students, 410 Boucke

Bldg. The Graduate Student Association Office at 312 HUB-Robeson Center, (814) 865-4211, open 9 am to 5 pm, is another resource on issues related to graduate student life. The Graduate Commons, located in the Kern Building, also provides a good introduction to the programs and services available on campus.

2.5.1 Keys/ID Cards

You will need a university ID card, and office and building keys. Information on these matters is available from the graduate coordinator in 108 Davey Lab. Keys are issued for the building and laboratories etc. as needed, with the approval of a faculty member. Key requests are electronically processed in the Physics Department Office (104 Davey). You will be notified by e-mail when the request has been approved. You will then return to the Physics Department Office with photo ID. Keys are not to be lent to anyone. It is unlawful to duplicate these keys.

All keys must be returned before a student leaves the University. Failure to return keys may result in a charge to the student's account until the keys are returned or until the cost of rekeying the facility is recovered.

2.5.2 Housing

It is important to seek housing as soon as possible and before your arrival in the United States. Full-time graduate students are not required to live on campus. Graduate students may apply to live in the on-campus White Course Apartments, which offer housing for singles, couples, and families. More information regarding housing can be found at http://www.hfs.psu.edu/housing/housing/graduate-and-family-housing/index.cfm.

2.5.3 Student Health Insurance

Injury and sickness insurance is available to graduate students, their spouses and eligible children. Information is available at http://studentaffairs.psu.edu/health/services/insurance/ There will be an orientation session soon after arrival for new students where detailed information is available.

Penn State requires international students and their accompanying dependents to have health insurance. If they do not purchase insurance from Penn State, they must demonstrate that they have appropriate insurance: http://studentaffairs.psu.edu/health/services/insurance/waiver.shtml

2.5.4 On-campus Health/Emergency Services

The University Health Services – see http://studentaffairs.psu.edu/health/ – offers a convenient campus location in the Student Health Center which is adjacent to the Eisenhower Parking Deck and the Bank of America Career Services Building off Bigler Road. The Campus Loop stops on Bigler just south of the Student Health Center.

In situations of extreme emergency, such as an accident or life threatening situation, the closest major hospital with full facilities is the Mount Nittany Medical Center, 1800 E. Park Ave., State College (814) 231-7000.

Health Services Phone Numbers

Ambulance/Emergency Calls	911
University Police	863-1111

Medical Services (at University Health Services)

Appointments	863-0774
Advice Nurse	863-4463
Alcohol Intervention Program	863-0461
Pharmacy	865-9321

2.6 International Students

If you are an international student, i.e., a student who is not a US citizen or permanent resident, the graduate coordinator and/or International Student Services should already have been in touch with you regarding immigration and naturalization matters. Additional information can be found on-line at http://global.psu.edu/info/internationals-psu/students. Upon arrival, international students will need to apply for a **Social Security Number**. They will also need to fill out a withholding form and open a bank account in order to receive a paycheck. Information on such matters can always be obtained from the graduate coordinator. At the website above, on-line information can also be found on both on-campus and off-campus housing. **International students are strongly encouraged to gain full proficiency with the English language at the earliest possible opportunity. This should be given high priority in the first year of graduate school.** On-line information on the *Intensive English Communication Program* can be found at the website above. See also Section 2.6.1 on physics department requirements, and 3.1.3 for university policy guidelines on English proficiency.

2.6.1 Evaluation of English Competency

Incoming international students will need to take a **test of oral English proficiency** administered by the Department of Applied Linguistics. An appointment for the test will be made for you so that it doesn't conflict with other activities in period after you arrive. Details of the test can be found at http://aplng.la.psu.edu/academicPrograms/ita_whatIsAEOCPT.shtml But do *not* register for the test on this website; as mentioned above, an appointment will be made for you.

International students who do not receive a high enough score on the test will be required to take one or more courses in English as a Second Language (ESL), and pass them with an grade of "A". Which courses are to be taken will depend on the student's score on the test – see http://aplng.la.psu.edu/academicPrograms/ita_whatIsAEOCPT.shtml Support as a Teaching Assistant (TA) requires that a student be enrolled in the appropriate ESL course(s) until such time as they are considered English proficient. This may require delaying one or more required courses; consult the Director of Graduate Studies to discuss any impact taking an ESL course may have on your Physics coursework.

2.6.2 Information on Visas for International Students

International students will need an appropriate visa. If this applies to you, the necessary information should have been sent to you after you have been accepted in the graduate program. If you have questions, contact Penn State International Student Services at (814)865-6348, or mailto:international@psu.edu. Additional information can be found at https://global.psu.edu/info/internationals-psu/students/pre-arrival-advising

2.7 Assistantships and Support

Most graduate students in the Department of Physics are supported by graduate assistantships and/or fellowships. The Department of Physics awards fellowships as well as research and teaching assistantships. In addition, the Graduate School provides a limited number of fellowships, tuition grants-in-aid and several loan programs. Normally, students who maintain regular academic status and who make adequate progress toward completing their degrees can expect continued support.

General university guidelines and rules on graduate assistantships can be found at http://www.gradsch.psu.edu/index.cfm/graduate-funding/infoga. Information on the terms of your appointment can always be obtained from the graduate coordinator, and from your adviser.

2.7.1 Teaching Assistantships (“TAs")

The Department of Physics awards 10 to 20 teaching assistantships to incoming graduate students each year.

Students supported by teaching assistantships work 15 to 20 hours per week teaching physics recitations and laboratory classes, grading problems and exams for instructors, etc. Two recent anonymous surveys of teaching assistants have shown that the load is 15 ± 2 hours per week.

For the summer, students are encouraged to seek alternative sources of funding. For example, a number of faculty have graduate researcher positions available. When such summer support is not available, some students for the first two years are supported as graduate teaching assistants. Beyond that, some departmental summer support may be available.

Summer support is conditional on a student being associated with a research group or adviser. This will not necessarily mean that the student has started on his/her thesis research, or that the thesis research will be on the same topic. However, it is important that a student start to gain research experience as soon as possible.

In addition to providing support for graduate students, teaching assistantships help students to enhance their classroom skill. To assist in this development, all incoming graduate students are required to participate in a TA training session at the beginning of Fall semester.

* ***Note that teaching assistants must report to the department a week before the semester begins. This is to allow for effective organization for large courses, etc. Teaching assistants must remain available until the end of the final exam period.***

After the first year or two that a student is in the department, adequate progress in research is a prerequisite for continued TA support. In particular, it is necessary to have been admitted to Ph.D. candidacy. TA support beyond the fifth year of the Ph.D. program will be granted only with the approval of the Department Head. TA support for students working for a M.S. will normally be limited to 2 years.

If a student is supported as a TA and starts working towards a non-physics degree, TA support will generally be terminated.

Guidelines for TAs for some physics courses are presented in Section 6.

2.7.2 Research Assistantships

Research assistantships ordinarily support students during the period that they are devoting full attention to work on their thesis research. Such assistantships are provided by research groups, from grants etc funded by external sources such as the National Science Foundation, the Department of Energy, the Office of Naval Research, or the National Aeronautics and Space Administration. No university general funds are used for research assistantships, and so the number available will vary from year to year. A research assistantship is supervised by the faculty member, or members, who have obtained funding for a specific research project. Normally, such funds are reserved for advanced graduate students and information on the assistantship will only be made available to qualified graduate students by the respective faculty members. Only in exceptional circumstances, or in cases where a faculty member's research grant is designated for research and/or education purposes, a research assistantship may become available to support an incoming graduate student. Such assistantships are decided on a case-by-case basis by the faculty member concerned.

2.7.3 Fellowships and Awards

The Department of Physics also awards fellowships. Entering doctoral students each year are automatically considered for the fellowships. These awards, in an amount of $2000-$8000 per year, are made in addition to the teaching assistantship or other primary source of financial support, e.g., external fellowship, etc., and on the basis of academic record, letters of recommendation, and performance on the GRE. The award is normally given for the first year of study and, in certain cases, is renewable for additional years.

The Graduate School has a number of fellowships, which it awards to outstanding students. Applicants must be nominated by the Department of Physics. The Graduate School also administers Minority Graduate Scholars Awards. They are granted to incoming students as part of the University's comprehensive educational opportunities program.. Details on some fellowships that are supplements to assistantships are as follows:

- *Braddock Fellowships* The Homer F. Braddock fund supplies fellowships for incoming graduate students. These awards are merit based and the decision to make the award takes place at the college level. The award is for $4,000–8,000 per student and can be either for 1–2 years. This fund also supports single year awards of $4,000 for advanced graduate students.

- *David C. Duncan Graduate Fellowships*: These are available to first- and second-year graduate students in physics and carry a stipend of up to $2,000 per year for each of the first two years.

- *Frymoyer Fellowship:* The Frymoyer Fellowship was established to provide recognition and financial assistance to outstanding graduate students enrolled or planning to enroll in the Department of Physics. One annual award shall be made to a student who has achieved superior academic records or who manifests promise of outstanding success, and will typically be renewed for subsequent years provided the recipient continues to make good progress toward a Ph.D.

- *Roberts Fellowships*: The Nellie H. and Oscar L. Roberts fund supports fellowships for incoming graduate students. The decision to make the award takes place at the college level. The award is for $4,000 per student and can be either for one or two years. This fund also supports single year awards of $4,000 for advanced graduate students. Only U.S. citizens may be supported by this fund.

2.7.4 Fellowships from External Agencies

Fellowships are also available to qualified graduate students from external agencies such as the National Science Foundation. Such information can be found at: http://www.gradsch.psu.edu/current/funding/external.html

2.7.5 Physics Department Awards

The department honors graduate students who are particularly outstanding teaching assistants. Awards are made near the end of the Spring semester. Among these is the 'Stan Shepherd Graduate Teaching Assistant Award' which is given to a senior Physics graduate student who has excelled in teaching and who has contributed to the instructional mission of the Physics Department above and beyond their assigned TA duties. This award honors Prof. Shepherd whose record of teaching and service to undergraduate students at Penn State was marked by such a commitment to excellence.

2.8 Physics Graduate Association (PGA)

The Physics Graduate Association (PGA) is an important departmental resource drawing together graduate students in different subfields for informal social and physics interaction. PGA activities in the past have included fielding a softball team, pizza lunches, providing orientation and tips for new students, meetings with the physics faculty and administration, sponsoring talks (on employment in physics, etc.), practice talks for meetings, and the maintenance of refrigerators, copy machines, etc. for student use. Women and minority graduate students in physics have also had informal groups that meet regularly, providing opportunities for peer support. Since the graduate student associations are designed by the current graduate student body, activities will vary from year-to-year.

2.9 Coffee Facilities and Informal Interaction

Canned soda and snacks are available from vending machines located next to room 310 Davey Lab and in the lobby of Osmond Lab. Sodas, and an informal interaction area maintained by the Physics Graduate Association (see above), are also available in the Undergraduate and Graduate Student Lounge, room 219 Osmond Lab.

A good venue to mingle with a broad spectrum of faculty, post docs, and graduate students is the weekly pre-colloquium coffee break, Thursdays 3:30—4:00 p.m. supplied by the Physics Department. It is held on the 2nd floor bridge connecting Davey and Osmond.

3 Degree Requirements

This section explains the requirements for the graduate degrees offered by the physics department: the Ph.D., M.S., and M.Ed. degrees. It is a combination of general university rules and the specific requirements of the Physics Department. In certain cases, exceptions to the rules may be granted --- see Section 1.1.

As for the rules at the university level, more details can be found in Penn State's *Graduate Degree Programs Bulletin,* which is available electronically at http://www.psu.edu/bulletins/whitebook/.

3.1 Common Requirements

In this section are listed rules that apply to all of the graduate degrees, as opposed to specific degrees. The requirements of the different degrees are a combination of a thesis (for the doctoral degrees, and optionally for the master's degrees), course work and departmental examinations.

3.1.1 Courses

Each course counts for a certain number of credits. There are requirements on the number of credits that a student registers for in order to maintain his/her status as a full-time student. A unit of a credit corresponds to a class hour, i.e., 50 minutes, per week of lectures in a standard course.

Graduate courses are numbered from 500 – 599. In addition, there are course numbers 600, 601, 610 and 611. These do not represent actual courses. Instead, they are used by students working on research for a thesis. A student registers for a number of credits under one of these numbers when doing research.

A student should register for Phys 600 for thesis research when the research is on-campus, and he/she also wishes to register for regular courses. Phys 601 is used when he/she does not register for regular courses. Phys 610 is used for off-campus research and Phys 611 for part-time students. Note that if a student is doing thesis research but is taking no courses, then it is advantageous to register for 601 instead of 600, because tuition fees are then lower. (601 and 611 have a credit hour value of zero, in contrast to 600 and 610.)

Undergraduate courses are numbered from 001 – 499. Those in the range 001 – 399 are strictly undergraduate courses. Graduate students take them only to fill in gaps or remedy deficiencies in previous education; credit for such courses cannot be applied to requirements for graduate degrees.

Undergraduate courses in the range 400 – 499 can be taken for a very limited number of credits in a graduate program, in general according to the requirements for each degree. In the Physics Department, graduate students take undergraduate courses in physics only when necessary to fill gaps in their previous education.

The responsibility for being properly registered for courses and maintaining full-time status rests with the student. This should be done in consultation with the student's adviser or the Director of Graduate Studies.

3.1.2 Grades

See Section 5.7 for the detailed university policy on courses and their grading.

A graduate student must maintain a minimum **grade point average (GPA) of 3.00**. This is a university requirement for graduate degrees. (Here A=4.00, A-=3.67, B+=3.33, B=3.00, B-=2.67, C+=2.33, C=2.00, D=1.00, F (fail)=0.00.) Although this minimum need not be maintained semester-by-semester, a Ph.D. student must meet the 3.00 minimum to pass candidacy, for admission to the comprehensive examination, the final oral examination, and for graduation. For a Master's degree, the 3.00 minimum applies for graduation. See also Penn State's *Graduate Degree Programs Bulletin,* at http://www.psu.edu/bulletins/whitebook/.

In addition, there are Physics Department requirements on admission to Ph.D. candidacy that involve a minimum course grade in the first-year courses---see Section 3.2.6.1.

3.1.3 English Proficiency

It is University policy that a candidate for the degree of Doctor of Philosophy demonstrate high-level competence in the use of the English language, including reading, writing, and speaking as part of the language and communications requirements for the Ph.D. Assessment should include pieces of original writing. The department must formally attest that a student has satisfied the English competence requirement before the student's Doctoral Comprehensive Examination may be scheduled.

The formal assessments by the Physics department are made with the aid of the courses Phys. 559 (Graduate Laboratory) and 590 (Current Research), which are taken by first-year graduate students in physics. These courses have assignments that include writing and the making of oral presentations.

In addition, the rules in Sec. 2.6.1 apply to international students. International students should also note that the passage of the minimal TOEFL requirements does not demonstrate the level of competence expected of a Ph.D. graduate from Penn State.

3.1.4 Residence Requirements

The University policy is that over some twelve-month period during the interval between admission to the Ph.D. program and completion of the Ph.D. program, the candidate must spend at **least two semesters** as a registered full-time student engaged in academic work at the University Park Campus, The Milton S. Hershey Medical Center, or Penn State Harrisburg. The normal course of study for a Physics Ph.D. student satisfies this requirement easily.

3.1.5 Continuous Registration

All graduate students should be registered at a credit level appropriate to their level of activity. After a Ph.D. candidate has passed the comprehensive examination and met the residency requirement (Section 3.1.4), the student must continue to register for every Fall and Spring semester until the Ph.D. thesis is accepted and approved.

Post-comprehensive Ph.D. students who are mainly engaged in research will normally satisfy the continuous registration requirement by registering for Phys. 601 (see Section 3.1.1). Ph.D. candidates registered for Phys. 601 who have both passed **the comprehensive examination**, and also met the **two-semester full-time residency requirement**, become eligible for reduced tuition. They may take up to three additional credits each semester with the payment of an additional flat fee and adviser approval.

Students who are supported by an assistantship for both fall and spring semesters are eligible to apply to the Summer Tuition Assistance Program. With adviser approval, students are able to register for up to 9 credits during the summer and the University pays the tuition.

3.2 Ph.D. Program

3.2.1 Summary of Typical Ph.D.

- First the student will either take, or be exempted from (see Section 3.5), the required core courses, which cover the main areas of physics. This typically takes one year. During this time, the student will be under the guidance of the Director of Graduate Studies, or possibly a research adviser. Students are encouraged to meet regularly with him/her to plan course work, learn of opportunities for research/financial support, and discuss with them any other concerns they may have regarding their progress in the graduate program. During both semesters of the first year, students take the course Phys. 590, which includes many presentations by faculty of their research; this gives a good opportunity for students to learn about current research in the department, which is important in selecting a research area and adviser to work for.

- All students must take the fall qualifying examination. If this exam is not passed, the student must take the qualifying exam given in the spring. At the end of the spring semester of the first year, the student's academic record is evaluated for admission to Ph.D. candidacy (see Section 3.2.6.1). (In previous years, the exam was called the "candidacy exam", but here we call it the "qualifying exam" to emphasize that passing the exam is only part of the candidacy requirement.)

- Although research does not normally start until after the student has passed candidacy, students are encouraged to start looking for a research adviser during the first year. This will be a faculty member who will advise them after the first year and may continue as **thesis adviser** through the completion of requirements for the Ph.D. degree.

- In order to get support during the first summer, students are encouraged to become associated with a research group or a faculty member.

- After admission to Ph.D. candidacy, the student should make a concerted effort to select a research adviser and begin research. In some subjects, especially for students with research interests in theoretical physics, this stage may be delayed until after the student has taken advanced courses (like 563/4 (quantum field theory)). Students are encouraged to consult with the Director of Graduate Studies and other faculty on finding a research adviser.

- A Ph.D. candidate will either take, or be exempted from (see Section 3.5.1), four physics graduate courses other than the core courses after consultation with their adviser. They may in addition take courses outside of the department with the written approval of their adviser and/or the Director of Graduate Studies (see Section 3.2.4). Graduate courses from other departments may be substituted for some of the four if they are directly relevant to the student's thesis and with the written approval of the thesis adviser. The sample four year course plan given in Tables 2 and 3 should be treated as guidance in developing the student's own course plan.

- The student, in consultation with his/her research adviser, will select **at least three** additional faculty members to serve on the student's doctoral **committee**, prior to taking the **comprehensive examination. At least one** member of this committee needs to be from outside the physics department. The comprehensive exam is normally taken about a year after the candidacy examination. Passing this examination is necessary to proceed to a Ph.D. degree.

- Starting at least after the comprehensive examination, the student will engage in research under the guidance of the thesis **adviser** towards completion of the Ph.D. degree. Students are encouraged to maintain regular contact with the members of the doctoral committee. During the final year of research, the student will write up the results of his/her research program in a thesis.

- The student will present the results contained in the thesis at a final oral examination before the doctoral committee. If the thesis is approved, the student will be awarded a Ph.D.

It is required by Penn State that a doctoral student must complete the program, including acceptance of the doctoral thesis, within **8 years** from the date of acceptance as a candidate. However, the graduate dean in appropriate circumstances may grant extensions. Moreover, a graduate student must maintain a minimum of a 3.00 grade point average (equivalent to a B grade). Although this minimum need not be maintained semester-by-semester, a Ph.D. student must meet the **3.00 GPA minimum** for admission to candidacy, the comprehensive examination, the final oral examination for the Ph.D. defense, and for graduation.

Subject to the approval of the adviser and the head of the department, a student may register for research to be done away from the University Park campus. In the Physics Department, this frequently happens for students in elementary particle experiments who are working on an experiment at a laboratory in another city or country.

There is no departmental foreign language requirement, although a reading knowledge of one foreign language may be needed in some areas of research. Generally, physics research results reported in journals and at conferences are presented in English.

3.2.2 Core Courses

It is necessary to pass, or be exempted from (see Section 3.5.1), all of the core courses which are listed below, with their typical timing:

First semester (fall):

- PHYS 525 (Methods of Theoretical Physics)
- PHYS 530 (Theoretical Mechanics)
- PHYS 561 (Quantum Mechanics 1)
- PHYS 559 (Graduate Laboratory)
- PHYS 590 (Current Research)

Second semester (spring):

- PHYS 517 (Statistical Mechanics)
- PHYS 557 (Electrodynamics I)
- PHYS 562 (Quantum Mechanics 2)
- PHYS 559 (Graduate Laboratory), if not taken in the fall semester
- PHYS 590 (Current Research)

See Section 4.1 for detailed descriptions of the courses. Students are strongly advised to fulfill this course requirement as soon as possible to avoid delaying progress in the Ph.D. program. However, individual circumstance, e.g., the need to take an English course, may necessitate a delay for one or two courses. An overall course plan for the first year should be developed in consultation with the adviser or the Directory of Graduate Studies, keeping in mind the requirements for admission to candidacy for the Ph.D. degree given in Section 3.2.6.1.

The Graduate Laboratory, PHYS 559, is offered in both semesters but the capacity of the facilities is such that only half of the incoming class can sign up each semester; students should therefore register at the first available opportunity.

Appropriate courses a student has taken at another university may be used to gain exemption from most of the required courses---see Section 3.5.1. The exception is the PHYS 590 course on current faculty research.

Occasionally, an incoming student will have inadequate preparation in a particular area: for example, the lack of an undergraduate quantum mechanics course which is a prerequisite for one of the core courses, Phys. 561 (Quantum Mechanics I). In such cases, the student's adviser or the Director of Graduate Studies may recommend that the student take certain undergraduate courses in their first year, which can delay completion of the Ph.D. degree. It should be noted that such a student must nevertheless take the **Qualifying Examination** on the same schedule as the rest of the incoming class, i.e., in the fall semester, and if necessary in the spring semester, of the student's first year (see Section 3.2.6).

3.2.3 Recommendations for advanced courses

Ph. D. candidates will either take, or be exempted from (see Section 3.5.1), **at least four** additional 3-credit, 500-level physics courses. (Graduate courses from other departments may be substituted for some of the four if they are directly relevant to the student's thesis and with the written approval of the thesis adviser.) Students should consult with their adviser in selecting these courses. They are strongly encouraged to take one or more courses in a subfield of physics that is not their area of specialization. Information on research areas of potential overlap with the student's subfield can be obtained from the adviser, the Phys. 590 course on current faculty research, and through informal interaction with faculty, post docs, and graduate students who are already engaged in research. The weekly physics colloquium (see Section 7.1) and department seminars are a valuable source of information on current research achievements of significance that span the breadth of physics. These are listed on the physics department web page.

Although there are no official requirements on the choice of advanced courses to be taken, the student, in consultation with the adviser, should ensure that course work directly relevant to his/her planned thesis research has been covered. It should be noted that not all of the relevant advanced courses might be available to the student every calendar year, due to departmental scheduling constraints. Modifications in an optimal course plan may therefore be necessary, and should be made in consultation with the student's adviser. In appropriate cases, a course of rigorous independent study under the supervision of a faculty member may be used in place of an advanced course. Lists of advanced courses that are planned to be offered during an academic year are sent to all students and faculty during the previous Spring semester.

Courses that are helpful for particular subfields are:

- *Atomic Physics*: 571 (Modern atomic physics), 572 (Laser physics and quantum optics), 518 (Critical Phenomena and Field Theory). 563

(Quantum Field Theory I) and additional out-of-department courses may be helpful.

- *Condensed Matter Experiment*: 512 and 513 (Quantum theory of solids), 514 (Physics of surfaces, interfaces and thin films), 518 (Critical Phenomena and Field Theory). 571 (Atomic, molecular and optical physics), 572 (Laser physics and quantum electronics) may be helpful.

- Condensed Matter Theory: 512 and 513 (Quantum theory of solids), 518 (Critical Phenomena and Field Theory), 527 (Computational Physics), 563 (Quantum Field Theory I). 564 (Quantum Field Theory II) and 510 (General Relativity) may be helpful.

- *Elementary Particle Experiment:* 541 (elementary particle phenomenology), 563 and 564 (Quantum field theory I and II), 542 (Standard model of elementary particle physics). 518 (Critical Phenomena and Statistical Field Theory) and 510 (General Relativity) may be helpful.

- *Elementary Particle Theory*: 563 and 564 (Quantum field theory), 541 (Elementary Particle Phenomenology), 542 (Standard model of elementary particle physics), and 510 (General Relativity). 518 (Critical Phenomena and Statistical Field Theory) and 526 (Methods of theoretical physics II) may be helpful.

- *Gravitational Physics*: 510 and 511 (General Relativity), 563 and 564 (Quantum field theory), 565 (Interface of general relativity and quantum physics), 545 (Cosmology), or 526 (Methods of Theoretical Physics II). 518 (Critical Phenomena and Statistical Field Theory) may be helpful.

PHYS 527 (Computational Physics) will be useful to many students irrespective of subfield.

Sample plans are in Tables 1, 2 and 3, and in Section 3.2.5 and should be used in consultation with the student's adviser.

There is no actual minimum on the number of credits needed for a Ph.D. degree, as opposed to requirements on courses taken, as described above. Most appointments in the department are designated half-time graduate assistants. A half-time graduate assistant at Penn State can take a minimum of 9 and a maximum of 12 credits per semester. Quarter-time assistants can take up to 14 credits per semester. Students must consult with the Director of Graduate Studies if the number of credits they are taking in a given semester is not consistent with these guidelines.

3.2.4 Courses Outside of the Physics Department

The graduate programs at Penn State span a wide range of different specialties, and even students who choose the standard option may need to take one or more out-of-department courses (see Section 4.2). Information on such courses may be obtained from advisers, faculty members, the Graduate Degree Programs Bulletin, or other departmental web pages. The Graduate Research Exhibition and the Science Seminars (see Section 7.2) are additional sources of information on out-of-department research specialties. Out-of-department courses are also an opportunity to acquaint the student with a faculty member outside of physics who may later serve on the student's doctoral committee.

While courses outside the Physics Department can form an important component of a student's graduate education, it is extremely important that a student consults with his or her adviser before taking courses outside the department. This consultation will insure that the schedule remains compatible with departmental course requirements and is furthering progress toward a physics degree. Students are required to notify their adviser if they intend to take courses outside the Physics Department. Notification will be made by presenting the adviser with a completed registration adjustment (drop/add) form (available from the department office), which the adviser must sign to acknowledge that he or she has been notified. The form must then be submitted to the graduate coordinator. The adviser will be responsible for informing the student if such courses are interfering with progress toward the Ph.D. If they do interfere with progress toward the Ph.D., taking such courses may be considered grounds for losing support.

3.2.5 When are courses given?

The information in this section should be taken as guidance in planning the student's coursework in consultation with the student's adviser. Up-to-date information on the scheduling of courses can be found at http://www.phys.psu.edu/graduate/graduate-courses/ and http://schedule.psu.edu. Since the number of students requiring an advanced graduate course is limited, not all of them can be offered every year. Courses offered every year are:

- Core graduate courses (fall only): 525, 530, 561;

- Core graduate courses (spring only): 517, 557, 562;

- Core graduate courses offered both fall and spring: 559 and 590;

- Intermediate graduate courses: Quantum Theory of Solids: 512–513; quantum field theory: 563–564; Gravity: 510.

- Computational Physics: 527.

The courses that may only be available approximately once every two years are, classified by area:

- Condensed Matter: 514, 518, 524.
- Elementary Particles: 541, 542.
- Gravity: 511, 565
- Atomic, Molecular and Optical Physics: 571, 572.
- Mathematical Physics: 526 (Methods of Theoretical Physics II).
- Special Topics: 597

In the case that any of the courses is not offered (for example, because of too low an enrollment), there may be the possibility of taking a rigorous independent studies course on the same material as a replacement.

Advanced courses that can only be offered in alternate years may, for example, be scheduled as shown in Table 1. The hypothetical four-semester sequence has been designated (even, odd), beginning in the Fall of an even year. For a student who is unable to obtain any exemptions due to prior work and has taken the full sequence of core courses, the four-semester advanced course sequence will be taken in the second to fourth years in their Ph.D. program. Up-to-date course scheduling information can be found at http://schedule.psu.edu.

Appropriate course plans for the graduate student, given the four-semester course schedule listed above, are given in Tables 2 and 3. They apply to a graduate student entering in the Fall of an even year who does not obtain any exemptions due to prior work. Due to the limited capacity of the graduate laboratory, only half the incoming class can take 559 in the Fall semester. 590 must be taken both semesters of the first year. For students entering in the fall of the odd year, years 3 and 4 would be reversed. (Note that the distinction between odd- and even-year scheduling is not strictly adhered to.)

A student with no exemptions will typically take a sequence of advanced courses in their third and fourth years in the Ph.D. program. Experimentalists will typically take fewer advanced courses than theorists; theorists, especially, are likely to take more than the required minimum number of advanced courses. Elementary particle experimentalists are encouraged to complete 541 and 563 in their second year, followed by 542 and 564 as soon as possible since they may need to be away from campus at their experiments. Experimentalists in condensed matter and in atomic, molecular and optical physics may find out-of-department courses especially helpful (see Section 4.2). These courses should be chosen in consultation with a student's adviser.

3.2.6 Admission to Ph.D. Candidacy

The department's candidacy committee evaluates each student's first year academic record at the end of the Spring semester of the first year, to determine whether the student should be officially admitted to Ph.D. candidacy. The candidacy committee (normally) consists of five members of the department, at least two of whom are experimentalists not in the same sub-field and two of whom are theorists not in the same sub-field. Exemptions from the candidacy requirements are only offered in very exceptional circumstances (see Section 3.5.2).

3.2.6.1 Candidacy Requirements

Admission to Ph.D. candidacy is granted to those candidates that the candidacy committee considers to have a knowledge of basic physics suitable for a professional physicist. Its evaluation is based on the entire first year record. This includes the qualifying examination (see Section 3.2.6.3), grades in all courses taken in the first year, performance in teaching and research, and any other relevant information brought to the attention of the candidacy committee. (The exam is called here the "qualifying examination" to emphasize that passing it is only part of the requirements for passing candidacy. It is commonly also called the "candidacy examination".)

Sufficient requirements for admission to Ph.D. candidacy are:

- Successful performance in the Qualifying Examination, of which details are given in Section 3.2.6.3.
- A grade of B or better in all the core courses. Students who have taken equivalent coursework at other universities may be exempted from this requirement for some or all of the core courses as outlined in section 3.5.

Note that performance on the course work is as important as performance on the candidacy exam.

3.2.6.2 Procedures, etc.

When each qualifying exam has been graded, students will be advised of their performance in writing (about two weeks after the examination). They may have passed the exam portion of candidacy or may need to retake the examination. The letter will include a statement of progress made towards candidacy.

At the end of the spring semester, after course grades are available, decisions are made on candidacy. Several outcomes are possible:

- Admission to candidacy.
- A student needs to retake the examination in the fall, or to address deficiencies in the coursework, or both.

- A student may be advised to consider leaving the program. This would result from sufficiently poor performance over the whole of the first year.

Students will be advised in detail of their situation and are encouraged to discuss their situation with their adviser and the Director of Graduate Studies.

In the case of poor course performance, the committee will decide what the student will need to do to remedy the grade and meet the standard of a B grade. This is based on the course instructor's assessment of the student's performance. In some cases, it will be necessary to retake the course and obtain a grade of B or above. In most other cases, the student will need to meet with the relevant course instructor as soon as possible to discuss what is to be done; typically this will involve studying the material over the summer and then taking and passing a test at the beginning of the next fall semester. In the last case, the instructor will evaluate this work and notify the Director of Graduate Studies in writing before the end of the first week of the fall semester.

In the case of students who are given the opportunity to remedy deficiencies, the Candidacy Committee will reevaluate the students after the remediation work has been done. Note that a student who is not awarded Ph.D. candidacy may still have the option of working towards a M.S degree–see Section 3.4–although this is not recommended in all cases.

- **It is the responsibility of every graduate student, in consultation with their adviser, to ensure that they satisfy the requirements for admission to Candidacy.**

Table 1: Sample schedule for ***advanced*** physics courses

Even Year (Fall)	Odd Year (Spring)
Quantum Gravity (565) Critical Phenomena (518) Particle Phenomenology (541)	Standard Model (542) Semiconductors and Devices (524 Adv. Topics General Relativity (511)
Odd Year (Fall)	**Even Year (Spring)**
Atomic, Molecular and Optical Physics (571) Computational Physics (527) Surfaces, Interfaces, Thin Films (514)	Methods of Theoretical Physics (526) Laser physics & Quantum Electronics (572)

Table 2: Sample 4-semester course sequence for theorists

Year	Fall	Spring
1	525, 530, 561, (559), 590	517, 557, 562, (559), 590
2	3 of 510, 512, 563, 518/541	2-3 of 511, 513, 542, 564
3	1-2 of 518/541, 565, other	1-2 of 511, 524, 542,564, other
4	1-2 of 514, 527, 571, other	1 of 526, 533, 572, other

Table 3: Sample 4-semester course sequence for experimentalists

Year	Fall	Spring
1	525, 530, 561, (559), 590	517, 557, 562, (559), 590
2	2-3 of 510, 512, 518, 541, 563	1-3 of 511, 513, 542, 564, other
3	1 of 514, 527, 571, other.	1 of 526, 533, 572, other.

3.2.6.3 Qualifying Examination for Candidacy

The Qualifying Examination is given twice a year near the beginning of the spring and fall semesters.

In each case, the examination takes place in two three-hour sessions (morning and afternoon), and is composed of a total of about eight questions covering the core areas of physics traditionally included in the undergraduate curriculum.

- Mechanics (including Special Relativity).
- Quantum Mechanics.
- Statistical Mechanics and Thermal Physics.
- Electricity and Magnetism:

The exam tests fundamental understanding and mastery of basic physical concepts. The level of knowledge needed is primarily that of undergraduate physics at all levels, but with a level of performance appropriate for a graduate student. A detailed description of the examination including sample questions and a list of representative textbooks is available from the Graduate coordinator; previous exams are also on the department's website. *Note carefully that passing this examination forms only a subset of the requirements for Ph.D. candidacy—see Section 3.2.6.1.*

All entering students are required to take the examination when it is given in the fall semester. A student who performs appropriately well on this examination will be considered to have satisfied the examination portion of the procedure for admission to candidacy. All other first-year students will need to take the examination in the spring semester; their performance on the first examination will be ignored in the candidacy decision.

Approximately two weeks after the spring examination, the candidacy committee will report its evaluation of the first-year students, as explained in Section 3.2.6.1. Those students who are asked to retake the examination by the Candidacy Committee will need to do so at the beginning of the next fall semester.

3.2.6.4 Delay of Candidacy

In general, students must complete the requirements for candidacy by the end of their first year. However, upon the recommendation of the student's adviser or the Director of Graduate Studies, a student with inadequate undergraduate preparation can request to delay being considered for candidacy for one year, to allow the completion of remedial course work. The request should be made in writing to the Director of Graduate Studies, who will consult with the Candidacy Committee before granting such a delay.

3.2.7 Research

Despite all the requirements in the preceding sections, the primary requirement for a Ph.D. is to perform good research, and this section explains some of the official issues.

3.2.7.1 Finding an adviser

It is a student's responsibility to find a research adviser. One aim of requiring students to take the 590 course is to ensure that they become acquainted with current research in the department. Students should speak with faculty in whose research they are interested and find out about the possibilities of working with these faculty. Students are strongly encouraged to find a research adviser by the end of the summer after the first year. This adviser will be polled twice a year by e-mail as to whether students are making satisfactory progress toward a degree. If a student has not yet found an adviser by the beginning of the second year, the Director of Graduate Studies will act as that student's interim adviser.

Second year students who are having difficulty finding a research adviser should consult with the Director of Graduate Studies. The Director of Graduate Studies will assist such students in finding a research area, with the goal that every student has a research adviser before the end of the spring semester of the second year.

3.2.7.2 Adviser outside the department

It is possible to obtain a Ph.D. in physics while doing research under the supervision of an adviser outside of the physics department. This has happened in the areas of materials science, chemistry, mathematics, and astronomy and astrophysics. Approval of research under an outside adviser is not automatic, but will depend on individual circumstances. The research must still be classifiable as physics. The student may also have a co-adviser in the physics department. If a graduate student is interested in working with a faculty member from outside the physics department towards a physics Ph.D. degree he/she has to petition the graduate program committee for approval to do so. If approved by the graduate program committee, it is expected that the adviser from outside the department will provide support for the student; for such students, it is departmental policy not to provide support as a teaching assistant.

Note that assistantship support from the Physics Department and status as a physics graduate student will be terminated if the student is not working towards a physics degree.

3.2.7.3 Change of adviser

Sometimes a student will change advisers, for any of a number of reasons, including a change of research interests.

3.2.8 Thesis Committee

With advice from his/her adviser, a Ph.D. student should locate four or more Penn State faculty members who will be willing to serve on the student's doctoral committee. This committee is responsible for the general guidance of a doctoral candidate. Normally, the student's adviser is one of the committee members. The committee has to have at least two members from within the student's major field (i.e., physics), and at least one member from outside the department. If the candidate has a minor field (e.g., education), then the committee must have a member from that field

See the University's Graduate Degree Programs Bulletin at http://www.psu.edu/bulletins/whitebook/ for more detailed rules.

The committee gives the comprehensive examination and the thesis defense, and it is responsible for approving the thesis.

3.2.9 Comprehensive Examination

The comprehensive examination should normally be taken about a year after the candidacy examination. It is an oral exam given before the student's thesis committee. The normal format is that the student will present a seminar of about 30 minutes in duration on his/her current or future research. This seminar should be pedagogically oriented, stressing the fundamentals and context of the general area of research. While the seminar may consist in part of a summary of personal research results, the comprehensive exam should not be delayed because of the absence of such results. For example, the seminar may simply be a review of a certain area of research. Thus it is not necessary that a specific research program be proposed.

After the seminar, there will be an oral examination on the research area and on related core areas in physics. The aim of the examination is to establish that the student has an appropriate level of expertise to continue with the research part of the Ph.D. program.

In addition, the student should prepare a written summary of his/her current research and give a copy to each of the members of the committee at least one week before the examination. The summary should be about 1—2 pages in length. If the student has not yet started research, this summary should be of the material presented in the seminar part of the examination.

The committee will establish the general areas of the questions for the oral part of the examination. The thesis adviser should communicate this decision to the student. Particular research groups may have a written policy on what subject matter a student should be proficient in at the comprehensive examination. A student preparing for the comprehensive examination should consult his/her adviser and the members of the committee on this issue. Three weeks' notice to the Graduate School is required for scheduling the examination.

3.2.10 After the Comprehensive Exam

After passing the comprehensive exam, the student will submit to the Ph.D. committee *on an annual basis* a 1—2 page report on his/her research progress over the intervening year. The research adviser will send a copy of this report, together with a brief assessment of the progress, to the Graduate Program Director.

If a student is supported by the department as a teaching assistant (TA), adequate progress in research is a prerequisite for continued support. (Of course, a TA's performance in teaching will also have to be satisfactory.) TA support beyond the fifth year in graduate school will be granted only with the approval of the Department Head.

3.2.11 Thesis for Ph.D.

A doctoral thesis is an account of a significant contribution to knowledge in the subject made by the candidate. It should be presented in a scholarly manner, document an ability on the part of the candidate to do independent research of high quality, and show considerable experience.

A *Thesis Information* is available and contains details about format, paper, and other requirements http://www.gradsch.psu.edu/current/thesis.html. The Thesis Office is in 115 Kern Building, 865-5448. In addition, you may wish to consult with fellow graduate students. They may have useful tips on using word processors and typesetting programs (e.g., TeX and LaTeX) to get one's thesis in the correct format. See also http://www.esm.psu.edu/~gray/psu-latex-thesis-class.html for a package and template for using LaTeX for a Penn State thesis.

In addition there are two courses that students may take to assist them in the writing of their thesis --- see Section 4.4.

It is common in physics that much of the work in a Ph.D. thesis will have been published in research journals or accepted for publication before the thesis is written. The thesis might then be based on the published papers. The papers need not have the student as the sole author. A thesis based on published papers will typically have added material, notably an introductory chapter, and will often be expanded relative to the published papers.

When a complete draft of the thesis is available, the student should submit it to the Thesis Office for format review. After the student's thesis committee approves the thesis, a final archival copy should be given to the department. This will then reside in the library.

3.2.11.1 Thesis Defense (Final oral examination)

When the thesis is complete, a thesis defense is arranged, before the student's doctoral committee. Three weeks' notice to the Office of Graduate Programs is needed for the scheduling of the examination, and the student should give a copy of the thesis to each member of the committee at least one week before the defense.

The defense consists of an oral presentation of the thesis, followed by a period of questions and responses. The questions will mostly relate to the thesis but may cover the candidate's whole program of study. The portion of the examination in which the thesis is presented is open to the public.

If a candidate fails, it is the responsibility of the doctoral committee to determine whether another examination may be taken.

3.3 M.S. Program

There are two options for the Master of Science (M.S.) degree: (a) thesis option and (b) non-thesis option. Read the requirements carefully to see which applies.

For all M.S. degrees, Penn State requires a minimum of 30 graduate credits and 3.00 GPA. For this purpose, graduate credits may include certain courses with numbers 400-499.

3.3.1 Summary of Typical M.S.

It should be noted that the required courses and the first part of the program are very similar to that of the Ph.D.

- First the student will take the required core courses for the M.S. degree; these cover the main areas of physics. The set of core courses for the M.S. differs somewhat from that for the Ph.D. degree. This typically takes one year. During this time the student will be under the guidance of an adviser.
- For the thesis option, a thesis is written based on original research by the student. For the non-thesis option, the student takes (at least) 6 credits of 500 level physics courses beyond the core ones and writes a paper.

Subject to the approval of the adviser and the head of the department, a student may register for research to be done away from the University Park campus. In the Physics Department, this frequently happens for students in elementary particle experiments who are working on an experiment at a national laboratory.

There is no departmental foreign language requirement, although a reading knowledge of one foreign language may be needed in some areas of research. (Generally, physics research reported in journals and at conferences is given in English.)

3.3.2 Required Courses for Standard M.S.

For a Physics M.S., it is necessary to pass the following core courses:

- PHYS 530 (Theoretical Mechanics)
- PHYS 557 (Electrodynamics I)
- PHYS 559 (Graduate Laboratory)
- Either PHYS 561 (Quantum Mechanics 1) or PHYS 410 (Quantum Mechanics) in the undergraduate curriculum.

In addition, for the non-thesis option, a further 6 credits of 500 level physics courses are required beyond the core ones listed above

Appropriate courses a student has taken at another university may be used to gain exemption from most of these required courses – see Section 3.5.1.

Normally, incoming students take the core courses for the Ph.D. – see Section 3.2.2 – thereby satisfying the requirements for core courses for the M.S.

3.3.3 Research

The information in Section 3.2.7, concerning research done for a Ph.D., is applicable with minor changes to students who are doing research for a thesis for an M.S. degree.

3.3.4 Paper

This is less formal than a thesis. It will be prepared under the supervision of a faculty member. If a student does not write a thesis for the master's degree, a paper must be written.

The content of the paper should be either an account of original research done by the student or a review of an area of research. The research or the review will have been done under the supervision of a faculty member as part of the M.S. program. A paper published in a regular journal is acceptable. Otherwise the paper should be written in a similar style to a journal article; it should represent a substantial piece of work, which will normally result in a length of at least 15 pages (with normal spacing).

3.3.5 Thesis for M.S.

For those students whose M.S. program entails a thesis, the requirements differ from the Ph.D. thesis in that the Master's thesis is based on a smaller amount of research work. A full-blown oral defense and final examination is not required. The thesis must be accepted by the student's thesis committee in order for it to count to the degree. You must follow the Master's Approval page found at the Graduate School's Thesis Information Page.

3.4 M.Ed. Program

At least 18 credits in physics are required, of which up to 6 credits may be for research, and 6 additional non-research science credits (which may be in physics). The candidate is required to earn 6 credits in education as directed by the faculty of one of the approved graduate programs in professional education. A thesis or term paper must be submitted and accepted by the department. The requirements of the Graduate School regarding a thesis must be met. Follow the department requirements regarding the master's paper.

3.5 Policy on Exemptions from Course Work and Examinations

3.5.1 Exemption from course requirements

A student may make a request to be exempted from one or more of the required courses (see Sects. 3.2.2 and 3.2.3 in the case of the Ph.D. degree, and Sect. 3.3.2 for the M.S.), on the grounds that he/she has already completed comparable course work at another institution or as an undergraduate. Ph.D. candidates should note that the University itself does not set any minimum number of credits for a Ph.D. degree, unlike the case for Masters degrees. Note also that although the curriculum for the core courses for a Ph.D. might appear to be similar to that for corresponding undergraduate courses, the graduate courses are taught at a higher, more sophisticated level. Thus having passed a normal undergraduate course in one of the core subjects is not an appropriate criterion for exemption from the corresponding graduate core course.

The request for a course exemption should be made to the Director of Graduate Studies and should be accompanied by the transcript showing that the student has successfully completed the course and an indication of the level of the course such as the syllabus or the text. If the request is reasonable, the student will be asked to meet one or two faculty members who have taught the course recently. The faculty member(s) will assess the student's knowledge, and send his/her comments to the Director of Graduate Studies. (In the favorable case, a few sentences might suffice.) The final decision is made by the Graduate Candidacy Committee and is based on all available information. If the exemption is granted, the information will be included in the student's file. A student who is exempted from one or more of the core courses will normally take appropriate advanced physics courses instead—see Section 3.2.3.

For the purposes of advancing to candidacy, it is important to note that all exemptions from the core courses are contingent on satisfactory performance in other courses a student might subsequently take and on passing the candidacy exam. Poor performance on either the exam or on courses taken subsequent to the granting of an exemption may result in the exemption being revoked and the student being required to take the courses in question.

Separately from the exemption from courses, Master's candidates can transfer up to 10 graduate-level credits from other universities in fulfillment of their minimum credit requirement (see Section 3.3). For detailed procedures, see the Graduate Degree Programs Bulletin.

3.5.2 Candidacy and previous work

In truly exceptional circumstances, it is possible to advance to Ph.D. candidacy on the basis of work at other universities. To do this, a student should make a petition to the Director of Graduate Studies. The Physics Department's Candidacy Committee will evaluate the petition. The student will need to provide documentation of the previous work. The committee's evaluation will be based on this material, possibly with the aid of an interview or an oral examination, and in the case of a foreign student, perhaps with the aid of consultation with faculty knowledgeable about the university system in the students' home country.

One situation in which the decision may be routine is for students who arrive with a new faculty member and who have completed the candidacy requirements at their original university.

The decision will be communicated to the student in writing , to the Director of Graduate Studies, with a copy put in the student's.record.

4 Course Descriptions

4.1 Graduate Physics Course Descriptions

This section gives descriptions of the graduate courses in the Physics Department. The course descriptions are only intended as a rough summary of the course material. The precise content of a course may vary depending on the instructor. Up-to-date information can be obtained from the physics department web page and from the course instructor. In addition, you may consult with your adviser or the Director of Graduate Studies on the appropriateness of any given course. The course numbers do not follow in order of difficulty. *A lower numbered course among the 500s is not necessarily less advanced than a higher numbered course*.

PHYS 510 *General Relativity* I (3 credits)
Prerequisite: PHYS 557.

- Incompatibility of Newtonian gravity and special relativity; equivalence principle.
- Differential geometry; manifolds, tensor fields, metrics, Riemannian geometry; connections.
- Einstein's equations; conceptual issues, novel aspects of general relativity.
- Gravity waves; mathematical description; polarization states; astrophysical sources; detection of gravity waves.
- Black hole physics; the Schwarzschild solution and its global structure; Kerr solution; ergospheres and the Penrose process; laws of black hole mechanics.
- Elements of cosmology; spatial homogeneity and isotropy; Friedmann-Robertson-Walker solutions; the evolution of our universe.

PHYS 511 *Advanced Topics in General Relativity (3 credits)*
Prerequisite: PHYS 510

Selected topics from:

- Asymptotic structure of space-time; physical boundary conditions; asymptotic symmetries; conserved quantities; positive energy theorems.
- Methods of solving Einstein's equations; Killing vectors and symmetry reduction; algebraically special solutions; Kerr-Schild technique.
- Observational tests of general relativity; solar system tests; strong field tests from the Hulse-Taylor pulsar.
- Cosmology; Bianchi models; chaotic behavior near the singularity in type IX model physical cosmology.
- Gravitational lensing; microlensing and MACHOS; lensing by galaxies; the Einstein cross.

PHYS 512 *Quantum Theory of Solids I* (3 credits)
Prerequisite: PHYS 412 or equivalent --- undergraduate Solid State Physics I.

- Specific heat and magnetic susceptibility of an electron gas; electrons in a periodic potential.
- Band theory of solids; the reciprocal lattice; electrons in electric and magnetic fields; Fermi surfaces and de Haas-Van Alphen effect.
- Pseudopotential and quasiparticles; screening; plasmons.
- Phonons; normal modes; specific heat of phonons; electron-phonon interaction.
- Homogeneous and inhomogeneous semiconductors.
- Boltzmann equation and transport theory; transport in metals and semiconductors; phonon-photon and phonon-phonon interactions.

PHYS 513 *Quantum Theory of Solids II* (3 credits)
Prerequisite: Phys. 512.

- Basic properties of superconductors; BCS theory; Landau-Ginzburg theory; Josephson effect.
- Hartree-Fock approximation and its applications.
- Landau Fermi liquid theory; introduction to density functional theory.
- Local description of solids; metal-insulator transition.
- Spin waves, magnons; disorder and localization.
- Introduction to many-body theory.

PHYS 514 *Physics of Surfaces, Interfaces and Thin Films (3 credits)*
Prerequisite: PHYS 412 or equivalent --- undergraduate Solid State Physics I.

- Surface structures; geometries and diffractive probes.
- Experimental probes; elastic and inelastic scattering of electrons, atoms, neutrons and photons; thermodynamics measurements; di-electric measurements; imaging.
- Electronic properties at surfaces; theories of structure and dynamics; work function.
- Surface dynamics; surface and interface thermodynamics.
- Adsorption; chemisorption; physisorption; kinetics at surfaces; phase transitions in two dimensions; film growth and wetting.
- Phase transitions; ultrathin film nucleation and growth phenomena.

PHYS 517 *Statistical Mechanics (3 credits)*
Prerequisites: PHYS 561 (graduate Quantum Mechanics I), and PHYS 420 or equivalent (undergraduate Thermodynamics, Statistical Mechanics).

- Thermodynamics; notion of entropy; the basic laws of thermodynamics.
- Classical statistical mechanics; distribution functions on the phase space; classical ideal gas; calculation of free energy; entropy and specific heats; Boltzmann transport equation.
- Quantum statistical mechanics; density matrices; canonical, micro-canonical and grand-canonical ensembles.
- Identical particles; ortho- and para- hydrogen; rotational and vibrational degrees of freedom of molecules.
- Bose and Fermi gases; derivation of Planck's black body distribution; Fermi energy levels.
- Elements of phase transitions and critical phenomena; Ising model.

PHYS 518 *Critical Phenomena and Field Theory (3 credits)*
Prerequisites: PHYS 517 and 563

- Phase transitions; infrared behavior; Hartree Fock approximation; large-N expansions.
- Field theoretical treatment of critical phenomena; perturbative evaluations of critical exponents; scaling laws; universality.
- Renormalization group and its mathematical structure; scaling laws; approximation methods.
- Gaussian model, Ising model; Landau-Ginzburg model.
- Elements of conformal field theory; fluctuations and random processes.

PHYS 524 *Physics of Semiconductors and Devices* (3 credits)
Prerequisite: PHYS 412 or equivalent.

- Electronic structure; electrons in periodic structures; semiconductor band structure; pseudo-potential and kp method; doping in semiconductors.

- Optical and transport properties of crystalline and amorphous semiconductors; Boltzmann transport equation; interactions of phonons with semiconductors; excitons; semiconductors in magnetic fields.
- Quantum wells; superlattices.
- Quantum Hall effect; quantum devices.

PHYS 525 *Methods of Theoretical Physics (3 credits*)

- Complex variables; complex-analytic functions; Laurent expansions; contour integration.
- Finite and infinite dimensional vector spaces; Hermitian structures; Hilbert spaces.
- Linear operators and their properties; self-adjoint operators; eigenvalues and eigenvectors; unitary operators.
- Calculus of variations and its application to classical mechanics and classical field theory.
- Fourier series; Fourier integrals and their properties; applications to differential equations; distributions; Green's functions.
- Differential equations that occur commonly in physics; special functions; orthonormality and completeness.
-

PHYS 526 *Methods of Theoretical Physics II (3 credits)*
Prerequisite: PHYS 525

- Elements of general group theory; finite groups; subgroups; normal subgroups and quotients.
- Lie algebras; examples of infinitesimal symmetries in physics.
- Manifolds, vector fields and forms; Lie derivatives; metrics.
- Lie groups; detailed treatment of SU(n); basic representation theory.
- Applications to condensed matter and particle physics.

PHYS 527 *Computational Physics (3 credits)*

- Introduction to computational methods; numerical methods; Monte-Carlo simulations and their applications to condensed matter and high-energy physics.
- Applications to condensed matter physics: statistical mechanical models, critical phenomena; simulations of electronic properties of solids.
- Hydrodynamics: problems in wave phenomena, applications to acoustics and astrophysics.
- Gravitational physics: algebraic manipulations, solving Einstein's equations on a computer; applications to cosmology and black hole physics.

PHYS 530 *Theoretical Mechanics (3 credits)*
Prerequisite: PHYS 419 or equivalent

Lagrange's equations, the variational principle, constraints, symmetry and conservation equations; linear oscillators; Hamilton's canonical equations, Poisson brackets, canonical transformations; Hamilton-Jacobi method, action-angle variables, perturbation theory, adiabatic invariance; nonlinear oscillators, stability analysis, parametric oscillators, discrete maps and chaos, KAM theorem.

The course is designed to show case the power of Lagrangian and Hamiltonian formalism of mechanics for solving complex problems in mechanics, as well as some important results in nonlinear dynamics. The principles and techniques taught in the course will be important for understanding issues and solving problems in other branches of physics, such as electrodynamics. These techniques will also be useful for research in contemporary physics and other sciences.

PHYS 533 *Theoretical Acoustics (3 credits)*
Prerequisite: PHYS 525 or equivalent.

- Euler equations (no viscosity); acoustics for an ideal Euler fluid (no thermal conductance).
- Special problems; spherical and piston sources; Helmholtz resonator.
- Navier-Stokes equations; viscous and thermal penetration depths.
- Acoustics of a Navier-Stokes' fluid; bulk attenuation, boundary attenuation; spherical resonator.
- Superfluids; acoustics of superfluids; first sound--fifth sound; Doppler shift.
- Wave propagation in random media; fractals, long wavelength---Biot equation; short wavelength---Anderson localization; acoustics of Penrose tilings.
- Acoustic imaging; medical imaging; non-destructive testing; geophysical survey; acoustic microscopy; acoustic holography.

PHYS 541 *Elementary Particle Phenomenology (3 credits)*
Prerequisite: PHYS 562

- Baryons and mesons; properties; isospin symmetry; stability and decay channels; resonances.
- Leptons and quarks; elementary properties; need for color; baryons and mesons from quarks; three generations; experimental data.
- Weak interactions; radioactive decays and their properties; qualitative treatment of the gauge principle; unification of electromagnetic and weak interactions.
- Quantum chromodynamics; basic ideas; discussion of experimental results; qualitative treatment of confinement and asymptotic freedom.
- Experimental techniques used in contemporary high energy physics.

PHYS 542 *Standard Model of Elementary Particle Physics (3 credits)*
Corequisite: PHYS 564

A detailed treatment of unification of the standard model of elementary particles;

- Yang-Mills theory for gauge groups SU(2) X U(1) and SU(3).
- Spontaneous symmetry breaking phenomenon, Goldstone theorem, Higgs particles, gauge invariant mechanisms for generating particle masses.
- Quantum chromodynamics; phenomenology; ideas from lattice gauge theory; confinement and asymptotic freedom.
- Selected topics from recent theoretical developments.

PHYS 545 *Cosmology (3 credits) – cross-listed with ASTRO 545*
Prerequisite: None

Cosmology is the scientific study of the universe as a whole: its physical contents, principal physical processes, and evolution through time. Modern cosmology, which began in the early 20th century, is undergoing a renaissance as a precision science as powerful ground- and space-based telescopes allow us to observe the formation of the first starts, galaxies and galaxy clusters; the echoes of the inflationary epoch as they are impressed upon the cosmic microwave background; and evidence for and clues to the nature of the mysterious dark energy, which is driving the accelerating expansion of the universe. This course will introduce students to the key observations and the theoretical framework through which we understand the physical cosmology of the early universe.

PHYS 557 *Electrodynamics I (3 credits)*
Prerequisite: PHYS 400 or equivalent. Approximately the following topics are covered:

- Special relativity, including its application to electromagnetic fields and Maxwell's equations.
- Electro- and magneto-statics; potentials; Poisson and Laplace equations; magnetic induction; physical boundary conditions.
- Boundary value problems; Laplace's equations in various coordinates; Green's functions; eigenvalue expansions; magnetized spheres in external field; magnetic shielding.
- Maxwell's equations; initial value problem; energy in an electromagnetic field; Poynting vector; conservation laws.
- Wave propagation in vacuum; plane electromagnetic waves; linear and circular polarization; reflection and refraction.
- Introduction to waveguides and cavities.

PHYS 558 *Electrodynamics II (3 credits)*
Prerequisite: PHYS 557.

- Radiation, scattering and diffraction.
- Covariant formulation of electrodynamics.
- Special topics on contemporary applications of electrodynamics: physics of lasers, nonlinear and quantum optics, quantum electronics, interactions of relativistic particles with matter.
- Dynamics of relativistic particles and electromagnetic fields.

PHYS 559 *Graduate laboratory* (2 credits)

This course offers about a dozen experiments. (The number is growing slowly.) They are in the areas of atomic and molecular physics, nuclear physics and condensed matter physics. Typical experiments include:

- Raman Scattering
- Studies using the Mőssbauer effect
- Nuclear magnetic resonance
- Experiments with superfluid 4He. Super conducting quantum interference device
- Electron spin resonance

Students will be required to complete two of the experiments and write a detailed report on each. They will also give a presentation on one of the experiments.

PHYS 561 *Quantum Mechanics I (3 credits)*
Prerequisite: PHYS 410 (undergraduate quantum mechanics) or equivalent.

Since 561 and 562 constitute a 2-semester sequence, some topics may be moved between the courses.

- Historical developments leading to quantum mechanics.
- Postulates of quantum mechanics; differences from classical mechanics; role of the observer in the measurement process.
- Applications of Hilbert space methods; uncertainty principle.
- Potentials in one dimension; scattering; adsorption and reflection off barriers; tunneling; general results on solutions to the Schrődinger equation in one dimension.
- Spin systems; bases and their interpretation; effects of measurements; evolution in presence of a magnetic field.
- Harmonic oscillator; creation and annihilation operators; spectrum of the Hamiltonian; coherent states and the uncertainty principle.
- Angular momentum algebra and its representations; rigid rotor; hydrogen atom.

PHYS 562 *Quantum mechanics II* (3 credits)
Prerequisite: PHYS 561

- Addition of angular momenta, Clebsch-Gordan coefficients; Wigner-Eckart theorem; selection rules.
- Stationary perturbation theory; non-degenerate and degenerate cases; first and second order corrections; Zeeman and Stark effects; time-

dependent perturbation theory; Fermi's golden rule.

- Scattering theory; Green's functions; solutions to the Schrődinger equation with an interaction; Born approximation; partial waves.
- Density matrices and their applications; identical particles; spin and statistics; scattering of identical particles.
- Interpretational issues of quantum mechanics; Copenhagen interpretation and its status, beyond Copenhagen.

PHYS 563 *Quantum Field Theory I* (3 credits)
Prerequisite: PHYS 562.

Since 563 and 564 constitute a sequence, some topics may be moved between the courses.

- Quantization of free fields; Fock spaces, Bose and Fermi statistics; scalar, vector (Maxwell) and Dirac fields; Lagrangians, Hamiltonians; Lorentz invariance.
- Canonical and functional integration methods.
- Interacting fields, scattering theory; Feynman diagrams; calculation of cross sections.
- Non-uniqueness of the vacuum; spontaneous symmetry breaking and its consequences.
- Renormalization
- Renormalization group and its applications to interacting field theories.

PHYS 564 *Quantum Field Theory II* (3 credits)
Prerequisite: PHYS 563

- Abelian and non-Abelian Yang-Mills theories; gauge principle; implications of gauge invariance; Hamiltonian formulation; internal charges and other conserved quantities.
- Faddeev-Popov determinants; modifications of Feynman rules; renormalizability of Yang-Mills theories.
- Operator product expansions and their applications in physical theories.
- BRST quantization; ghosts and anti-ghosts; BRST charge; physical states applications to gauge theories.

PHYS 565 *Interface of General Relativity and Quantum Physics (3 credits)*
Prerequisites: PHYS 510 and 563

- Need for a quantum theory of gravity.
- Quantum field theory in curved backgrounds; black hole evaporation; black-hole thermodynamics; back-reaction; issue of loss of unitarity in presence of black holes.
- Field theoretic methods; perturbative techniques; perturbative non-renormalizability of quantum general relativity and supergravity; higher derivative theories; problems with unitarity.
- Canonical methods; Hamiltonian formulation of general relativity; role of constraints; geometrodynamics and connection dynamics.
- Loop-space methods; non-perturbative quantization of general relativity; status.
- Gravitational aspects of string theory.

PHYS 571 *Modern Atomic Physics (3 credits)*
Prerequisite: PHYS 411, PHYS 561, or CHEM 565

Students will learn the physics behind most of the major recent developments in the field of atomic physics, at the level required for research at the graduate level. Material to be covered will include selected topics from the following list: Light-atom interactions, atomic structure, laser cooling, atom trapping and atomic optics, atom interferometry, precision measurements with atoms, quantum computing with atoms, atomic Bose-Einstein condensates, degenerate Fermi gases, reduced dimensionality systems, simulating condensed matter physics with atoms. Students will enhance their technical writing and presentation skills. Students will use the background they have acquired to develop an oral presentation related on a research advance related to modern atomic physics.

PHYS 572 *Laser Physics and Quantum Optics* (3 credits)
Prerequisite: PHYS 410, PHYS 561, or CHEM 565

Students will learn the basic physics of lasers, how they work and how they are used, primarily in the context of physics research at the graduate level. They will become familiar with a broad array of the most important topics of laser physics including mode competition, pulsed lasers, pulse propagation, non-linear laser spectroscopy, laser stabilization, and the quantum nature of laser light. Students will enhance their technical writing and presentation skills. Students will use the background they have acquired to develop an oral presentation related on a research advance related to lasers.

PHYS 580 *Elements of Network Science and Its Application* (3 credits)

Network Science is the study of network representations of physical, biological, and social phenomena leading to predictive models of these phenomena. This class will focus on four main questions asked by network science: (i) How do we use data analysis methods to determine or infer the interaction graphs underlying complex systems? (ii) How can we characterize the organizational features of large-scale networks? (iii) What are the mechanisms that determine the common topological features of a wide variety of networks? (iv) To what extent does the organization of the interaction network underlying a complex system determine the dynamical behavior (e.g. steady state or oscillations) of the system? Applications in social, biological and technological networks will be examined. Network

Science is an interdisciplinary field of research, and the course is relevant to wide range of subject areas, not only physics, but also social sciences, life sciences, mathematics, engineering, and computer science.

PHYS 590 Current Research (1 credit)
There are several parts to the course:

- A meeting of one hour each week, when faculty describe research that they are involved in.
- The Physics Department's colloquium, which takes place every Thursday afternoon.

The course also includes discussion of research ethics, and requires completion of the Penn State SARI (Scholarship and Research Integrity) program. The grading is usually based on (a) attendance and (b) written evaluative projects at the end of the semester.

Phys. 596 Individual Studies (variable number of credits)
Creative projects, including non-thesis research, that are supervised on an individual basis and which fall outside the scope of formal courses.

PHYS 597 Special Topics (number of credits and topics vary))

PHYS 600 Thesis Research (variable number of credits)
Used to give credit in thesis research.

PHYS 601 Thesis Preparation (0 credits)
Used by graduate students for thesis research after completion of course requirements and credit-hour requirements, to maintain status as a full-time student. Because registration under 601 counts as 0 credits, the tuition rate is lower.

PHYS 610 Thesis Research (variable number of credits)
Same as Phys. 600, but used for off-campus work.

PHYS 611 Thesis Preparation (0 credits)
Same as Phys. 601, but used by part-time students.

4.2 Physics-related courses in other Departments

The following list gives examples of courses offered in other departments outside of Physics, which may be relevant for graduate students. Other courses may also be relevant. Students should e-mail advisers for approval and copy the Director of Graduate Programs. If both faculty approve the request, students may register for the course.

Students should also know of the possibility of adding to their degree the Graduate Minor Program in Computational Science, for which details can be found at http://www.csci.psu.edu/minor.html. This minor can be particularly helpful to students doing computationally intensive work in Physics research.

Mathematics (MATH)

505 Mathematical Fluid Mechanics
506 Ergodic Theory
507/8 Dynamical Systems I, II
515 Class. Mech. and Variational Methods
521 Complex Analysis: Theory and Applications
556 Finite Element Methods

Computer Science and Engineering (CSE)

451 (Math 451) Numerical Computations
455 (Math 455) Introduction to Numerical Analysis I
456 (Math 456) Introduction to Numerical Analysis II
457 Concurrent Scientific Computing
550 (Math 550) Numerical Linear Algebra
551 (Math 551) Numerical Solution of ODE's
557 Concurrent Matrix Computation
418 Computer Graphics

Electrical Engineering (EE)

414 Principles and Applications of Lasers and Masers
511 Engineering Electromagnetics
524 Lasers and Optical Electronics
559 Nonlinear Control and Stability

Engineering Mechanics (E MCH)

409 Advanced Mechanics
415 Fracture Mechanics
446 Mechanics of Viscoelastic Materials
461 Applied Finite Element Analysis
507 Theory of Elasticity and Applications
516 Mathematical Theory of Elasticity
520 Advanced Dynamics
521 Stress Waves in Solids
532 Fracture Mechanics
540 Introduction to Continuum Mechanics
546 Theory of Viscoelasticity and Applications
560 Finite Element Analysis
562 Boundary Element Analysis
563 Nonlinear Finite Elements

Engineering Science (ESC)

577 Engineering Thin Films

Mechanical Engineering (ME)

521/2 Foundations of Fluid Mechanics I, II
535 Physics of Gases
597 Stability Mechanics of Structure

Metal 534
(E MCH 534) Micromechanisms of Fracture

4.3 Relevant 400-Level Physics Courses

Phys 400: Intermediate Elec. and Magnetism I (3)
Phys 401: Electricity and Magnetism II (3)
Phys 402: Electronics for Scientists (4)
Phys 406: Subatomic Physics (3)
Phys 410: Intro to Quantum Mechanics I (3)
Phys 411: Intro to Quantum Mechanics II (3)
Phys 412: Solid State Physics I (3)

Phys 413: Solid State Physics II (3)
Phys 419: (Math. 419) Theoretical Mechanics (3)
Phys 420: Thermal Physics (3)
Phys 443: Intermediate Acoustics (3)
Phys 457: Experimental Physics (1 or 3)
Phys 458: Intermediate Optics (4)
Phys 461: (Math. 461) Theoretical Mechanics (3)

The numbers in parentheses are the number of credits for the course.

4.4 English Courses relevant to Thesis Preparation

Engl 497G Thesis Workshop (3 credits)

Engl 497G is designed for graduate students who have begun writing their theses. The course will focus on principles of effective writing, including discipline-specific forms of argument, standards of evidence and documentation, as well as general principles of presentation and style.

SpCom 297G Thesis Writing for Non-native Speakers of English (3 credits)

SpCom 297G is designed for non-native speakers of English who are at the beginning stages of doctoral thesis writing and will focus on such matters as idea development, organization, coherence, documentation, and clarity of expression.

5 Course Administration Procedures

The material in this section will be of use both to students taking classes and to those who are involved in the teaching of courses (e.g., as a teaching assistant).

5.1 Course Registration

Students will normally register well in advance of the first day of classes --- in late September for the following Spring semester, in February for the following summer session, and in late March for the following Fall semester; instructions and dates may be found in the Schedule of Courses for that semester. The Schedule of Courses is available at http://schedule.psu.edu. Once preliminary course schedules have been distributed, schedule adjustments may be made prior to the first day of class. Students may register for or drop courses during the first week of classes at no charge, but after the first week there is a nominal charge for making changes.

Students not on assistantships who are paying their own tuition and who wish to drop classes must do so before the first day of class in order to get full reimbursement. For drops after classes have begun, a 20% tuition penalty will be assessed during the first week, with 10% more for each subsequent week through the eighth week.

5.2 Examination Procedures

Written notification of the examination procedures (including the instructor's final examination policy) to be used in each section of each course must be made available to the students in the section during the first ten calendar days of a semester or its equivalent.

A written notice of the examination procedures to be used in each section of each course is to be placed with the head of the department. These notices will be maintained in a public file for reference by both students and faculty upon request.

5.3 Posting of Grades

When displaying student scores or grades publicly, you may not use a student's name, PSU ID, social security number, or any other personal identifier. Instructors can instead assign a secret code to each student in the class and post grades with this code. Codes used to post grades must be random and not correspond to students in alphabetical, social security number or PSU ID order.

5.4 Evaluations of Teaching Effectiveness

The professor in charge of the course evaluates the quality of teaching in the recitations and laboratories. In addition, the students in each section of every course are asked to evaluate the course and the recitations - see Section 5.5.

The results of the evaluations are assessed by the department's Teaching Committee and by the Department Head. Continuation of teaching assistant support is contingent upon satisfactory performance as teaching assistants.

5.5 Student Ratings of Teaching Effectiveness

In each course for which a graduate student is a TA, the students are asked to evaluate the quality of the teaching. This also applies to individual sections of large courses, to evaluate recitation and laboratory teaching. The process is called the SRTE (Student Rating of Teaching Effectiveness) and is an on-line process. Students are prompted by e-mails to go on-line and complete evaluations for their courses. Every effort should be made to obtain maximum participation.

Physics faculty members teaching courses at all levels, from large introductory lectures, through advanced graduate seminars, are also evaluated by their students using this same process. Any Physics graduate student taking courses themselves will be prompted by e-mails to go on-line and complete evaluations for their courses.

5.6 Final Exams

All courses have a final examination or some other means of testing the student integration of the instructional material (e.g., term paper, final project report, take-home examination, etc.). Course instructors determine which of these methods is most appropriate. Students should not make travel plans which prevent them from being present for a final exam.

Term papers, take-home exams, etc., when used in place of a standard final examination, must be due no earlier than the first day of the final exam period. Written final examinations must be scheduled in the final examination period. No examinations may be given during the last week of classes, with the exception of quizzes and narrowly limited tests in support of classroom instruction.

Unless the instructor of a course informs the students otherwise, the time and date of the final exam for a course can be determined from the schedule available in eLion. *But in the case of graduate courses, there may be changes from the published university schedule*; the instructor must make it clear when and where the examination is to be held. In the case that the examination is not at the standard time, the instructor should consult the students to avoid conflicts.

Occasionally, instructors come under inappropriate pressure to cancel finals, or to move final exams from the scheduled time. If the students ask for a change, then a procedure should be used that assures that all students want it.

5.7 Grading

In normal courses, the following "quality" grades can be assigned: A, A-, B+, B, B-, C+, C, D, or F. Grade point averages are based on a four-point scale, with A=4.00, A-=3.67, B+=3.33, B=3.00, B-=2.67, C+=2.33, C=2.00, D=1.00, F(fail)=0.00. The University requires that all graduate students maintain at least a B, or 3.00, average - see Section 3.1.2. The Department has further minimum requirements – see 3.2.6.1. The meanings of the grades are defined[1] as follows: A = excellent, B = good, C = satisfactory, D = poor, F = failure.

5.8 Course-like registration for research

A student doing research needs to register for an appropriate number of credits (using course numbers 596, 600, or 610 as appropriate). There is a limit to the number of credits of research credits that can be assigned letter grades: 6 credits for master's candidates and 12 credits for doctoral candidates. Beyond these limits a grade for satisfactory research is reported as R. This denotes satisfactory progress and is not used in calculating a grade point average.

[1]Note that in the Physics Department, the standards for letter grades are influenced by Ph.D. candidacy requirements. As part of these, a first-year graduate student is expected to maintain a B minimum in the first-year courses-see Section 3.2.6.1.

5.9 Deferred Grades

If work is incomplete at the end of a semester because of extenuating circumstances, then the instructor may report DF in place of a grade, which will appear temporarily on the student's record. It is not appropriate to use the DF either casually or routinely to extend a course beyond the end of the semester or to extend a course for a student who has failed so that the individual can do extra work to improve the grade. The DF must be removed (i.e., the course must be completed) within 25 weeks beyond the end-date of the course.

There is a possible exception to this limit:A completion deadline longer than the normal limit may be allowed in extenuating circumstances with the concurrence of the course instructor. A memo with a justifying statement and the agreed-upon date must be submitted by the instructor to the Office of Graduate Enrollment Services in order to request an extension.

It is to be emphasized that no deferred or missing grade may remain on the record at those times when a student reaches an academic benchmark. Benchmarks for the Physics Department include completion of a Master's program and the Doctoral Candidacy, Comprehensive, and Final Oral Examinations. See Sects. 3.2.6.1, 3.2.9, and 3.2.11 for details on these.

5.10 Grade Changes

There are only three circumstances under which a course grade, once assigned, can be:

1. If there was a calculation or recording error on the instructor's part in the original grade assignment (Senate Policy 48-30);

2. If it is a course for which an R grade has been approved and in which an initial R can be assigned and can be changed later to a quality grade. The only courses in the Physics Department for which an R is given are PHYS 596 Independent Study, PHYS 600 and 610 Thesis Research;

3. If a DF (deferred grade) was assigned (Section 5.9) and the deadline for course completion has not yet passed.

Changes in assigned and recorded grades cannot be made to allow a student to improve a mark ex post facto, or to permit long-delayed completion of a course. Senate Policy 48-30, found in the Policies and Rules for Students, governs grade changes.

The above policy refers to "quality grades," i.e., A through F. Instructors of graduate-level courses (500 level and above) may report DF (deferred) in place of a grade when work is incomplete at the end of a semester for a reason beyond the student's control. This deferred grade must be removed and the mark changed within 25 weeks of the end of the course, or the grade deferral will lapse to an F.

Changing grades on transcripts is a serious matter. In the following situations, the Graduate School requires that the course instructor submit with the Grade Change Authorization Form a memo stating the reason for the requested change when:

1. an F grade is being changed,
2. more than one year has lapsed since the grade was assigned, or the student has graduated.

6 Additional Guidelines for Teaching Assistants

The purpose of this section is to establish a uniform set of rules for graduate Teaching Assistants (TAs) in the Department of Physics. The guidelines presented here are primarily intended to ensure that the teaching of undergraduate introductory physics (the 2XX series of courses) be done in a uniform manner. This is particularly important since these courses have large enrollments and many laboratory and recitation sections. Since the students in these courses all take common examinations it is very important that they are all exposed to the same material in their various recitation and laboratory sections. These guidelines are typical, but may vary for different courses or professors. In reading this section, students are urged to refer back to Section 5 on *Course Administration Procedures* when necessary.

6.1 General Guidelines for All TAs

These guidelines generally apply to both laboratory and recitation instructors. They will be presented in outline form. As a preface to the outline it is noted that the 1/2 time assistant is expected to devote 20 hours per week to his/her teaching duties. The TA is expected to work for 18 weeks per semester (one week before classes start and one week after they end).

6.1.1 Specific Duties of TAs

1. All scheduled classes are expected to be taught. If you are ill or unavoidably required to be absent from your assigned class you **must** arrange for some other TA (preferably in your course) to teach your class effectively and also advise the course or laboratory supervisor of any such arrangements.

2. Arrive at class a few minutes before the class starts and begin class promptly at the scheduled time.

3. Be prepared to stay a few minutes after class to answer questions from your students.

4. Establish and publicize regular office hours when you are available to your students for consultation. Notify your course supervisor or laboratory supervisor of these hours.

5. Remind students of the Learning Resource Center and other tutoring services. (The course professor should know of these.)

6. Attend TA weekly meetings held by the course or laboratory supervisor.

7. Prepare for your teaching assignments before going to class.

6.1.2 Other duties that may be assigned to you during the term are:

1. Proctoring of examinations
2. Writing exam questions
3. Grading exam questions
4. Preparing student grades and keeping the roster of students and grades up to date.

5. Occasionally completing forms indicating the progress of some students in athletic programs.

6.1.3 Matters to be brought to the attention of the course or laboratory supervisor include:

1. Cheating by students

2. All excuses by students pertaining to missed bluebook examinations

3. Excessive absences by a student.

6.1.4 Student records and privacy issues

There are some important legal requirements governing how educational institutions control and safeguard their student records. All employees of educational institutions, including TAs, must abide by these rules, from The Family Educational Rights and Privacy Act (FERPA) of 1974. TAs will receive training on the FERPA requirements.

6.1.5 Materials needed for the TA’s teaching assignment

These materials such as textbooks are generally available in the Physics Department Office in 104 Davey Building.

6.2 Particular Guidelines for Laboratory TAs

6.2.1 Laboratory Duties

1. Check before class starts and after class ends to see that all equipment is there.

    a. Report deficiencies in writing to the laboratory supervisor, indicating when the deficiency was discovered.

b. Notify Mr. Lucas in 213 Osmond. If he is not available leave him a note.

2. Notify Mr. Lucas immediately about faulty equipment. Leave him a note if he is not available.

3. Keep equipment together in complete set-ups. Do not allow students to move it from place to place.

4. Sign out small items to the students. These items are usually placed on the desk at the front of the room.

5. Be available to the students for help and encourage them to ask you questions.

   a. Move about the room asking students pertinent questions, which motivate them to think about what they are doing.

   b. Do not grade lab reports in class or do other work while you are teaching. This sort of activity makes the students feel that they disturb you when they ask questions.

6. Do all the experiments yourself before teaching them. Outline the results you get and note any difficulties you have so that you are prepared to help the students through the rough spots.

   a. You will be expected to take your results obtained when doing the experiment to lab with you. Your laboratory supervisor will from time to time ask to see them.

   b. The lab equipment necessary for a given lab will be available for your use a few days before you teach that lab.

7. It is expected that the lab instructors will refrain from:
   a. Congregating in the hall and talking among themselves while lab is in session.
   b. Having friends come to lab while class is in session.
   c. Spending large amounts of time absent from your assigned room while lab is in session.

6.2.2 Rules for Students in the Labs Taught by TAs

1. No horseplay by students is to be tolerated.

2. No smoking, food, or drink is allowed in the laboratory rooms. Cell phones should be turned off.

3. The student will take all labs at the times assigned, unless written permission from the course professor is provided. Students will receive official notification of any changes in their lab schedule. Students wishing to make schedule changes must do so at the Physics Department Office in 104 Davey Building. No schedule changes will be made after the add/drop deadline without the approval of the course professor.

4. All labs start on time. Students who are habitually late will be penalized.

5. The above rules concerning the students in lab should be made very clear to the students at the instructor's first meeting with them.

6.3 Particular Guidelines for Recitation TAs

Graduate students assigned to the teaching of recitation sections have many of the responsibilities of faculty in this assignment. They proctor examinations for their classes and may be asked to construct and administer make-up exams. They take their turns in manning the Learning Resource Center help-session for students in any of the introductory courses.

The recitation classes are the heart of the course for most students. It is here that they learn to solve the problems that show whether they really understand the course content. The instructor is often made aware that the students have failed to understand either the text or the lecturer and there is a tendency to feel the students need more lecturing. While this may be true where topics have been omitted from the lecture, it is usually best to start the class with the problems and deal with the difficulties as they arise. It may be necessary to find out which problems caused the most difficulty at the beginning of the class. In no case may the class be dismissed early because there are no more questions or because the work seems to have been covered. There is always more work that can be done on any of the lessons. If necessary, prepare one or two extra problems to present to the class.

Try to show the students how to set up a problem and discuss problem-solving skills. Try to do problems in as general as possible a manner so they can learn how to attack a problem totally new to them. Encourage them not to plug in numbers until the very end; this is normally an appropriate approach. At the recitation before a quiz, remind the students and tell them what subject matter will be covered. When you return a quiz, you should write the average score on the board. After you have collected homework/quiz, only rarely should it not be graded and returned at the next recitation. Please check your mailbox and e-mail every day, particularly before you go to class.

The names of the students should be learned as soon as possible. In addition, every effort should be made to give the students the strongest possible impression that the instructor knows and cares how well each student is doing.

The instructor's recitation grade will be some fraction (perhaps 20-30%) of the total grade in the course, as specified by the professor in charge. It may be based partly on his/her observation and judgment of the student's work in class and partly on short one- or two-question quizzes given approximately weekly; again the details are determined by the professor in charge of the course. Although the TA instructor may do the bookkeeping to determine the final grade, under no circumstances should he/she tell the class that he is the final arbiter of the student's grade. This has led to many unfortunate situations in the past; especially when the instructor has implied that the grade would be determined in a specific way from quiz grades, etc.

There will be weekly meetings of TAs for the course at a time suiting all the schedules. If for any reason an instructor must miss a class he should arrange for a competent substitute and notify the course director as soon as possible. There will be various bookkeeping duties such as making entries in the course roster. These must be carried out promptly so that discrepancies can be spotted quickly.

High performance in the teaching assignments of the Department has led to strong recommendations for teaching positions upon graduation.

6.4 Termination of Assistantship due to Inadequate Performance

When a supervisor (professor in charge of a course) determines that a graduate assistant is failing to meet acceptable standards, the supervisor will meet with the assistant. Together, they will review the duties and responsibilities expected of the graduate assistant, and the supervisor will identify those areas in which the performance of those duties and responsibilities is judged to be substandard. The supervisor should then advise the graduate assistant that if his/her performance does not improve to a satisfactory level within a time period specified by the supervisor, the assistantship would be terminated. As soon as possible following this meeting (generally within three days) the supervisor will provide the assistant with a written summary of the meeting, a copy of which will also be sent to the Physics Department Head. Subsequent failure to improve may result in termination of the assistantship.

If a graduate assistant wishes to appeal a termination decision, he/she may follow the grievance process in the policy titled, "Resolution of Problems Outside the Classroom" in Appendices in the "Graduate Degree Programs Bulletin.

Detailed guidelines may be found in "Termination of Assistantships in the appendices in the "Graduate Degree Programs Bulletin."

6.5 Relationships between TAs and Students

Romantic or sexual relationships between faculty/staff and students have the potential for adverse consequences, including the filing of sexual harassment charges. The apparent consensual nature of a relationship may be inherently suspect when one party has the power to give grades, thesis advice, recommendations, or performance evaluations. Even when both parties have consented to the relationship, there may be serious concerns about conflict of interest as well as unfair treatment of others. See Appendix A1 for details of the University's sexual harassment policy.

7 Miscellaneous

7.1 Colloquia and Seminars

Physics colloquia, seminars, and special lectures, are listed on the department web page at http://www.phys.psu.edu/seminars/. Colloquia are offered every week on a variety of topics. A colloquium is intended to be accessible to physicists who are not specialists in the subject matter of the colloquium. First year graduate students are required to attend these colloquia (Physics 590). The good habits thus learned are sustained and beneficial in one's career: it is expected that all students will attend most departmental colloquia.

Seminars are offered, normally every week, by visiting scholars or Penn State researchers in the main areas of physics: biological, condensed matter, atomic, molecular and optical physics, particles and fields, and gravitational and mathematical physics. Seminars are offered in overlapping topics between physics and chemistry, between physics and mathematics, and between physics and material science. The weekly list of seminars (Science Seminars) in all areas of science is available at http://science.psu.edu/science-seminars, where one can also find out how to receive the weekly list by e-mail.

In addition, each year a number of endowed special lectureships bring to the Penn State campus distinguished scientists in several different fields. These include the Chemerda Lectures in Science, the Marker Lectures in the Physical Sciences, the Mueller Lecture in Physics, and the Whitfield Lectures in Physics. Many outstanding researchers, including Nobel laureates, from all over the world visit Penn State through these lectures. Each of the lecturers of these series offers a public lecture followed by 2-3 lectures of a special topic. Amongst Nobel laureates in physics who gave these lectures or colloquia are: Anderson, Bardeen, Bethe, Bloembergen, Chandrasekar, Cornell, Esaki, Gell-Mann, Giaever, von Klitzing, Lederman, Lee, Leggett, Prigogine, Purcell, Rohrer, Schawlow, Schrieffer, Schwartz, 't Hooft, and Yang. There are similar lecture series in other areas, e.g., chemistry, mathematics and astronomy and astrophysics. All these lecture series are widely publicized in the university community.

7.2 Graduate Research Exhibition

The annual Graduate Research Exhibition (http://gradschool.psu.edu/index.cfm/exhibition/) is open to all Penn State graduate students. To enter, students do not need to have finished the research for their master's degree or doctorate. Any sound, scholarly research or creative activity can be entered, as long as a well-defined part of the project is complete.

Exhibits are judged on their quality in three areas: content, display, and oral presentation. All exhibitors receive certificates of appreciation; those whose exhibits are judged best receive award scrolls as well as monetary awards in the form of budget support, which can be used to attend professional meetings or purchase books or equipment needed for research.

In each area, judges consider the following:

Content (40% of total score): The research project exhibited should address a problem of significance to scholars; its potential significance to the general public should also be considered. The research project should be well designed and executed, with clear results that are well interpreted.

Display (30% of total score): The core of each exhibit is a poster, with text and graphics intended for a more general audience. The poster must be mounted on the exhibit board provided and may not exceed its dimensions, which are 3.75 feet wide by 4 feet high. The poster should attract attention and convey information. Language should be simple and descriptions brief. Jargon should be avoided; necessary technical terms should be defined. Spelling and grammar must be correct. All text should be large enough to be read from a distance of 4 to 6 feet.

Photographs, drawings, charts, tables, or graphs should be simple, well-organized, and carefully chosen to quickly explain complicated technical concepts to a wide audience. A tabletop model, computer display, video, original artwork or other demonstration may be included in the exhibit. These demonstrations, however, must clarify the work presented, not simply attract attention.

The following should be clearly presented and readable from a distance of 4 to 6 feet:

1. title of the exhibit
2. student's name
3. collaborators, advisor, and department
4. funding sources
5. regulatory committee approval (if the project involved human or animal subjects)
6. objectives or reason for research
7. significance/relevance to the field
8. significance/relevance to society in general
9. project design and execution
10. methods
11. findings
12. results
13. interpretation of results and conclusions
14. directions for future research

Oral Presentation (30% of total score): Each student should have prepared a five-minute oral summary of his/her research project. This summary should be clear and concise, and should include the major points presented on the poster (numbers 6 through 13 above). If the student worked with collaborators on the project, then this presentation should clearly describe the student's individual role in the entire project.

7.3 Intellectual Property, Publications, etc.

Sometimes department research uncovers knowledge with possible commercial applications. It is necessary to take appropriate steps for patent protection. The precise university policy is given in App. A.2. All university employees (including graduate students on assistantships) sign a patent agreement that indicates their responsibilities. The university's Intellectual Property Office has the responsibility (in concert with inventors) to patent and market inventions.

In general, inventions (including computer software) are owned by the university, but the inventors receive a share of the proceeds. However, “the copyright of literary, scholarly and artistic works, including books, articles, contributions to collective works, and other means of presentation, but excluding instructional materials, is considered to be outside the scope of employment and therefore owned by the creator, whether or not created on University time or using University resources.”

Graduate students are strongly encouraged to submit manuscripts for publication of their findings. The authorship of these papers is determined by the norms and ethics for scientific papers in the field of study. It is frequent, but by no means universal, that the adviser is a co-author on a student's paper.

8 Facilities

8.1 Computer Facilities

There are computer facilities provided both by the university and the department. New students will get information during their orientation sessions, so this section only gives a brief overview.

You need to get a university computer account (“Access Account”) soon after arrival. There are many things you will need to do on-line for which will need you to login using your Access Account username and password. Examples include registering for courses, Official e-mails from the university and department will normally go to the e-mail address associated with your Access Account.

8.1.1 University Computing Facilities

Your Access Account allows you access to the following, among others:

1. To use your university e-mail. This can be accessed by the web, at https://webmail.psu.edu/ or by a suitably configured e-mail client on your own computer. You should check this account at least once a day.
2. To login to many of the computers available on campus, e.g., in the libraries.
3. To be able to connect your own computer (e.g., a laptop) to the university WiFi system.
4. To access many university services, e.g., registering for courses, accessing some library services, and many others.

8.1.2 Physics Department Computing Facilities

The situation regarding computing facilities in the physics department is changing, so the information here is subject to change.

Departmental facilities include:

1. A Computer Lab in 215 Osmond Lab. This includes Windows XP systems to which you login to using your Access Account. It also has a color printer and a monochrome printer that are available for general use by members of the physics department, and can be used from your own computer. Access to the lab is by a card-swipe system, using your university ID card. You will need to request door access to have your ID included in the system; ask in 104 Davey Lab about this.
2. Physics Department Educational Systems: These Windows XP machines are used primarily for the Introductory Physics series (PHYS 211, 212, 213, 214, 250, 251).
3. Some Linux systems (and an associated e-mail system) with a separate physics department username and password. The set-up for this system is subject to change in the near future. Graduate Student Offices: There are Windows XP (Access Account) and Linux (Physics Account) systems available in the graduate student offices located in 5 Osmond Lab and 114 Osmond Lab.

8.2 Copy Machines

Machines are available in 104 Davey for copying. The copier, which requires a special number (PIN) to operate, should be used only for departmental and research-related documents. These numbers are assigned by the accounting staff in the department for research-related copying. Teaching Assistants receive PIN numbers from the faculty member in charge of their assigned course.

Personal copying is prohibited on departmental copiers. There are coin-operated copiers available in the lobby of Osmond Lab and in the Hetzel Union Building (HUB) for personal copying. Local commercial copying shops (for example, Kinko's) have coin operated machines and extensive fax/copying facilities available at a competitive cost.

8.3 FAX and Telephones

The Physics Department has a FAX machine in 104 Davey. Its number is 814-865-3604. Incoming messages will be put in the recipient's mailbox. Use of the machine for sending messages requires the use of a special identification number (PIN), and is only for use on departmental and research business. PINs for the FAX are assigned by the Accounting Staff, and you should talk to your adviser if you need a number for research use. Personal faxes may be sent at a competitive cost from local commercial shops, such as Kinko's.

Telephones in offices can be used for local calls. Long-distance and international calls are only allowed for research and departmental purposes. Long distance international calling cards are also available at local international grocery stores.

Note that local telephone calls made from a campus phone do not require that you dial the full number: simply dial 5-xxxx, or 3-xxxx, as appropriate. Off-campus local calls (within the area code "814") can be made from a campus phone by dialing: 8-xxx-xxxx. Long distance and international calls cannot be made from campus phones without special authorization, available only to faculty members.

8.4 Libraries

The Physical and Mathematical Sciences (PAMS) Library is located at 201 Davey Lab, phone (814) 865-7617. All incoming students are strongly encouraged to attend the orientation to library facilities upon arrival on campus. Information on the orientation schedule can be obtained by calling the telephone number above. Questions and concerns regarding the physical sciences library facilities may be brought to the notice of the Head Librarian, 201 Davey Lab, 865-7617.

On-line information on the library systems at Penn State is available at http://www.libraries.psu.edu/. This includes an on-line catalog, details of the multiple libraries at Penn State, and links to many databases.

All physicists should also be aware of the e-print archives at http://arxiv.org/. Based at Cornell University, these were initially established for electronic preprints by Paul Ginsparg. But now they cover many areas of physics, mathematics, nonlinear sciences and computer science, and in certain areas of physics constitute the primary means by which research results are initially published.

8.5 Machine Shop and Technical Facilities

A large number of shop and technical facilities are located within the University Park campus. A selected list, with location and contact person, is as follows:

- Physics Machine Shop, 2 Osmond, Timothy Bowmaster, Instrument Maker, 865-4142
- Physics Lecture Preparation, 11 Osmond, Randy Penn, Demonstration Specialist, 865-5542; 213 Osmond, Paul Lucas, Equipment Specialist, 777-0267
- Glassblowing Shop, 2 Whitmore, Russ Rogers, Scientific Glassblower/Supervisor, 865-7051
- Research Instrument Shop, 121 Chemistry, Rod Kreuter, Director, 863-0579
- NMR Facility, 8 Chemistry, Alan Benesi, Director, 865-0941

8.6 Departmental and University Facility Use Policies

In the sections below, brief information about policies for the use of selected facilities is provided.

8.6.1 Student Use of Facilities

Services such as secretarial, graphics, and technicians are restricted to work in support of research activities with approval of the adviser. Under no circumstances will these services be available for activities related to course work or thesis preparation.

Departmental computers are available to all members of the department-see Section 8.1.

8.6.2 Student Use of Shop Facilities and Services

Students are expected to fabricate experimental equipment needed for their thesis research if the equipment is not otherwise available. Students must follow all guidelines and policies in regard to safety.

A Student Machine Shop is located in room 10 Osmond Lab. The shop is intended only for research and teaching activities. All graduate students must attend and satisfactorily complete a course of instruction on the proper and safe use of shop facilities and tools before using the facilities. Upon completion of this course, the graduate student will be extended the privilege of shop access. Faculty and staff are expected to complete the sessions as well. The course may be arranged through the Physics Machine Shop Supervisor (see above).

Eye protection (safety spectacles or cover goggles) and hearing protection are provided free of charge to all graduate students for use in the Student Shop.

In cases of extensive or complex fabrication, shop personnel may help with the work. The student's adviser must arrange use of shop personnel in advance. Graduate students should not use general shop supplies (metal, plastic, pipe, wood, etc.) without prior approval of the Shop Supervisor and faculty adviser.

8.6.3 Use of University Vehicles

University vehicles are for official use only. Operators of university vehicles must abide by all state highway laws. Special courtesy to other drivers should be exercised at all times, since one is representing the Department, University and Commonwealth when driving a university vehicle. No passengers are allowed to ride in any of these vehicles unless the passengers are authorized to participate in official business.

A valid Pennsylvania driver's license is required to operate university vehicles, except that operation of vehicles heavier than 30,000 pounds gross requires a Class 2 license. A Class 3 license is required to drive a vehicle towing a trailer over 10,000 pounds. Caution: Only persons employed by the University are covered by insurance while operating a university-owned vehicle. A student on an assistantship meets the employment criterion. In order to reserve a university vehicle, you must make arrangements through the Physics Department office. The office will also provide procedures for purchasing fuel and maintaining vehicle records.

8.6.4 Building Management

Each graduate student has access to many parts of the building and various laboratory facilities. If any damage is done, it is not important to assign blame; what is important is that damage be reported at once so that facilities may be made functional as soon as possible.

8.6.5 Purchasing

This section concerns purchasing of materials, supplies, and equipment required for conducting research contributing to a departmental research program that may be supported by research grants. All purchases made for research, and teaching activities, whether related to thesis research or not, must be approved in advance by the student's adviser.

Faculty with research funds normally have a Purchasing Card which allows quick procuring of products under $2000. A Purchasing Card (normally just called a P-card) is a Visa charge card with the charges billed directly to the university. The principal investigator can also approve the issuing of a Purchasing Card to other members of the research group. (The maximum amount per transaction may be set to less than $2000 for a particular card.) In most cases, holders of these cards order supplies and materials. There are situations when the Purchasing Card cannot be used, at which time orders must be processed on a Limited Order, Purchase Order, or by some other method. See http://guru.psu.edu/policies/PSU/BS14exc.html for the current list of restrictions on the use of Penn State Purchasing Cards. Anyone obtaining a Purchasing Card is required to take a series of on-line quizzes to ensure that they understand the proper use of the P-card.

A Purchase Order may be used for supplies, materials or equipment and must be used for purchases larger than $2,000. The Purchase Order must be further approved in Penn State's Purchasing Services Department at 101 Procurement Building, and the order will be placed from there. If an emergency situation exists, then the purchase order may be walked through the system.

Any order with a total amount exceeding $10,000 may be sent out for bids by university purchasing. To avoid this, an order may be accompanied by a Sole Source Justification form (available from the department Financial Assistant).

Interdepartmental Charges and Credits (IDCCs) are for purchases from university stockrooms, etc. They are processed like limited orders, but approval may be via computer network.

After an order is received, the package contents should be checked for defects and compared against the packing list to make sure that all the merchandise has been received. The signed and dated packing list should be returned to the department Financial Assistant within one week so that the bill can be paid. Without the signed packing list the Financial Assistant has no knowledge that the order has been received and the vendor will not be paid.

For immediate ordering of supplies and materials (not equipment) with prior approval, Standing Orders may be placed with vendors. A graduate student must obtain adviser approval and have his/her name placed on a list for each standing order vendor. For standing order purchases, delivery slips must be given to the adviser for his/her signature before submitting it to the Physics Office. These slips are kept on file in the Physics Office to be checked against the monthly bills. For relatively small purchases without a purchasing order (under $2,000 per transaction) a Penn State Purchasing Card may be used-see above. If a purchase by other means is necessary, a request for reimbursement by check may be made; the minimum here is $50.

8.6.6 Recycling

Each graduate student is expected to participate in the University's recycling program. For further information on the recycling program, see the following website. http://sustainability.psu.edu/mobius.

8.6.7 Smoking Policy

For the consideration of health, comfort and safety of all people in the Department, smoking is not allowed in any form in any area of the University buildings or in any of the University vehicles.

8.6.8 University Police and Public Safety

The Clery Act requires all institutions to collect crime reports from a variety of individuals and organizations that Clery considers to be “campus security authorities.” More information can be found at http://www.police.psu.edu/clery/.

Appendices

A Copies of Relevant University Policies

A.1 Sexual Harassment

The Department of Physics is committed to providing an environment that is welcoming, sensitive and supportive to all students. It is our policy to maintain an academic and work environment that is free of sexual harassment. The information that follows has been designed to assist you in knowing where to go if you have questions or complaints regarding sexual harassment.

Policy
Sexual harassment of faculty, staff or students is prohibited and will not be tolerated at The Pennsylvania State University. It is the policy of the University to maintain an academic and work environment free of sexual harassment. Sexual harassment violates the dignity of individuals and impedes the realization of the University's educational mission. The University is committed to preventing and eliminating sexual harassment of faculty, staff and students through education and by encouraging faculty, staff and students to report any concerns or complaints about sexual harassment. Prompt corrective measures will be taken to stop sexual harassment whenever and wherever it occurs. (see policy statement http://guru.psu.edu/policies/AD85.html on consensual relationships)

What is sexual harassment?
Sexual harassment s defined as unwelcome sexual advances, requests for sexual favors, and other verbal or physical conduct of a sexual nature that is unwanted, inappropriate, or unconsented to. Any type of Sexual Harassment is prohibited at the University.
Sexual harassment when committed by a student can lead to discipline under the Code of Conduct. The precise definitions of the Code of Conduct should be reviewed and applied when a student is accused of or commits harassment. (See Student Code of Conduct at http://studentaffairs.psu.edu/conduct/codeofconduct/.)
Sexual Harassment committed by an employee or third party can lead to discipline or corrective action when:

1. Submission to such conduct is made implicitly or explicitly a condition for employment, promotion, grades, academic status, or participation in the University's activities; or
2. Submission to or rejection of such conduct is used as the basis for employment or academic or other decisions affecting an individual; or
3. Such conduct is sufficiently severe or pervasive so as to substantially interfere with the harassed individual's employment, education or access to University programs, activities and opportunities, or creates a hostile or offensive environment for that individual or others.

Examples of Sexual Harassment:

SEXUAL HARASSMENT (unwelcome sexual advances, requests for sexual favors and other verbal or physical conduct of a sexual nature)

SEXUAL MISCONDUCT (rape, sexual assault, sexual battery, sexual exploitation and other forms of non-consensual sexual activity)

STALKING (repeatedly following, harassing, threatening or intimidating including by telephone, mail, electronic communication or social media)

DATING VIOLENCE (including emotional, verbal, and economic abuse without the presence of physical abuse)

DOMESTIC VIOLENCE (including emotional, verbal and economic abuse without the presence of physical abuse)

RETALIATION (adverse employment, academic or other actions against anyone reporting or participating in an investigation of Title IX allegations)
These examples are not all-inclusive of the types of conduct that may constitute sexual harassment. Each situation must be considered in light of the specific facts and circumstances to determine if sexual harassment has occurred.

Who can help?
Penn State has a policy prohibiting sexual harassment (AD-85) and a complaint procedure to assist students, faculty and staff who have complaints of sexual harassment. Many problems can be resolved through the informal resolution portion of the process. The individuals listed below are available for you to talk with in regard to issues related to sexual harassment. Concerns/complaints may be taken directly to the department head, the Human Resources office of the Eberly College of Science or to the Affirmative Action Office located in 328 Boucke Building (863-0471).

Amanda Jones
512 Thomas Bldg
863-0212
axj11@psu.edu

Marianne Karwacki
520 James Elliot Bldg
865-1387
mlk6@psu.edu

Henry McCoullum
428 Thomas Bldg
863-0285
hwm1@psu.edu

Peggy Lorah
204 Boucke Bldg
863-2027
mal273@psu.edu

For a complete list of individuals who are available to help you, please see the Penn State Affirmative Action web site at http://www.psu.edu/dept/aaoffice/index.html

The individuals' names listed above and on the Affirmative Action web site are available to assist you in answering questions, listen to your complaint, advise you on procedures, see that appropriate action is taken, and assure that you are protected from retaliation. All situations are handled in the most confidential manner possible.

A.2 Intellectual Property

This appendix contains Penn State's policy on intellectual property: http://www.research.psu.edu/policies/intellectual-property/. You can also visit the Office of Technology Management's web site at http://www.research.psu.edu/patents.

A.2.1 Introduction

This document is intended to serve as an overview of patent and copyright matters of interest to University personnel (faculty, staff, students, fellows, wage payroll employees, and persons on "visiting" appointments). The implementation of the policies and procedures outlined in this document should be subordinate to the University's graduate and undergraduate education, research and service missions.

Inasmuch as the University only recently initiated a program to enhance its stewardship of its patent and copyright activities, the policies and procedures cited herein are subject to ongoing review and possible future modification.

The management of patent and copyright processes in a university setting is a complex, highly specialized endeavor. As the need for details regarding policies and procedures arises, University personnel are urged to contact cognizant University administrators (deans and department heads, program and center directors, office supervisors, etc.) and the University Office of Technology Management for assistance.

Universities are major sources of fundamental knowledge underlying the new products and processes essential to economic competitiveness. In this context, facilitating the process whereby university creative and scholarly works may be put to public use and/or commercial application (i.e., "technology transfer") is an important aspect of the service mission of a land grant university. In turn, the protection of concepts with commercial potential (inventions or creations) via patents and copyrights is an essential aspect of the technology transfer process. Without such protection, companies are unlikely to invest the funds required to commercialized new technology.

A.2.2 Rights in Inventions

Inventions with commercial potential may involve novel machines, devices, compositions of matter (compounds, mixtures, genetically engineered cells, plants, animals), genetic forms, software and computer systems, production processes, plant varieties, etc. Such inventions, and the patents and copyrights that reserve rights to them, are termed Intellectual Property. University personnel have an obligation to disclose promptly to the University (Office of Technology Management) inventions developed a) with University resources, facilities, funds, or equipment), or b) within the fields of expertise and/or within the scope of employment for which they are retained by the University. This obligation is manifested in the patent agreement signed by all employees of the University.

A.2.3 Patent Practice and Procedures

University personnel who believe they may have developed an invention should immediately notify the cognizant University administrators, and the Intellectual Property Office. They will be asked to complete an invention disclosure form by the Office of Technology Management. The invention disclosure defines the nature of, and provides the basis for a legal claim to, the invention in question. The Office of Technology Management evaluates invention disclosures for patentability and market potential. A preliminary patent search is generally performed using the computer facilities of the University Libraries. If this process suggests that the invention has significant commercial potential, the following sequence is set in motion.

1. The Office of Technology Management, in concert with inventors, will attempt to identify companies whose technology interests coincide with the invention in question. Non-enabling disclosures are sent to these companies to inform them of the general nature of the invention, without divulging its essential elements. Upon the expressed interest of a potential licensee, additional detailed information about the invention is released following the execution of an appropriate Confidentiality Agreement.

2. In return for rights to an invention, licensees will be expected to file a patent application at their expense in the name of the University. If an invention requires further research to bring it to the point of commercial utilization, companies will be encouraged to provide the necessary research support as part of either a Research and License Agreement, or an Option Agreement. Where an option is involved, companies are offered an exclusive right to negotiate a license in return for a research commitment and/or appropriate payment.

3. The University (Office of Technology Management in accord with the cognizant administrators) may, under certain circumstances, elect to apply for a patent concurrent with the search for a licensee. This option is very selectively applied as a consequence of the limited funds available for

this purpose, and is restricted to unusually promising inventions in dynamic, highly competitive fields. Where this option is contemplated, the results of the University Libraries preliminary patent search will be submitted to a patent attorney in the appropriate art area for a patentability opinion. A decision to proceed will be based on a judgment that the invention is patentable, is not encumbered by other patents, and has sufficient commercial potential to justify patent expense.

4. If, in concert with inventors, the Office of Technology Management is unable to identify a licensee in a timely fashion, the disclosure will typically be sent to Research Corporation Technologies (RCT) for evaluation. RCT may thereafter elect to accept the disclosure, file a patent application, and initiate the licensing process.

5. Inventors may petition the University for the assignment of invention rights to them when it

   a) is consistent with the policies and best interests of the University,

   b) would advantage the transfer of technology to the private sector, and

   c) is in accord with the University's obligations to sponsors and other third parties.

   For example, should the Office of Technology Management fail to identify a licensee, and Research Corporation Technologies subsequently elect not to accept the invention, inventors may petition the University for the assignment of invention rights to them.

The foregoing procedure is based on the premise that a close working relationship between University inventors and the Office of Technology Management is important for the successful management of inventions. The reasons are varied. Inventor's knowledge of their research areas, and of companies active in related technologies, are key elements of the technical and market assessments for an invention, and of the search for licensees. In addition, inventions can serve as powerful catalysts for industrial research support. The search for such support is greatly enhanced by close collaboration between inventors and Office of Technology Management staff. Finally, the search for licensees willing to underwrite the cost of concept refinement and/or patent prosecution represents a useful “market test” for an invention.

A.2.4 Copyright Practice and Procedures

The University encourages faculty, staff, and students to create literary, scholarly, and artistic works, including textbooks and other instructional materials. In this context, copyright ownership of such works generally rests with the creator(s) unless they are generated within the scope of the creator's employment, commissioned by the University, or are subject to a sponsor's agreement, which provides for a different ownership.

The copyright of literary, scholarly and artistic works, including books, articles, contributions to collective works, and other means of presentation, but excluding instructional materials, is considered to be outside the scope of employment and therefore owned by the creator, whether or not created on University time or using University resources. Conversely, copyrights in research or survey instruments (questionnaires, etc.), instructional materials (including videotapes), and in computer software created on University time are considered within the scope of employment and hence owned by the University. University personnel creating such materials are urged to contact the Office of Technology Management, through the cognizant University administrators, for assistance in the copyright process and for subsequent licensing efforts.

A.2.5 Related Issues

The commercial exploitation of inventions, in the form of products and processes for business and industry, is a highly competitive enterprise. It is therefore critical that inventors begin the disclosure process as soon as the possibility of an invention becomes evident. Delays give others an opportunity to establish a claim, which may deprive an original inventor of his/her rightful recognition and compensation. Some other considerations follow.

1. In general, it is prudent to delay the oral disclosure or publication of research details that are specific to an invention until such time as the invention has been evaluated and, as appropriate, protected. Such decisions, however, should not be allowed to adversely affect the progress of students toward their degrees. In most cases the omission of information from publications that would compromise a commercial application does not impede the free flow of fundamental knowledge. In particular, inventions in a University setting are usually practical manifestations of an underlying body of fundamental knowledge. As such, one can frequently engage in the free exchange of basic ideas without compromising the practical application. If inventors have questions about the disclosure or publication of research, they are encouraged to discuss the matter with the Office of Technology Management.

2. Public disclosure of a concept in the open literature (in abstracts and texts of presentations at meetings, and in theses, etc.) generally precludes obtaining patent protection

in most foreign countries. In the U.S., one may obtain a patent as long as the application is filed within one year of the date of public disclosure. The impact of the waiving of foreign rights for an invention depends upon the size of U.S., and foreign markets, the relative market shares of foreign and domestic companies in the technology in question, etc.

3. Rights to inventions arising from industrially sponsored research are usually prescribed in a research contract containing a work statement and other terms and conditions of the award. Sponsors generally receive the first option on a license to technology resulting from research that they support. As the contractor for the specified research, the University must ensure that it has not committed rights to technologies to multiple sponsors. In dealing with potential industrial sponsors, faculty investigators should thus be sensitive to this possibility. The consequences of commingling intellectual property rights can be substantial. Until such time as they are resolved, disputes over sponsor rights can limit or eliminate opportunities for additional industrial support for promising research areas. Unfortunately, such disputes can last for years.

4. Federal agencies allow contractors, including universities, to retain ownership of intellectual property arising from research that they sponsor. The government retains non-exclusive rights to such intellectual property for its own purposes. The University has a contractual obligation to inform sponsoring agencies of inventions within two months after they are disclosed to the Office of Technology Management, to elect to retain title within two years, and to file a patent within one year of election.

5. Members of research consortia are typically given non-exclusive rights to inventions conceived in whole or part with consortium funds. Such arrangements can, unfortunately, seriously compromise the commercial potential of an invention. In particular, the resulting lack of marketplace exclusivity may deter companies from investing in the production facilities and marketing strategies required to commercialize an invention. Faculty concerned about this issue may wish to restrict the use of consortium funds to the support of pre-proprietary research.

6. Consulting contracts sometimes contain provisions which limit the disposition of research results, including intellectual property, in promising research areas. They should be examined to ensure that the assignment of rights to intellectual property evolving from consulting activities does not conflict with the patent agreement signed by all University employees. In general, faculty may, within the scope of a consulting agreement, assign rights to intellectual property in their fields of expertise where organizations engaging their services have legitimate prior claims to the development(s) in question. Examples include consulting activity leading to the refinement of an existing product or process, or to a development for which background patents or prior art claims exist. In any case, faculty should bring consulting contracts to the attention of cognizant University administrators prior to executing them.

A.2.7 Revenue Distribution

The Pennsylvania Research Corporation, a subsidiary of the Corporation for Penn State, is a nonprofit organization dedicated to advancing scientific research within the Commonwealth of Pennsylvania, and to supporting the development of inventions at the University. It serves as the University agent for managing the fiscal aspects of intellectual property issues. The Corporation thus distributes intellectual property revenues, with the distribution formula depending on whether the University (Intellectual Property Office) or Research Corporation Technologies executes the cognizant license. Intellectual property revenues derived from the liquidation of, or dividends from, University equity holdings will be distributed according to the formulas below.

The University will be the licensor for employee copyrights and patents when either a licensee has filed the relevant patent application in the name of the University, or the University has elected to file on its own. In either case, the inventor(s) will receive a $1,000 incentive payment at the time a patent application is filed. Note that these incentives do not apply to copyrights or registrations. After recovery of any direct patent or copyright prosecution, maintenance, or infringement litigation costs incurred by the University, royalty revenues are distributed as follows: begin

- 40% Inventor(s)/Creator(s)
- 20% Originating administrative unit
- 40% Pennsylvania Research Corporation

In the event that the Intellectual Property Office is unable to either identify a licensee willing to underwrite the cost of patent prosecution, or justify filing a patent application with University funds, Research Corporation Technologies will be given an opportunity to evaluate invention disclosures. The royalty distribution for patents which they elect to prosecute, and subsequently license, is as follows:

- 40% Research Corporation Technologies
- 25% Inventors

- 10% Originating administrative unit
- 25% Pennsylvania Research Corporation

Research Corporation Technologies provides cash incentives to inventors when they accept a disclosure for patent prosecution, or request an extended period for disclosure evaluation. The magnitude of the cash incentives has varied in the past, but in no case has been less than $1,000 for inventions for which a patent application is filed.

University personnel whose invention is licensed to an entity in which they have a proprietary interest (i.e., company officer, founders equity position, stock holdings exceeding 10% of the total issued, etc.) will not receive the inventor's share of University royalties derived from said license. They will, however, receivethe inventor's share of royalties from any other licensees.

The Pennsylvania Research Corporation's share of royalty revenues is utilized to support research, and a portion of the cost of operating the Intellectual Property Office. Funds are also set aside to defray legal expenses associated with infringement actions and product liability litigation accruing to University patents and copyrights.

A.3 Coauthorship

It is the policy of The Pennsylvania State University that proper credit be given to those individuals who make material contributions to activities which lead to scholarly reports, papers and publications.

Rigid prescriptive requirements in this area are considered unwise, because the situation with respect to coauthorship varies from one discipline to another and from one publication to another. Nevertheless, it is recommended that the authors of scholarly reports, papers and publications abide by the following principles regarding coauthorship.

1. Coauthorship should be offered to anyone who has clearly made a material contribution to the work.

   Moreover, each coauthor should be furnished with a copy of the manuscript before it is submitted, and allowed an opportunity to review it prior to submission. An author submitting a paper, report or publication should never include the name of a coauthor without the person's consent. Exceptional circumstances, such as death or inability to locate a coauthor, should be handled on a case-by-case basis. In cases where the contribution may have been marginal, an acknowledgment of the contribution in the publication might be more appropriate than coauthorship.

2. In the case of theses for advanced degrees, if the thesis or paper based upon it is not published with the degree recipient as sole author, then that person should normally be listed as the first author. In no instance should theses, or papers based upon them, be published under the sole authorship of the thesis adviser.

3. Anyone accepting coauthorship of a paper must realize that this action implies a responsibility as well as a privilege. As a general rule, each coauthor should understand the content of the publication well enough to be able to take responsibility for all of it; otherwise the publication should clearly indicate the parts of which each coauthor has responsibility. If a potential coauthor has doubts concerning the correctness of the content or conclusions of a publication, and if these doubts cannot be dispelled by consultation with the other coauthors, the individual should decline coauthorship.