Department of Physics and Astronomy Guide for Graduate Students

February, 2015

Foreword

Welcome to the Department of Physics and Astronomy at Rice University! A graduate degree in the sciences is a challenging but rewarding path to choose, and Rice has a great tradition of fundamental science and graduate education. Our department has active researchers with programs spanning much of the spectrum of modern physics and astronomy, including atomic and molecular physics, biological physics, condensed matter physics, nuclear and particle physics, space physics, galactic astronomy, solar physics, and high energy astrophysics. We have theorists and experimentalists, with access to state-of-the-art research infrastructure, including active projects at national user facilities.

Graduate education is a unique mixture of instruction, training, mentorship, and scientific collaboration. In our program we want each student to get the most out of their experience, contributing to the advancement of science through outstanding original research, while at the same time preparing the student for a professional career. Our department matriculates 15-20 students per year, with this scale favoring access to faculty time and research infrastructure. These students are provided with departmental fellowship support (a stipend and waiver of tuition) during their first year, and acquire continuing financial support via faculty research grants thereafter. Our students have gone on to outstanding, diverse professional careers, including academic research, government research and service, technical careers with companies ranging from oil services firms and large corporations to exciting startups, consulting, education, etc.

While this handbook is meant as a resource for P&A graduate students, providing a handy , concise guide to essential information about the graduate degree program, it is only one source of information. If you cannot find the answers to your departmental programmatic questions here, please do not hesitate to contact the departmental staff (including the graduate coordinator, Ms. Rosa Almendarez), the Chair of the Graduate Program Committee (currently Prof. Douglas Natelson), the Associate Chair of the department (Prof. Stan Dodds), or the Departmental Ombudsperson (currently Prof. David Alexander). For current students, faculty are specifically assigned as graduate student advisers to answer academic questions. Current graduate student advisers are Prof. Stan Dodds and Prof. Frank Toffoletto. We are available to guide you through the process. That being said, graduate students are adults, and there is a presumption that students will take responsibility and initiative – these are certainly necessary for a successful doctoral degree! Please ask questions and keep on top of deadlines and requirements. We look forward to working with you.

Introduction

This handbook has been prepared to provide information and assistance to all graduate students in the Department of Physics and Astronomy. Revisions or additions may be made from time to time, and will be distributed as needed. A current version of this handbook will be available via the departmental webpage at this url:
http://physics.rice.edu/uploadedFiles/Degree_Programs/Gradhbook.pdf

Students, as a matter of course, should keep a personal file containing this document, future memos about rule changes and other departmental matters, and documentation related to graduate progress.

Official communications from the Office of Graduate Studies, the Registrar and the department will be sent to your **Rice email address** only. You must **check your Rice email regularly**, even if you routinely use a different account. If you have questions regarding your Rice email account, please see the relevant IT webpage (http://it.rice.edu/email/) or contact the IT help desk (helpdesk@rice.edu).

Applied Physics students, regardless of home department, should consult the Applied Physics web page (http://rqi.rice.edu/academics/graduate/graduate.php) for applicable academic regulations. The AP program is a distinct graduate program with its own policies and procedures, administered through the Rice Quantum Institute.

Departmental Staff

The P&A department is fortunate to have an excellent departmental staff. As a graduate student you are welcome to ask our staff members for assistance at any time. The staff directory is listed below, with responsibilities described as relevant to graduate students

Title and responsibilities	Name	Phone extension (713-348-xxxx)	Email (@rice.edu)
Department administrator (oversight; research accounting and administration)	Rose Berridge	2152	berridge
Graduate program coordinator (**your primary contact**; degree progress, pay issues)	Rosa Almendarez	6348	physgrad
Staff assistant (reception, receiving, room reservations)	Sarah Curtiss	4938/2579	sarah.curtiss
Event and travel coordinator (scheduling visitors, arranging functions, travel reimbursement)	Barbara Braun	4146	bbraun
Departmental coordinator (faculty/postdoc searches, departmental administration)	Valerie Call	4138	vcall
RSI/conference administrator	Umbe Cantu	4939	umbe
Technical support (lab demos, seminar room A/V)	Jack Johnson	2513	jack.johnson
Purchasing and accounting coordinator (research-related purchasing)	Angela McFarland	3939	angelacm
Accounting assistant (purchasing documentation)	Saray Ortiz	2701	saray.ortiz
Bonner Lab administrator	Pamuela Reynolds	5313	xedrss

To reserve a departmental conference room for a meeting, please use the following website, which automatically forwards your request to the relevant staff member: http://paroomcalendar.weebly.com/

Useful pointers

- ***ESTHER***. The Employee and Student Tools, Help, and Electronic Resources system is a web application used by all students, faculty, and staff to handle human resource and academic issues. ESTHER is how students enter their contact information, set up direct deposit, register for courses, and receive their grades electronically, for example. Please see this page for complete information: http://registrar.rice.edu/students/esther_FAQs/

- ***Graduate stipends***. Graduate students are paid on a semimonthly schedule, receiving a constant amount per pay period with two pay periods per month (funds issued on the 15th and the last day of the month, or on the preceding business day if paydates fall on holidays or weekends). The P&A graduate stipend is revised annually by the department. The stipend for the 2015-2016 academic year is $28,500/yr before doctoral candidacy, and $29,700/yr after doctoral candidacy.

- ***Student Health Services***. Information about student health is available here (http://health.rice.edu/). Rice students are required to have **health insurance**. If a student enrolls in the Rice Student Health Plan, the billing can be annual or semiannual. This is set up via ESTHER, and you can contact the cashier's office for payment options (713-348-4946). If you have your own insurance from some other source, you are required to complete an insurance waiver form (http://graduate.rice.edu/forms/). All new students must submit a Health Data Form (http://health.rice.edu/Content.aspx?id=106) prior to enrollment, which includes documentation of vaccination records. Rice also has an outstanding **counseling service** (http://rcc.rice.edu/ , wellbeing@rice.edu, 713-348-3311).

- ***Grad studies office***. The Office of Graduate and Postdoctoral Studies (graduate@rice.edu, 713-348-4002, Allen Center 323) is a great resource for all things related to general graduate study at Rice not particular to the P&A department.

- ***Common graduate student forms***. The Grad Office maintains a library of commonly used forms here (http://graduate.rice.edu/forms/), including those related to enrollment, leaves of absence, withdrawals, masters and doctoral candidacy, thesis defenses, thesis formats, and degree conferral. For forms specifically concerned with course registration and transfer credit, please see the Registrar's office (http://registrar.rice.edu/online_forms/#GR).

- ***International student issues***. When in doubt, please consult the website of the Office of International Students and Scholars (http://oiss.rice.edu/, oiss@rice.edu, 713-348-6095). International students are generally eligible to apply for a social security number the summer following their first year. Appropriate procedures and forms for students on F-1 and J-1 visas may be found here (http://oiss.rice.edu/content.aspx?id=102).

- ***Graduate Student Association***. There is a global graduate student association for all of Rice, with a website here: http://gsa.rice.edu/ (gsa@rice.edu, 713-348-5931). They are a terrific resource with lots of information about getting settled at Rice (http://gsa.rice.edu/content.aspx?id=222).

- ***PAGSA***. The P&A department has its own graduate student association that plans events throughout the academic year. PAGSA is always looking for enthusiastic new members! The current officers are Eteri Svanidze (President, eteri.m.svanidze@rice.edu), Jake Fry (Internal VP, jacob.a.fry@rice.edu), and Loah Stevens (External VP, las11@rice.edu).

- ***Laboratory safety***. Laboratory safety is a very serious issue and should not be treated lightly. General information about laboratory safety may be found at safety.rice.edu, and the Environmental Health and Safety team is available for questions during business hours at **713-348-4444**. Incoming graduate students receive a minimal briefing about safety issues during orientation. Prior to working in a research laboratory, students must attend a scheduled general laboratory safety training session. Note that individual research groups also have their own specific safety procedures, and depending on the laboratory may require additional organized training sessions (e.g., high powered laser safety). If you have a general laboratory safety concern, please do not hesitate to bring this to the attention of the department chair. If you encounter an emergency situation on campus you should call **713-348-6000** (the campus police – calling 911 is likely to bring a slower response). If a situation involves research chemicals, biological materials, etc., please also notify EH&S at **713-348-4444**.

- ***Campus maintenance issues***. If you ever come across an urgent campus maintenance problem, particularly if you think you are the first person to notice it (e.g., you see water leaking onto the floor of the hallway in Brockman from a pipe fitting), please contact Facilities at **713-348-2485** and then notify departmental staff Use your judgment about whether it is important to notify a lab principal investigator, the P&A office staff, or the department chair. Non-urgent requests for facilities issues should go through department staff, particularly to help us track repeated problems.

- ***How to be a good graduate student***. This is an informal collection of tips. Be responsible and communicative. Ask questions if you don't understand something. Be mindful of schedules and deadlines – this means coming on time to meetings and course commitments, turning in requested assignments and paperwork promptly, etc. Actually be a finisher – really get things done. Graduate school is more like a job than your previous educational experiences – be professional. Make lists. Plan your time intelligently. Don't let flexibility of schedule throw you into working inefficiently.

Academic Timeline, Procedures, and Regulations

Information about the PhD and MS degree requirements and Department policy regarding admission to candidacy for these is provided here as a convenience for enrolled graduate students. While we make every effort to keep the following current and accurate, the official Rice University advanced degree requirements are those described in the General Announcements (http://ga.rice.edu). The section there titled "Graduate Students" outlines basic rules and expectations for *all* graduate students. Thesis formats and requirements are stated on the Office of Graduate Studies web page (http://graduate.rice.edu/thesis).Like many other programs at Rice, the P&A department has additional requirements that are found in their own section (http://ga.rice.edu/programs.aspx?FID=2147483718 under "Graduate Requirements").

It is Rice policy that if university requirements change while a student is enrolled, the student may choose to graduate under the rules in effect when they were admitted to the program, or under those in effect when they graduate.

Normal Progress and Deadlines

The doctoral program in P&A has several milestones. In the first year, students take required ***coursework*** (described below) and ***affiliate with a research adviser***. In the second semester they begin fulfilling their ***teaching practicum*** (PHYS 700). Generally required coursework is completed in the second year, while students perform research in the group of their research adviser. During the fifth semester, students complete a ***research progress and proposal report*** (involving a written document and an oral presentation described below) and take an ***oral PhD candidacy exam*** (described below). Each year (except the first), there is an ***annual evaluation*** to make sure that satisfactory progress is being made toward the doctoral degree.

Students, in consultation with the research adviser, complete a ***doctoral thesis*** and undergo an ***oral thesis defense*** with a committee of three faculty, one of whom must be the thesis adviser and one of whom must be a faculty member with a primary appointment outside P&A. The time required to complete a PhD depends on many variables, including the type of project, and the effort expended, talent, and (many times) luck of the student. Doctorates in P&A have taken as little as 4 years; the university's absolute upper limit is 8; and the mean is around 6.

Below, the typical degree progress is outlined in tabular form.

Year	Fall semester	Spring semester
1	Register for recommended and required classes in areas of interest. Complete PHYS 710 (required). Attend faculty research presentations, begin meeting with potential research advisers.	Continue course work. Start PHYS 700 (teaching practicum) if assigned. Formal research affiliation no later than mid-semester (the sooner the better). Advisory/masters committee is formed.
2	Annual advisory committee meeting. Course work as needed, including PHYS 700, PHYS 800.	Complete department lecture-course requirements.
3	Annual advisory committee meeting. Continue research and teaching. Research Progress and Proposal report and presentation; pass PhD candidacy oral; file for PhD candidacy	Continue research and teaching.
4	Continue research (and teaching if necessary).	Research
5	Research	Research
6	Research	Complete and defend PhD before end of semester (preferred) / Research
7 (if needed)	Research	Research
8 (if needed)	Research	University deadline for completion and defense of PhD before end of semester.

The PhD deadlines shown in red are the absolute maximum allowed by the university. Students should make every effort to complete their degrees sooner.

Requirements for Candidacy and Degrees

The P&A department admits graduate students into the doctoral program. It is not the intent to admit students who only wish to pursue a masters degree.

Completion of a masters degree is not a requirement for the PhD. However, we recognize that this credential is important to some students. Students can request the awarding of a (non-thesis) MS degree on the way to completion of the doctorate upon satisfaction of the requirements listed below.

MS Degree

The MS degree is conferred upon successful completion of specified coursework.The type of degree and the degree name, either Physics or Astrophysics, will be specified by the student in consultation with the adviser and chair of the graduate program committee. The formal requirements are:

1. Master’s students must complete at least one full fall or spring semester in full-time study in a graduate program at Rice University.

2. The student must complete, with acceptable grades, 30 semester hours of approved advanced courses, including research.

3. The student must complete with acceptable grades, or otherwise satisfy the requirements of, four of the basic courses for the doctoral degree, as specified below, plus two other approved courses. An average grade of B or better will normally be expected in the student's graduate level physics and astronomy courses, excluding research and teaching.
4. The student must be engaged in a research project involving the candidate’s own independent and original work. The satisfaction of this requirement is to be certified by means of a written statement from the student’s research adviser stating the area of the research.

PhD Candidacy

Achieving candidacy for the PhD implies that a graduate student has completed all required coursework, passed required exams to demonstrate his/her comprehensive grasp of the subject area, demonstrated the ability for clear oral and written communication, and shown the ability to carry on scholarly work in his/her subject area. The requirements for candidacy are:

1. The student must complete with acceptable grades all required courses (see below), or demonstrate equivalent accomplishment elsewhere. An average grade of B or better will be expected in the student's graduate level physics and astronomy courses, excluding research and teaching practicum.

2. The student must complete five semesters of the teaching practicum, PHYS 700.

3. The student must be enrolled in Graduate Research (PHYS 800) and be progressing satisfactorily toward completion of the PhD thesis.

4. The student must complete a ***Research Progress and Proposal (RPP) report*** (see below for report requirements) and an ***oral research presentation*** of that report to the satisfaction of the examining committee (the advisory committee plus one additional outside-area member assigned by the Graduate Program Committee).

5. The student must pass an ***oral candidacy exam*** (see below for exam details), and the examining committee (the advisory committee plus one additional outside-area member assigned by the Graduate Program Committee) must certify the student as an acceptable candidate for the PhD in the research area covered by the RPP. If the student later changes research direction, the candidacy exam should be re-administered in the research area in which the doctoral research will take place.

The research presentation and the first attempt at the candidacy exam must be completed by early in the student’s **fifth semester** (no later than the end of the fifth week of the fifth semester). If needed, a second attempt at the candidacy exam must be completed by the end of the student's **fifth semester**. If the student does not pass the second time, then the student will be asked to leave the doctoral program.

Research Progress and Proposal report: The report serves three valuable purposes: (1) To demonstrate that the student is conducting research at an appropriate level; (2) to give students practice at writing about their work; and (3) to provide essential context and background so that the outside-area members and peers can understand the research plan. The report should be carefully written with properly cited references. The RRP should contain:

- An introduction sufficient to explain the context of the research area and project(s) to the outside members.
- A summary of what research the student has been doing so far. This could include preliminary results, or a discussion of a particular project, even if that project is unlikely to be the direct doctoral thesis topic.
- A brief discussion of the expected doctoral thesis topic (or *possible* topics) – what they would entail and how they fit in with the context provided.
- Properly formatted references for cited works or use of figures from the literature.

Again, while this does not have to be polished like a publication, it is strongly encouraged that the adviser should read this document and provide feedback to the student prior to the document being given to the committee. The RPP should be no longer than 20 double-spaced pages including figures and references (no longer than about 5 journal pages). The RPP should be given to the committee at least two weeks prior to the presentation. The document will be retained in the student's internal departmental record.

The oral presentation should be no longer than about 30 minutes, and touch on the three main elements above. The research presentation can be public at the discretion of the adviser.

Oral Candidacy Exam: The oral candidacy exam will be closed-door (just the student and the committee members) and will be based on the subject-specific topics listed in the Graduate Handbook and on the P&A departmental webpage. The student will demonstrate competence in the chosen research area by being able to correctly answer questions on the topics described in the sub-discipline exam topics list. Typical lists of important topics by specialty are on the department web pages, although greater specificity may be defined by discussion between the examining committee and the student in advance of the examination. See http://www.physics.rice.edu/Content.aspx?id=57 - PHD Candidacy or follow the links Degree programs -> Graduate study -> Graduate degree programs - PhD Candidacy at www.physics.rice.edu. These topics are also added here as appendices to this handbook.

The questions should cover a significant fraction of the topics on that list. The exam may also end up covering basic core physics competency as examiners attempt to guide the student, and the student should demonstrate competence in core physics and/or astronomy topics by satisfactorily answering questions in those areas. The combined duration of the exam and research presentation in one session is to be no more than two hours. The exam by itself should be no more than 90 minutes.

The outside-area member of the student's advisory committee will keep track of the questions asked and will write up a brief summary for internal department records.

PhD Degree

To complete the PhD degree a candidate must write a doctoral thesis and publicly defend it in the final oral examination, which is conducted by the PhD Examination Committee. The type of degree and the degree name, either Physics or Astrophysics, will be specified by the student in consultation with the adviser and chair of the graduate program committee. The formal requirements for the PhD are:

1. The student must complete all course work specified for their matriculating class and any additional courses required by the thesis adviser.

2. The transcript must show at least 90 semester hours credit, including research and teaching, beyond the Bachelor's Degree. A total of at least four full semesters, not including summer terms, must be spent in full-time study at Rice.

3. The student must successfully complete a research project involving independent and original work. The work must be reported in an approved thesis, and defended in a public oral examination.

Course-work Requirements

All degree programs in Physics and Astronomy require students to complete certain courses, listed below, with satisfactory grades. Since course content changes from time to time, these requirements are subject to modification and students should be careful to fulfill the requirements in effect for their class.

For students matriculating after 1 August 2013 the departmental requirements for the PhD are:

1. At least eight full (3-credit) graduate courses, other than teaching or research, in the Physics and Astronomy Department. These courses must be chosen from the list given in Appendix: Graduate Courses by Topic. A student may petition the Graduate Program Committee to use courses outside of this list to satisfy the requirement.

2. At least four of the eight courses must be chosen from the following list:
   - ASTR 470 Solar System Physics
   - ASTR 451 Sun and Stars
   - ASTR 452 Galaxies and Cosmology
   - PHYS 480 Introduction to Plasma Physics
   - PHYS 515 Classical Mechanics
   - PHYS 521 Quantum Mechanics I
   - PHYS 526 Statistical Physics
   - PHYS 532 Classical Electrodynamics
   - PHYS 541 Radiative Processes

3. At least one of the eight courses must be outside the student's research area. The courses listed in item 2 may be used to satisfy this requirement, but a single course may not be used to fulfill both item 2 and item 3.

4. Five semesters of PHYS 700, ***Teaching Practicum***. This typically consists of some combination of running undergraduate lab sessions, grading homework and exams for undergraduate or (when appropriate) graduate courses.

5. Completion of PHYS 710, Graduate Seminar in Physics and Astronomy, during the first Fall semester in residence.

6. Such additional courses as the thesis adviser may require.

In addition to meeting the departmental *requirements* above, students should consult the appended list of course *recommendations* by research area and their thesis adviser to ensure that their course work provides optimal preparation for thesis research. A list of courses by research area is also appended for use in meeting requirement 3.

Requests for modification of the course requirements must be addressed to the Graduate Program Committee. If a petition is necessary, students are strongly encouraged to submit the request before taking a course they wish to substitute for one of the requirements.

Satisfactory performance, academic probation, dismissal

Grades of B or better are considered evidence of satisfactory performance. An average grade of B or better will normally be expected in graduate level physics and astronomy courses, excluding teaching and research. Some research advisers may have additional expectations.

Students receive a written letter from the department chair in January regarding progress in the first-year graduate courses, giving instructions on whether the progress has been satisfactory to warrant formal affiliation with a research adviser.

Note that grades in PHYS 800, the physics research course, are one way for an adviser to provide formal feedback about the progress of research. An unsatisfactory grade (below B) in this course is cause for concern.

Rice University's official policy on **academic probation, dismissal, and termination of financial support** is here: http://ga.rice.edu/Home.aspx?id=2147483680

Leaves and Withdrawals

Rice University's policy on leaves and withdrawals is here: **http://ga.rice.edu/GR_withdrawals/**

Vacations

Arrangements for time off beyond university holidays (http://people.rice.edu/holidays.aspx) must be made in advance in consultation with the adviser and must be in compliance with university rules and guidelines from funding agencies.

Teaching

The department considers teaching experience an essential part of graduate training. Thus, full-time graduate students should expect to assume some teaching duties (e.g., teaching labs, grading papers, grading exams, etc.) in addition to research. The amount of time required for any individual student for such tasks will normally not exceed an average of six hours per week. Assignments will be made for 5 semesters, beginning with the second semester at Rice.

Students involved in teaching register for PHYS 700 (Teaching Practicum), which indicates on their transcript that they have had teaching experience. Questions about teaching assignments should be directed to the associate chair.

Semesters of required teaching may be waived for students who have had significant experience teaching physics or astronomy elsewhere. Service as a graduate TA would generally qualify for exemption, but work as an undergraduate grader would not. A request for a waiver should be discussed with the Chair of the Graduate Program Committee soon after arrival at Rice, preferably documented with records from the prior institution.

Previous Graduate Work

Certain requirements may be modified for students who have done equivalent graduate work elsewhere. Students should consult with the Chair of the Graduate Program Committee to verify the application of the guidelines described below to their particular case.

Graduate-level courses taken elsewhere may be substituted for required courses for the masters and/or PhD degree. The equivalence of previous courses with Rice courses will be evaluated by means of an interview with an appropriate faculty member (e.g., the Rice professor who teaches the Rice equivalent graduate course). Course requirements will be waived in areas where the student has sufficient background.

Petitions and Appeals

In accordance with University policy found in http://ga.rice.edu/GR_disputes/, graduate students may petition for exceptions to academic requirements, regulations, and judgments. Petitions regarding Physics and Astronomy Department requirements, regulations, or judgments should be addressed to the chair of the Graduate Program Committee.

General Information

Course selection and advising during the first year

Incoming graduate students go through a series of ***placement interviews*** during orientation week with a selection of Rice faculty members, to document prior instructional background and help suggest the appropriate level of first-year graduate coursework. Following these interviews, at the end of orientation week, the first-year students will meet with faculty aligned to their stated research interests. These faculty members will advise the students on a suggested first year curriculum, as well as common elective coursework pursued in the appropriate sub-disciplines. Prior to the registration deadline for the second semester, students will be given the option of a second such meeting, though some students may have already found a research adviser at this point. Students are also encouraged to discuss course selection with faculty they might be interested in as potential research advisers. In addition, faculty are specifically assigned as graduate student advisers to assist students with any academic questions they might have. These faculty are listed at http://www.physics.rice.edu/Content.aspx?id=53.

In January students will be informed in writing by the department chair regarding their academic standing based on coursework from the first semester. This notification may contain particular advice regarding course selection.

Affiliation and Research Advisers

Formal affiliation is by mutual agreement between the student and adviser and the submission of the appropriate form to the department graduate coordinator.

The P&A department does not have a formal research rotation or matchmaking process. ***During the first semester*** students should explore research opportunities of interest to them by attending the faculty research presentations scheduled during lunch-time. Students should then further investigate any areas of interest by direct discussion with the potential adviser(s). Exploring a range of research areas is important because not all faculty members have resources or openings for additional students in any particular year.

By the end of the first semester, the focus should narrow to a few research groups, and the student should make every effort to speak with the most likely faculty mentors and the current students in their research groups. An informed choice requires consideration of many issues: Where are graduates of that group employed? Is funding adequate? What is the typical duration of a PhD in that group? What journals does the group publish in and how often? And most importantly, is the research interesting to you?

At the beginning of the second semester, the P&A department faculty reviews the performance of all beginning students. Those who are making satisfactory progress will receive written notice that they should make a research affiliation. Those showing unsatisfactory or marginal classroom records will be so advised and their eligibility for research affiliation will be considered by the faculty on a case-by-case basis. Students are encouraged to affiliate as early in the second semester as possible.

All research expenses in the department, including most student stipends, are paid by grants and contracts held by faculty. Thus, students must make a research affiliation no later than the middle of the spring semester of their first year in order to continue in the program and to receive further support. An earlier affiliation allows a more rapid transition to research at the end of the semester.

Students desiring to work with someone who is not a regular faculty member or Faculty Fellow in Physics and Astronomy may do so with the permission of the Graduate Program Committee. They will be required to submit a brief outline of the proposed work and to obtain the support of a faculty member within the department who will act as departmental adviser. The proposed topic must be appropriate for a degree in physics or astronomy, and the thesis director must be qualified to supervise the project. Approval will initially be granted only up through PhD candidacy, with an additional petition and review required for the PhD.

Graduate Student Advising and Committees

Graduate Program Committee

The departmental Graduate Program Committee administers the academic aspects of the program on behalf of the faculty. The committee consists of several faculty members appointed by the chair.

If a student desires a special exemption or change from the stated departmental regulations and procedures, he or she should consult with the Chair of the Graduate Program Committee. The chair will advise on the drafting of a petition and arrange for a meeting of the committee to resolve the request. Students are strongly urged to submit all petitions as soon as possible.

Advisory Committee

Each student has an assigned **Advisory Committee** which will serve as a resource throughout the student's graduate career. The Advisory Committee is normally composed of three members of the department with the rank of faculty or Faculty Fellow. One member is the thesis adviser, one member is appointed by the Graduate Program Committee to represent the department, and the third is chosen by mutual agreement of the student and thesis adviser.

During the **Fall semester each year** the Advisory Committee will meet with the student and assess progress towards the PhD. A progress report will be filed with the Graduate Program Committee and a copy given to the student. Typically, the Advisory Committee will also serve as the MS Committee and PhD Candidacy Committee. ***The Advisory Committee continues in its functions and meets annually to assess progress even after a doctoral thesis committee has been formed***. The purpose of the meeting of the Advisory Committee is a formal, written **annual evaluation**, informing the graduate student about whether the course of research progress is satisfactory.

The entire Advisory Committee should serve as a resource for the student. The student may consult the members of the committee at any time for guidance on all aspects of their graduate program and post-graduate planning.

In the event that non-academic problems or conflicts arise, students are encouraged to consult any member of their Advisory Committee, any member of the Graduate Program Committee, or the Departmental Ombudsperson for advice. Particularly serious matters should be discussed with one of the associate chairs, or with the department chair. The university provides more formal grievance procedures if these discussions within the department do not lead to a satisfactory resolution. Refer to the General Announcements under *Grievances* and *Problem Resolution*.

Doctoral Thesis Committee

A final thesis committee is appointed upon application for PhD candidacy. The committee is composed of two faculty members or Faculty Fellows from the department, and an additional Rice faculty member from outside the Physics and Astronomy department. Typically the two departmental members are chosen from the student's Advisory Committee.

The committee administers the oral examination for the student's thesis defense and has final authority and responsibility for approval of the doctoral thesis.

Honor System

The student body at Rice, through its commitment to the Honor Code, accepts responsibility for assuring the validity of all examinations and assignments. The Honor Council (http://honor.rice.edu/) is responsible for investigation of all reported violations and for trial in those cases where the facts warrant.

Graduate students are expected to observe the provisions of the Rice University Honor Code, as presented in the information provided at orientation. Violations may result in serious penalties including a failing grade in the course and suspension from the university.

The faculty will state the restrictions applying to various forms of class work. If in doubt about the conditions for a particular assignment, it is your responsibility to ask the faculty member in charge of the course.

Plagiarism is a particularly thorny issue. Never explicitly or implicitly claim someone else's work as your own. The School of Engineering has prepared a nice document about this here: http://engineering.rice.edu/uploadedFiles/School_of_Engineering/Current_Students/Graduate_Students/Plagiarism--Recognize%20and%20Avoid%20It.pdf

The university library system has prepared an excellent webpage about this issue as well: http://libguides.rice.edu/content.php?pid=94943&sid=1024480

Changing advisers

Students are required to have a research adviser to remain in good standing. Therefore, to remain in good standing in the program any student changing advisers in "mid-stream" must secure a new adviser. Changing advisers can seriously disrupt a student's progress toward the doctorate. Adviser changes are, thankfully, infrequent, but may arise for a variety of reasons, either from the student side (change of research interests; perceived mismatch in student/adviser personalities or other irreconcilable differences) or the faculty side (inadequate research progress; perceived mismatch in student/adviser personalities or other irreconcilable differences).

If a graduate student wants to change advisers, the student should avail themselves of their Advisory Committee for feedback and advice, and should bring this issue to the attention of the Chair of the Graduate Program Committee as well as the graduate program coordinator.

If a graduate adviser wants to terminate financial support and a research advising relationship with a student that has formally affiliated, this requires a timely warning (through the annual Advisory Committee process or separately through an explicit notification cc-ing the Graduate Program Committee and the Office of Graduate and Postdoctoral Studies) and a written justification. The procedures are outlined here (http://ga.rice.edu/GR_dismissal/). A student may appeal such a dismissal through the petition and appeal process (http://ga.rice.edu/GR_disputes/).

Conflict Resolution

In general, it is best to try to resolve conflicts between and among students and faculty at the lowest level possible (e.g., through direct discussions between the student and the doctoral adviser). Within the department, we strive to provide many avenues for discussion and mediation, including the Advisory Committee, the Chair of the Graduate Program Committee, the department chair, and the departmental ombudsperson (currently Prof. David Alexander, dalex@rice.edu). The university's formal procedures for conflict resolution are here: http://ga.rice.edu/GR_disputes/ near the bottom of the page, and of course students are always free to discuss matters with the Office of Graduate and Postdoctoral Studies.

Prizes and Awards

Internal Awards and Fellowships

The department awards several prizes to outstanding graduate students. They are:

- The Tom Bonner Book Prize, given annually to a first year student for outstanding performance in course work.
- The Robert L. Chuoke Awards, presented to the second and third year graduate students who show the most promise as evidenced by performance in courses and progress in research.
- The Umland Award, given annually to a graduate student for meritorious service to Physics and Astronomy graduate students.
- The Marlar Scholar Award in recognition of outstanding achievement in Space Science by a US citizen.
- The Gordon Fellowship to the astronomy or space physics student who has best demonstrated academic and research achievement.
- The Dunlap Fellowship to an outstanding graduate student in any field.
- The Kevin Strecker Award for the most outstanding MS thesis.
- The H. A. Wilson Award for the most outstanding PhD thesis.

There are also several fellowship funds, administered through the department or the university, which provide full or partial support for graduate students.

Students are automatically considered for all internal awards and fellowships for which they are eligible.

External Awards and Fellowships

A number of government agencies, professional societies, and private foundations external to Rice provide prizes and fellowship support for outstanding graduate students. Interested students should investigate opportunities from the National Science Foundation, The Hertz Foundation, the Department of Defense, and relevant professional societies. Any information the department receives will be posted near the main office.

Prizes and awards that are not intended as stipends will go to the student in full. These are most commonly travel awards or "best presentation" prizes associated with a professional meeting.

The department encourages research supervisors to financially supplement certain external awards, often called fellowships, that provide significant support for an individual student in pursuit of graduate studies. To be eligible, the fellowship must be external to the university, independent of grants made to Rice or Rice faculty, and obtained principally through the efforts of the student. If these conditions are met, the department recommends that the stipend be increased according to the following formula:

$$S' = S + A \qquad \text{for } A < 0.2S$$

$$S' = 1.2S \qquad \text{for } 0.2S < \mathrm{A} < 1.2S$$

$$S' = A \qquad \text{for } \mathrm{A} > 1.2S$$

where A is the annual amount of the award, S is the normal annual stipend, and S' is the total amount paid to the student. Exceptions to this recommendation may be required to comply with fellowship rules or other funding limitations. The final determination of the stipend supplement is the responsibility of the research supervisor, who should be consulted in advance.

Appendix: Course Recommendations By Research Specialty

Astronomy and High-Energy Astrophysics
The following courses are suggested for students interested in this research area. The recommendations are in addition to the departmental requirements for the various degrees.

A wide variety of research topics are available within these two groups. Hence, the best courses for each student will vary on a case by case basis, taking into account the background of the student and the recommendations of the adviser. In many astronomy departments it is not unusual for students to take as many as 12 graduate courses in physics and astronomy.

Core courses required for all research in astrophysics are

ASTR 451 Sun and Stars and
ASTR 452 Galaxies and Cosmology.

Most research projects require

PHYS 541 Radiative Processes.

Students also must participate in the AU (ASTR 500), a weekly astronomy seminar given by faculty, students, and outside speakers in order to gain experience presenting talks.

In addition, students typically take several of the following

ASTR 470 Solar System Physics
ASTR 542 Nebular Astrophysics
ASTR 554 Astrophysics of the Sun
ASTR 555 Protostars and Planets
ASTR 565 Compact Objects
PHYS 480 Introduction to Plasma Physics
PHYS 521 Quantum Mechanics I
PHYS 561 General Relativity

Students who lack a strong foundation in thermodynamics and statistical physics should consider taking PHYS 425 (Statistical and Thermal Physics).

Other useful courses include PHYS 522 (Quantum Mechanics II), PHYS 532 (Classical Electrodynamics), PHYS 515 (Classical Dynamics) and PHYS 526 (Statistical Physics). A good course for observers and experimentalists is ASTR 450 (Experimental Space Science). Students who want to specialize in numerical simulations will probably want to take PHYS 516 (Mathematical Methods) and advanced computation courses in the Computational and Applied Mathematics Department.

Atomic, Molecular and Optical (AMO) Physics
The following courses are suggested for students interested in this research area. The recommendations are in addition to the departmental requirements for the various degrees.

AMO physics studies simple systems that reveal the behavior of matter and light at a fundamental level. While the phenomena can be complex, physical intuition stems from a strong grounding in the classical areas. Further study introduces students to the terminology, concepts, and techniques of the field.

The core courses required for research in AMO physics are

PHYS 521 Quantum Mechanics I
PHYS 526 Statistical Physics
PHYS 532 Classical Electrodynamics
PHYS 515 Classical Dynamics

Students also typically take

PHYS 522 Quantum Mechanics II
PHYS 571 Modern Atomic Physics
PHYS 572 Fundamentals of Quantum Optics

Other valuable courses are

PHYS 516 Mathematical Methods
PHYS 537/538 Methods of Experimental Physics I and II
PHYS 563 Introduction to Solid State Physics I
PHYS 664 Condensed Matter Theory: Many-Body Formalism
CHEM 630 Molecular Spectroscopy and Group Theory

During the first year, interested students are encouraged to discuss course selection with professors doing research in AMO physics.

Biophysics
The following courses are suggested for students interested in this research area. The recommendations are in addition to the departmental requirements for the various degrees.

Biophysicists study the physical principles underlying the complex processes of living systems at all levels. Experimental and theoretical approaches to biophysical research require a strong background in fundamental physics. Due to the highly multidisciplinary nature of biophysics, additional coursework is determined by the area of specialization. Current research in the department focuses on molecular biophysics.

The core courses required for Biophysics are

PHYS 521 Quantum Mechanics I
PHYS 526 Statistical Physics
PHYS 532 Classical Electrodynamics
PHYS 515 Classical Dynamics

Students also typically take

PHYS 522 Quantum Mechanics II
PHYS 563 Introduction to Solid State Physics I

Other valuable courses are

PHYS 537/538 Methods of Experimental Physics I and II
PHYS 533/534 Nanostructure and Nanotechnology I and II
PHYS 551 Biological Physics
PHYS 552 Topics in Biological Physics
PHYS 610 Biological and Molecular Simulation

During the first year, interested students are encouraged to discuss course selection with professors doing research in Biophysics.

Condensed Matter and Nanoscale Physics
The following courses are suggested for students interested in this research area. The recommendations are in addition to the departmental requirements for the various degrees.

Condensed matter physics concerns systems with many degrees of freedom (e.g. metals) where many-body phenomena play an important role (e.g. superconductivity and magnetism). Nanoscale physics examines the evolution of these properties as the system size approaches the atomic scale. Graduate level proficiency in the fundamental concepts is an essential prerequisite, while further coursework focuses on specific phenomena and techniques of the field. The department sponsors both theoretical and experimental research in these areas.

The core courses required for research in CM and nanoscale physics are

- PHYS 521 Quantum Mechanics I
- PHYS 526 Statistical Physics
- PHYS 532 Classical Electrodynamics
- PHYS 515 Classical Dynamics

Most students also take

- PHYS 563 Introduction to Solid State Physics I
- PHYS 564 Introduction to Solid State Physics II

Courses with an emphasis on theory include

- PHYS 663 Condensed Matter Theory: Applications
- PHYS 664 Condensed Matter Theory: Many-body Formalism

Other valuable courses are

- PHYS 533/534 Nanostructures and Nanotechnology I and II
- PHYS 539 Characterization and Fabrication at the Nanoscale
- PHYS 566 Surface Physics
- PHYS 567 Quantum Materials
- PHYS 516 Mathematical Methods
- PHYS 537/538 Methods of Experimental Physics I and II

During the first year, interested students are encouraged to discuss course selection with professors doing research in CM and nanoscale physics.

Nuclear and Particle Physics
The following courses are suggested for students interested in this research area. The recommendations are in addition to the departmental requirements for the various degrees.

The courses required for research in particle physics are:

PHYS 521 Quantum Mechanics I
PHYS 522 Quantum Mechanics II
PHYS 532 Classical Electrodynamics
PHYS 542 Introduction to Nuclear and Particle Physics
PHYS 543 Physics of Quarks and Leptons

and one of

PHYS 515 Classical Dynamics
PHYS 516 Mathematical Methods

Depending on their interests, most students are also advised to take some of the following courses:

PHYS 526 Statistical Physics
PHYS 561 General Relativity
PHYS 622 Quantum Field Theory
ASTR 452 Galaxies and Cosmology

Space Plasma Physics

The following courses are suggested for students interested in this research area. The recommendations are in addition to the departmental requirements for the various degrees.

Courses that are essential to space plasma physics:

- ASTR 470 Solar System Physics
- PHYS 480 Introduction to Plasma Physics
- PHYS 532 Classical Electrodynamics

Additional courses that some space physics faculty advise their students to take:

- ASTR 451 Sun and Stars
- PHYS 521 Quantum Mechanics I

Relevant Math Courses:

PHYS 516 (Mathematical Methods) deals mostly with the classic theoretical methods of physics and is recommended for people who wish to use a lot of analytic theory in their research or who need some brushing up in that type of work. People who wish to do computer simulations in their research should take PHYS 517 (Computational Physics) and may wish to take a course in numerical methods or programming from another department. Possibilities include CAAM 420 Computational Science I, and CAAM 520, Computational Science II.

Some advanced courses in space plasma physics are offered every two or three years. A graduate student specializing in space plasma physics will probably be advised to take some of these courses, depending on the situation.

- PHYS 510 Magnetospheric Physics
- PHYS 519 Plasma Kinetic Theory
- ASTR 554 Astrophysics of the Sun

Appendix: Graduate Courses by Topic

For purposes of meeting PhD course requirements, an 'outside the research area' course is one not in the student's general thesis area, and not in the General Physics group. The Chair of the Graduate Program Committee are available to assist with interpretation of this rule.

General Physics
Note that these courses may not be used to satisfy the "outside the area" requirement for the PhD.
PHYS 515 Classical Dynamics
PHYS 516 Mathematical Methods
PHYS 517 Computational Physics
PHYS 521 Quantum Mechanics I
PHYS 522 Quantum Mechanics II
PHYS 526 Statistical Physics
PHYS 532 Classical Electrodynamics
PHYS 537/538 Methods of Experimental Physics I and II

Astronomy/Astrophysics
ASTR 470 Solar System Physics
ASTR 505 Processes in Cosmic Plasmas
ASTR 542 Nebular Astrophysics
ASTR 451 Astrophysics I
ASTR 452 Astrophysics II
ASTR 554 Astrophysics of the Sun
ASTR 555 Protostars and Planets
ASTR 565 Compact Objects
PHYS 541 Radiative Processes
PHYS 561 General Relativity

Space Plasma Physics
ASTR 470 Solar System Physics
ASTR 505 Processes in Cosmic Plasmas
ASTR 451 Astrophysics I
ASTR 554 Astrophysics of the Sun
PHYS 480 Intro to Plasma Physics
PHYS 510 Magnetospheric Physics
PHYS 519 Plasma Kinetic Theory

Condensed Matter Physics
PHYS 533/534 Nanostructure/Nanotechnology I and II
PHYS 535 Crystallography and Diffraction
PHYS 539 Characterization and Fabrication
PHYS 563/564 Introduction to Solid State I and II
PHYS 566 Surface Physics
PHYS 567 Quantum Materials

PHYS 568 Quantum Phase Transitions
PHYS 605 Computational Electrodynamics
PHYS 663 Condensed Matter Theory: Applications
PHYS 664 Condensed Matter Theory: Many-Body Formalism

Biophysics
PHYS 551 Biological Physics
PHYS 552 Topics in Biological Physics
PHYS 610 Biological and Molecular Simulation
PHYS 643 Cell Mechanics, Mechanotransduction

Nuclear and Particle
PHYS 542 Intro to Nuclear & Particle Physics
PHYS 543 Physics of Quarks and Leptons
PHYS 622 Quantum Field Theory

Atomic, Molecular and Optical Physics
PHYS 569 Ultrafast Optical Phenomena
PHYS 571 Modern Atomic Physics
PHYS 572 Fundamentals of Quantum Optics

Special Topics
PHYS 600 Special Topics in Physics and Astronomy

Appendix: Candidacy exam topics by subdiscipline

Astronomy and Astrophysics:

Introduction: The following list of topical areas and subtopics covers the areas of astronomy and astrophysics which students are expected to have some mastery of. This is a very broad research area and examinees are not expected to be deeply knowledgeable in all topics. Typically they should be somewhat knowledgeable of topics well removed from their research area(s), and fairly knowledgeable about all topics of close relevance to their research area. The examining committee and student may, after consultation, refine and focus this list.

Basic Observational Astronomy: Celestial sphere, coordinates, photometric systems, magnitude equation, distance modulus, extinction, parallax, spectral types, telescopes, resolution, basic spectrometer properties, HR diagram

Radiation Processes: radiative transfer terms definition and usage, the fundamental equation of radiative transfer, definition of source function and optical depth, electromagnetic spectrum regions, blackbody radiation, Einstein A and B coefficients, Maxwell equations and electromagnetic waves, power emitted from accelerated charges (amount, angular pattern, and polarization), Four vectors, covariance, relativistic transformations involving E and B fields, free-free emission (bremstrahlung), bound-free (photo-electric effect) and free-bound processes and spectra, cyclotron and synchrotron radiation, Compton scattering (cross section and effect on spectrum), inverse compton scattering, pair creation and annihilation, plasma effects of rotation measure and dispersion measure, basic atomic structure of single-electron and multi-electron atoms spectroscopic notation, definitions of permitted and forbidden emission lines, line broadening (natural, thermal, and collisional), energy levels of diatomic molecules, symmetries, rotation-vibration spectra of molecules.

Stellar Atmopheres:

Energy Transport: Conductive, radiative and convective energy transport and conditions for each, basic thermodynamics

Stellar Continua: Sources of continuous opacity, Saha equation, shapes of stellar continua, changes with temperature, gravity, metallicity, limb darkening, line blanketing

Model Photospheres: Hydrostatic equilibrium, radiative equilibrium, plane parallel assumption, LTE, a schematic understanding the structure is calculated and what is needed to specify the structure

Spectral Lines: Boltzmann equation, Gaussian and Lorentz profiles, Voigt function, line broadening mechanisms and what they diagnose about a stellar atmosphere, equivalent width, Zeeman effect, contribution function, curve of growth, behavior of spectral lines with temperature, gravity, and metallicity, line blanketing

Advanced Topics: Determining fundamental stellar properties (temperature, radii, abundance, rotation), basics about NLTE (when it is important, first order effects), stellar winds and the formation of a P-Cygni profile

Stellar Structure:

Equations of Stellar Structure: Basic hydrodynamics, hydrostatic equilibrium, mass continuity, energy generation, radiative transport, convective transport, required constitutive relations

Homologous Models & Polytropes: Homologous relations, definition and examples of polytropes

Nuclear Energy Generation: P-P chain and its properties, triple-alpha reaction, CNO cycle and its properties, minimum mass for hydrogen fusion and brown dwarfs, He fusion and beyond, iron catastrophe

Pre-Main Sequence Stellar Evolution: Hertzsprung-Russell diagram, Jeans mass and Radius, Pre-main sequence evolutionary tracks, accretion disk diagnostics, feedback into the interstellar medium

Post-Main Sequence Stellar Evolution: Evolution of low mass stars including formation of planetary nebulae and white dwarfs, evolution of high mass stars to supernova and neutron star or black hole formation

Compact Objects:

Special Relativity: Relativistic kinematics, Lorentz transformations, Lorentz invariants and covariance

General Relativity: curvature, geodesics, classic experimental tests, black holes, Schwarzschild radius, redshift, gravitational waves

Post-Main Sequence Stars: quantum degeneracy pressure in white dwarfs and neutron stars, mass-radius relationship, Chandrasekhar and neutron star mass limits

Accreting Systems: Eddington luminosity and mass accretion limit, Bondi accretion, Shakura-Sunyaev alpha disks

Nebular Astrophysics and the Interstellar Medium

Physical Processes: Collisions, charge Exchange, photoexcitation, decay, fluorescence, photoionization, recombination, collisional ionization, energy levels, collisional excitation and deexcitation

Forbidden Lines: critical density and excitation, optical depth, examples

HII Regions: Stromgren sphere, inclusion of dust, overall spectrum, temperature, abundances, simple applications

Planetary Nebulae: Formation, excitation, spectrum

Dynamics: Kepler's Laws, virial theorem, fluid equations, instabilities, shocks and ionization fronts, gravitational collapse, simple applications

ISM: Phase of the ISM, dispersion and rotation measures

Supernova remnants: dynamics, Sedov phase, line spectroscopy, cosmic ray production

Normal and Active Galaxies:

Galaxy phenomenology: Discovery of galaxies, Shapley-Curtis debate, Hubble's classification scheme,

Spiral galaxies: structure of the Milky Way, the Galactic center region, velocity dispersions, rotation curves, dark matter inferences, Tully-Fisher relation, spiral structure, density wave theory

Elliptical Galaxies: triaxiality, subclasses of ellipticals, Faber-Jackson relation, King's model, gravitational relaxation, gas cooling

Active Galaxies: Seyfert galaxies, broad and narrow emission line regions, reverberation mapping, Lyman-alpha forest, radio galaxies, lobes and hot spots, VLBI, unification schemes

Extragalactic Jet systems and Microquasars: quasar and blazar phenomology, superluminal motion, Doppler boosting, shock acceleration

Structure of the Universe and Cosmology:

Cosmic structures: distance determination techniques, Hubble's Law, galaxy distributions, galaxy clusters, supernova surveys, large scale structure, gravitational lensing

Newtonian cosmology: Olber's paradox, the cosmological principle, cosmochronology – dating the universe, Friedmann's equation and solutions, critical density, matter-dominated universes

Relativistic cosmology: Robertson-Walker metric, radiation and cosmological constant in Friedmann's equation, global solution for our universe, particle horizons

Observational cosmology: deceleration parameter, angular diameter and luminosity distances, cosmological determinations using supernovae

Early universe: cosmic microwave background anticipation and discovery, COBE and WMAP results and implications, acoustic oscillations and gravitational seed perturbations, recombination, redshift of last scattering, primordial nucleosynthesis, inflation, GUT era.

Atomic/Molecular/Optical Physics:

Introduction: The following list of topical areas and subtopics covers the broad field of Atomic, Molecular, and Optical Physics. This is a very broad research area and examinees are not expected to be deeply conversant with all topics. Typically they should be barely conversant with topics well removed from their research area(s), and fairly knowledgeable about all subtopics of close relevance to this area. The adviser and examinee may, after consultation, alter this list.

Atomic Units and Fundamental Constants: Atomic units in terms of Ñ, e, c, m, numerical values for length and energy. The fine structure constant, energy and length hierarchies (a_0,aa_0,,...). What are the fundamental constants and how are they determined?

Light: Basic E&M of light, polarization, standing and traveling waves, density of states, blackbody radiation, 2nd quantization, coherent states and squeezed states, Fock states.

Atoms: Spectroscopic notation (term and configuration); Bohr atom, one electron atom (alkali cf. H, relativistic effects, Lande g factor, Rydberg atoms); hyperfine structure, multi-electron atoms (Hund's rules).

Atoms in Static Fields

Magnetic: Basic interaction, (anomalous) Zeeman effect, Paschen-Bach decoupling, magnetic trapping.

Electric Fields: Polarizability, linear regime, field ionization.

Resonance and Spectroscopy: Interaction Hamiltonian, magnetic resonance, two-state spectroscopy (Rabi solution, density matrix, Bloch equations, transition rate, Ramsey spectroscopy), dressed atom, types of transitions, selection rules, and approximate spontaneous decay rates. 3-level systems: (Autler-Townes effect, dark states).

Laser Cooling and Trapping of Atoms: Radiation pressures (scattering and dipole forces), Doppler cooling, sub-Doppler cooling, magneto-optic trap, optical dipole trap, optical lattice

Multi-Photon Processes: Two-photon excitation, Raman processes, perturbation theory for higher order processes.

Coherence: Single atom (.e.g. Ramsey Spectroscopy,quantum beats), localized ensembles (superradiance), extended ensembles (See atom optics: phase matching, 4-wave mixing), quantum computing, entanglement.

Line Shapes: Broadening mechanisms (homogeneous vs. inhomogeneous), lorentzians and gaussians, Doppler shift and recoil, Voigt profile.

Molecules: Long-range potentials between atoms (van der Waals R^{-6}, resonance R^{-3}), short range (vibrational and rotational spectra, molecular orbitals), photoassociative spectroscopy, cold molecules.

Atomic Collisions: Classical (cross section, mean free path, center of mass transformation), quantum (partial wave, scattering lengths, differential and total cross section, Bom approximation), inelastic scattering, effects of identical particle symmetry and ultracold temperatures, evaporative cooling, Feshbach resonances

(See next page)

Bose-Einstein Condensation: Ideal gas, mean-field theory for a weakly interacting gas (Gross-Pitaevski equation, Thomas-Fermi approximation, elementary excitations, spinor condensates, superfluidity), second quantization.

Quantum Degenerate Fermions: Equilibrium properties, BCS state and Cooper pairing

Linear atom optics: gratings, waveguides, mirrors, atomic deflection and diffraction

Cavity Quantum Electrodynamics: Jaynes-Cummings model, 2nd quantization of light, dressed atoms

Nonlinear and quantum atom optics: wave mixing, solitons, phase coherent amplification, entanglement, spin squeezing

Miscellaneous: Landau-Zener crossing

Biophysics**:**

*This list covers many topics in biological physics and the student is not expected to master them all. The student will agree on relevent topics to be covered in the exam with his/her committee***.**

Biomolecular Structure: The chemical structures of peptides, nucleic acids, lipids, and saccharides, as well as their basic structural motifs such as bilayers and secondary structures of proteins.

Biomolecular Interactions: Guoy-Chapman theory, van der Waals interactions, the hydrophobic effect, and hydrogen bonds. Chemical equilibrium and cooperative effects.

Hydrodynamics: Reynolds number and the differences between lamellar and turbulent flow. Viscosity and pressure propagation, and the effects of low Reynolds number.

Interfacial Phenomena: Surface tension, osmotic pressure, line tension, the Gibbs and Langmuir isotherms, and humidity.

Elasticity: Normal and Gaussian curvature, spontaneous curvature, persistence length, polymer elasticity models.

Diffusion: diffusion equation, random walks.

Fundamental Techniques: Light scattering, X-ray and neutron diffraction, traditional and multiphoton microscopy, sedimentation, absorption spectroscopies, fluorometry, and vibrational spectroscopies.

Specialized Techniques (for experimental students): Near field optics, scanned probe microscopy, small angle X-ray scattering

Statistical Mechanics (for theory students): Monte Carlo and molecular dynamics methods, random energy models, spin glass systems, GNK model, basic features of the immune system

***Condensed Matter Physics*:**

Introduction: The following list of topical areas and subtopics covers the broad field of experimental condensed matter physics. This is a very broad research area and examinees are not expected to be deeply conversant with all topics. Typically they should be barely conversant with topics well removed from their research area(s), and fairly knowledgeable about all subtopics of close relevance to this area. The adviser and examinee may, after consultation, alter this list.

Fundamentals

Length, energy, and time scales: Interatomic spacings in solids, elastic and inelastic mean free paths for electrons, phonon energy scales, typical band widths and band gaps, vibrational time scales, electronic time scales, plasma frequency

Electricity and magnetism: Basic E&M of light, polarization, standing and traveling waves, density of states, blackbody radiation, 2nd quantization, gauge invariance

Basic quantum mechanics: Bohr atom, one electron atom (Lande g factor); hyperfine structure, Bohr-Van Leeuwen theorem, multi-electron atoms (Hund's rules), harmonic oscillator, Aharonov-Bohm phase, particle-in-a-box, perturbation theory, time-dependent perturbation theory, Fermi's golden rule, Landau levels, Zeeman effect, Born-Oppenheimer approximation, WKB approximation, sudden vs. adiabatic approximations

Statistical mechanics: Boltzmann factor, partition functions, Maxwell distribution, Fermi gas, Bose gas, density of states, degeneracy, kinetic concepts, chemical potential, diffusion, Debye model, heat capacity, first and second order phase transitions, Landau-Ginzberg theory of phase transitions

Solid state physics:

Tight binding, nearly-free electron picture, band structure, reciprocal space, diffraction, Bloch states, crystal momentum, acoustic vs. optical phonons, semiconductors, quasiparticles, holes, Fermi surface techniques, Fermi velocity, effective mass, valley degeneracy, p-n junctions, depletion widths, screening, plasma frequency

Magnetism: Exchange energy, Pauli paramagnetism, Landau diamagnetism, types of magnetic order, crystal field anisotropy, local vs. itinerant magnetism, Stoner criterion

Thermodynamic and transport properties: heat capacity, resistivity (different contributions in metals, semiconductors etc).

Dielectric and optical properties: Kramers-Kronig relations, piezoelectricity, Claussius-Mossotti relation, selection rules, lasers

Superconductivity: Meissner effect, Cooper pairs, penetration depth, coherence length, Type I vs. Type II, Josephson effect, flux quantization, superconducting quantum interference devices

Nanoscale physics: Coulomb blockade, conductance quantization, 2d electron systems, Landau quantization, integer quantum Hall effect, fractional quantum Hall effect, weak localization, universal conductance fluctuations, Aharonov-Bohm effect, tunneling density of states, van der Waals/Casimir forces, radiation pressure

Miscellaneous: Landau-Zener crossing, crystal structures (space groups, point group symmetry), liquid crystals

Experimental emphasis

Characterization techniques (how they work & what they tell us): x-ray diffraction, electron diffraction, neutron diffraction, photoemission, ARPES, Mossbauer, heat capacity, thermal conductivity, resistivity, Hall coefficient, magnetic susceptibility

Electronic methods: two-terminal vs. four-terminal measurements, lock-in techniques, van der Pauw technique, Hall resistance, Wiedemann-Franz Law, shot noise, Johnson-Nyquist noise, 1/f noise

Magnetic methods: NMR, EPR, FMR, magnetization, magnetoresistance

Nanoscale methods: STM, AFM, MFM, EFM, Kelvin probe

Low-temperature methods: accessible temperatures for 4He, 3He, and dilution refrigerators; principles of operation; superconducting magnets

Data analysis: error analysis, confidence intervals, chi^2, lineshapes – Gaussians, lorentzians

Theoretical emphasis

Basic Theory Models: Ising Model, Heisenberg model, Hubbard model, t-J model, Kondo/Anderson (single-impurity/lattice) models, luttinger liquid, Sine-Gordon model, non-linear sigma model, valence-bond models, spin-ice models

Many-body formalism: Landau theory of Fermi liquids, Second quantization, Static-mean-field approaches, Green functions and Feynman diagrams (zero temperature, Matsubara, Keldysh), hydrodynamic approach (memory functional), Diagram resumations, functional integrals, large-N/S expansions (slave particles, Schwinger bosons, Holstein-Primakov bosons, etc.), Hubbard-Stratonovich decoupling, 1-d methods (bosonization, conformal symmetry, integrability), renormalization group theory (bosons, fermions), quantum phase transitions (Hertz theory), (high/low-T) series expansions, solitons and instantons

Computational methods: exact diagonalization, Lanczos, (quantum) Monte Carlo, numerical/density-matrix renormalization group, dynamical mean field theory (LISA, DCA, etc.), ab-initio and density functional methods (Thomas Fermi, LDA, LSD, pseudopotentials), molecular dynamics

Disordered Systems: weak/strong(Anderson) localization, replica theory, supersymmetric methods, time-loop methods, random matrix theory.

Nuclear and Particle Physics:

Special relativity and important ideas from nonrelativistic quantum mechanics:

Relativistic kinematics, Lorentz transformations, Lorentz invariants

Fermi's golden rule, perturbation theory, addition of angular momenta

Passage of radiation through matter and detectors:

Rutherford scattering, Compton scattering, energy loss due to Ionization, multiple scattering, electromagnetic and hadronic showers

Basic principles of operation of the various detectors used in nuclear and particle physics and what determines their resolution.

Dosimetry

Nuclear physics:

Fermi gas model, liquid drop model, binding energy per nucleon, shell model, basics of nuclear spectroscopy, nuclear form factors

Classification of the hadrons and conservation laws

Construction of meson and baryon wave functions, spectroscopy and spectroscopic notation.

Baryon number, lepton number, lepton flavor, hypercharge, isospin, C, P, CP, and CPT.

Symmetries and groups, role of gauge symmetries in field theories of interactions:

U(1) and electromagnetism

SU(2), spin, isospin, Electroweak interaction

SU(3) and color - QCD

Photon and massive vector boson propagators

Connection between bosons and the generators of symmetry groups

Relativistic Quantum Mechanics:

Dirac equation, spinors, antiparticles, bilinear covariants

Feynman diagrams, Feynman rules

Photon polarization

Be able to discuss qualitatively loops, running coupling constants, renormalization

Phenomena:

Hadronic structure, parton distribution functions. Bjorken scaling

Experimental evidence for QCD, R ratio in e+e-

Weak interactions, V-A, the weak interaction current

CKM matrix, K and B meson mixing, CP violation

Neutrino masses and mixing

Specific to Particle Physics students:

Phenomena at collider experiments

Theories beyond the standard model (should know what some of them are and give examples of what to look for in experiments)

*Space Physics***:**

Introduction: The following list of topical areas and subtopics covers Space Plasma Physics, which includes Solar Physics and Magnetospheric Physics. The more specialized topics under Solar and Magnetospheric Physics pertain to students in those respective areas.

Electricity and Magnetism

Maxwell's Equations: Basic properties, electrostatics, magnetostatics, boundary value problems, waves

Basic Numerical Methods

Roundoff and truncation errors, curve fitting and interpolation, numerical integration, basic linear algebra, solutions to ordinary and partial differential equations

Basic Plasma Physics

• Plasma characteristics:

o Plasma Frequency, Debye Length, coulomb collision frequencies, Spitzer resistivity

• Particle motion in electric and magnetic fields.

o Drifts, adiabatic invariants Waves in plasmas

o Cold unmagnetized and magnetized plasma waves

• Magnetohydrodynamic description of plasma

o MHD Approximation, frozen-in-Flux, MHD equilibria, waves, instabilities, shocks, force and motion in MHD

• Magnetic reconnection

o Basic features, MHD models

• Kinetic Description of plasma

o Vlasov theory, Landau damping, basic kinetic instabilities, the Fokker-Planck equation and binary coulomb collisions

Solar Physics

• Basic Information about the Sun

o Radiative interior/convective envelope, radius/mass/luminosity,structure of atmosphere

• Radiative Transfer

o Specific Intensity, limb darkening, transfer equation

• Hydrostatic atmospheres

o Hydrostatic equilibrium, coronal heating scaling laws

• Magnetic Field

o Potential vs. force-free, open vs. closed, MHD/magnetostatic descriptions

• Particle Acceleration and Transport

o DC vs. stochastic acceleration, energy loss mechanisms

• Radiation Processes
o Thermal vs. non-thermal, bremsstrahlung, synchrotron
• Observational Issues
o Spectroscopy vs. Imaging, remote sensing vs. in-situ
• Eruptive Phenomena
o Flares vs. CMEs, role of reconnection
• Solar Wind
o Fast vs. slow, Parker spiral, Parker's model

Magnetospheric Physics

• Basic information about the Magnetosphere
o Magnetopause, bow shock, plasma sheet, ring current, radiation belts, plasmasphere and associated current systems
• Basic information about the Ionosphere
o Structure, Chapman Theory, conductances
• Solar wind magnetosphere interaction
o Energy transfer processes, role of the solar wind and the ionosphere
• The aurora
o Types of aurora, acceleration processes
• Magnetospheric Storms and Substorms
o Definition, basic properties, relation magnetic Indices
• Magnetospheric Convection
o Basic properties, theoretical foundations
• Magnetosphere Ionosphere coupling
o Basic properties, theoretical foundations
• Basic information about the magnetospheres of the other planets
o Rotation dominated planets, Ionosphere dominated planets