Department of Physics and Astronomy Guide for Graduate Students

July, 2024

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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.

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 financial support (a stipend and waiver of tuition), guaranteed financial support is for the first two semesters, and acquire continuing financial support via faculty research grants and limited teaching 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.

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 on the departmental webpage.

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), the Associate Chair for the Graduate Program, the Associate Chair for Administration, or the Departmental Ombudsperson. For current students, faculty are specifically assigned as Graduate Student Advisers to answer academic questions. 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.

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 or contact the IT help desk helpdesk@rice.edu.

Students outside of P&A are governed by their home department even when working with P&A faculty.

Academic 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 *Graduate Students* section of the General Announcements

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.

Academic Staff

Title and responsibilities	Name	Phone extension (713-348-xxxx)	Email (@rice.edu)
Chair of the Graduate Program Committee	Prof. Kaden Hazzard	2861	kaden
Graduate program administrator (**your primary contact)**	Rosa Almendarez	6348	almendar
Associate Chair for Administration	Prof. Stan Dodds	2510	dodds
Departmental Ombudsperson	Prof. David Alexander	3633	dalex
Graduate Student Advisor	Prof. Stan Dodds	2510	dodds
Graduate Student Advisor	Prof. Frank Toffoletto	2513	toffo5

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. Generally, required coursework is completed in the second year, simultaneous with research in the group of their research adviser. During the fifth semester, students complete a research progress and proposal report and take an oral PhD candidacy exam. Each year, except the first, there is an 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, the effort expended, talent, and sometimes 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 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 800. Continued teaching practicum as needed.	Complete department lecture-course requirements.
3	Annual advisory committee meeting. Continue research and teaching as needed. Research Progress and Proposal report and presentation; pass PhD candidacy oral; file for PhD candidacy	Continue research (and teaching as needed).
4	Continue research	Research (university deadline for doctoral candidacy)
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 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.

MS Degree Requirements

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.

1. The student 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.

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 Degree Requirements

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 student must satisfy the requirement for four semesters of teaching assistance.

3. The student must achieve PhD candidacy no later than the university deadline.

4. The final 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.

5. 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.

Detail of course work, teaching, and candidacy are given below.

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.

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 the appendix *Selected graduate courses*. 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 451 Sun and Stars
ASTR 452 Galaxies and Cosmology

ASTR 570 Solar System Physics
PHYS 515 Classical Mechanics
PHYS 521 Quantum Mechanics I
PHYS 526 Statistical Physics
PHYS 532 Classical Electrodynamics
PHYS 580 Introduction to Plasma Physics
PHYS 622 Quantum Field Theory

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

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

In addition to meeting the departmental *requirements* above, students should review the appended list of course *recommendations* by research area with their thesis adviser to ensure that their course work provides optimal preparation for thesis research.

Requests for modification of the course requirements must be addressed to the Chair of 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.

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 department accounts for the labor effort in units of nominal 5-hour/week semester blocks. Assignments typically begin in the second semester at Rice, with one such unit that semester. A student is expected to complete a total of four of such units (one in the first year, three in subsequent years).

Units 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.

Questions about teaching assignments should be directed to the associate chair of the department.

PhD Candidacy

Achieving candidacy for the PhD implies that a graduate student has completed all required coursework, passed required exams to demonstrate their 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 their subject area. The requirements for candidacy are:

1. The student must complete with acceptable grades all required courses, 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.

2. The student must complete four nominal 5-hour teaching practicum assignments.

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 purposes: (1) To demonstrate that the student is conducting research at an appropriate level; (2) to give students practice writing about and presenting their work; and (3) to provide essential context and background so that the outside-area members and peers can understand the research plan. The written report should be carefully structured to 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.

While this does not have to be polished like a publication, it is strongly encouraged that the adviser 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.

For the oral part of the RPP, the student should prepare a presentation that touches on the three main elements above. The length of the presentation excluding questions should be less than 30 minutes. Including questions, the presentation cannot exceed 60 minutes. The research presentation can be public at the discretion of the adviser.

Oral Candidacy Exam

The oral candidacy exam will be closed-door, with only the student and the committee members present. The student will demonstrate competence in the chosen research area by being able to correctly answer questions on topics relevant to the field of study. Typical lists of important topics by specialty are in the *Candidacy exam topics by subdiscipline* appendix, although greater specificity may be defined by discussion between the examining committee and the student in advance of the examination.

The questions should cover a significant fraction of the topics on that list. The exam may also end up covering basic core physics and/or astronomy competency. The exam should be no more than 120 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.

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 when the student can demonstrate high achievement in the course and mastery of the material. The suitability of previous work will be evaluated by means of an interview, or multiple interviews, if necessary, with an appropriate faculty member (e.g., the Rice professor who teaches the Rice equivalent graduate course). Final approval must be given by the Chair of the Graduate Program Committee.

Internships

Occasionally industrial internship opportunities arise for doctoral students. Pursuit of an internship while remaining a doctoral student must be approved in advance of the relevant semester by the thesis adviser and the Chair of the Graduate Program Committee.

For domestic students, the main concern is that the internship should not delay timely progress toward the graduate degree. For foreign students, there can be considerable complications regarding visa status – this requires detailed discussions between the student, the Office of International Students and Scholars (OISS), and the adviser, and there are strong requirements that the topic of the internship be integral to the student's doctoral research. In case of external fellowship support, it is the student's responsibility to ensure that an internship does not conflict with the conditions of such a fellowship.

Students participating in internships do not receive a graduate stipend during the period of the internship. Financial arrangements must be finalized with the adviser and the graduate coordinator prior to the internship, in time for necessary procedures to be completed. Students must provide documentation of the internship to the graduate coordinator for record-keeping.

At least one month before the desired start of an internship, students should begin discussion with their advisor, the chair for the graduate program, and (for international students) OISS. Formal request for an internship must be made at least two weeks before the internship is intended to start. Formal request is made by submitting the following materials to the Graduate program coordinator, subject to the approval by the Chair of the Graduate Program Committee:

1. A copy of the employment offer letter, printed on company letterhead with the following information:
   a. The employer/company name
   b. A specific start date (mm/dd/yyyy). The start date must be a future date from that date it will be approved.
   c. A specific end date (mm/dd/yyyy).
   d. A job title
   e. A brief job description
   f. A physical work site address where you will conduct your job
   g. Number of hours to be worked per week
   h. Whether you will be paid or not
   i. Letter must be signed by employer
2. A letter of support from the student's advisor stating
   a. support for the internship and any pertinent descriptive information
   b. whether the student will be enrolled at Rice in PHYS 800 or not be enrolled during the internship
   c. what modifications should be made to the payment of the student's stipend
   d. for international students, if the internship will be count as Curricular Practical Training, the letter must explain how the internship is integral to the student's thesis research

For international students, a summary of and copy of relevant communications with OISS, and a completed Curricular Practical Training (CPT) Application Form if required. The CPT application form must be approved by the Chair of the Graduate Program Committee before being passed to the OISS. Please note that the OISS has its own procedure for applying for CPT, which must be followed. The OISS has its own procedure for applying for CPT, which must be followed.

Vacations

Vacation time is governed by Wiess School of Natural Sciences policy.

• Graduate students must coordinate their vacation plans with their advisers sufficiently far in advance to avoid last-minute conflicts. Graduate students who are teaching must also coordinate their plans with their teaching supervisor or graduate chair. Students may sometimes be required to work on University Staff holidays in order to staff ongoing projects and operations; students who work on a University Staff holiday will be able to use this paid day off at another time.

- Full time graduate students are entitled to 10 weekdays of paid annual leave based on a 12- month appointment, for any reason, in addition to days listed on the staff holiday calendar**.** Unused days may not be carried forward year to year and do not accrue payable time upon departure.

- Time away for professional activities (conferences, workshops, interviews, for instance) shall not count against paid annual leave.

- Short absences (those anticipated to be less than one week) due to a student's illness or that of a family member should be granted upon notice to a student's supervisor, provided they are commensurate with the episode. These should not be deducted from paid annual leave.

- If a graduate student cannot fulfill the duties of his or her appointment due to a medical emergency or the adoption or birth of a child, the student may be temporarily released from their academic responsibilities. Enrollment and stipend support may be continued for up to six weeks or until the appointment expires (whichever occurs first). A full description of the University short-term medical and parental release policy may be found on the Leaves page of the Graduate Programs site.

- Graduate students who would like to report a deviation from this policy should talk to their department ombudsperson, their department chair or the Natural Sciences Ombudsperson.

Academic Discipline

Satisfactory performance

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 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.

Probation and dismissal

Rice University's official policy on academic probation, dismissal, and termination of financial support is found in the Academic Policies and Procedures section of the General Announcements.

Leaves and Withdrawals

Rice University's policy on leaves and withdrawals is also found in the Academic Policies and Procedures section of the General Announcements.

Petitions and Appeals
Graduate students may petition for exceptions to academic requirements, regulations, and judgments in accordance with university policies found on the Dispute Resolution page of the General Announcements.

Petitions regarding Physics and Astronomy Department requirements, regulations, or judgments should be addressed to the Associate Chair for the Graduate Program.

General Information

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 (713-348-xxxx)	Email (@rice.edu)
Executive administrator (oversight; research accounting and administration)	Rose Berridge	2152	berridge
Graduate program administrator (management of graduate program; degree progress, graduation, recruiting, etc.)	Rosa Almendarez	6348	almendar
Travel and event administrator (scheduling visitors, arranging functions, travel reimbursement)	Barbara Braun	4146	bbraun
Tech II, Technical support (lab demos, seminar room A/V)	Jack Johnson	2513	jj2
Research Administrator (research awards and administration, payroll reviews, labor distributions)	Mirela Willhelm	2701	mmw13
Accounting Assistant III (purchasing, shipping labels, packing slip receipts, equipment fabrications)	Elaine Chen	3639	bc53
Bonner Lab administrator (Program Administrator III, HBH occupancy)	Elena Webster	5313/2579	ew22
HCM (Assistant to chair, Human Resources, appointments, payroll reviews)	Aaron Barelas	4939	avb1
Administrative Assistant (Reception, package receiving, BRK occupancy, key distribution, conference room reservations, workroom oversight, office supplies)	Deidre Richard	4938/4138	dr70

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 physics.rice.edu.

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. In particular, student financial support beyond the end of the Spring semester (typically around May 15) depends on successful affiliation with a research adviser. 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 faculty member 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 department faculty members. 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 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. Investigation of all reported violations and for ajudication in those cases where the facts warrant is the responsibility of the Graduate Academic Integrity System.

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 document about this, available here.

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 research directions must secure a new adviser. Please keep in mind that changing advisers can significantly disrupt a student's progress toward the doctorate. Adviser changes 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; lack of funding; perceived mismatch in student/adviser personalities or other irreconcilable differences). Regardless of the reasons, students and/or advisers should contact the Chair of the Graduate Program Committee if they are considering ending an adviser-advisee arrangement. Both parties should notify the Chair when a final decision has been made to change advisors.

Adviser's Responsibilities: If an adviser determines that a student's research performance is not adequate for timely progress toward a Ph.D., the adviser must explain in writing (through the annual Advisory Committee process or separately through an explicit notification to the Graduate Program Committee and the Office of Graduate and Postdoctoral Studies) the reasons and establish expectations and a timeline so that the student can fully address the issues. A minimum timeline of 2 months (half a semester) is recommended. If the student fails to meet the expectations set by the deadline, the adviser can ask the student to leave the group after documenting in writing how the student has continued to fail (copying the Graduate Program Committee and the Office of Graduate and Postdoctoral Studies). The procedures are outlined in the Dismissal paragraph of the graduate regulations in the General Announcements. A student may appeal such a dismissal through the petition and appeal process in Dispute Resolution.

Student's Responsibilities: A student who is considering changing advisers should discuss this with the Chair of the Graduate Program Committee, and the graduate program coordinator. The student's Advisory Committee may also be a valuable resource for feedback and advice. To avoid potential conflicts that may result in a change of research groups, students are encouraged to communicate often with their advisers and, in case of any issues, ask for written feedback and a suggested path forward including deadlines. If the student voluntarily decides to switch to a different research group, they must give current adviser a timely (we recommend a 2-month) written notice. To remain in the program, students must have a thesis adviser and must be making satisfactory progress towards their degree. Therefore, students should have guaranteed support from another adviser before they change groups.

Graduate Program Committee's Responsibilities: The Chair of the Graduate Program Committee will assign a new Advisory Committee to the student after he/she changes advisers. If the student changes advisers prior to achieving candidacy, the committee, in consultation with the new advisor, will determine a reasonable timeline for the Research Progress and Proposal report and the oral candidacy exam to be completed.

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 named in the Academic Staff table. The university's formal procedures for conflict resolution are in Dispute Resolution, 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 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 or Research Report/Proposal.
- 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:

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

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

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

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.

Useful pointers (resources)

Room reservations 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/ . For rooms in Brockman Hall you may email the Administrative Assistant listed under Department Staff. For Herman Brown Hall, email the Bonner Lab Administrator.

Program in Writing and Communication Help with writing papers and theses, presentation skills through individual consultations and workshops: https://pwc.rice.edu/.

Center for Teaching Excellence (CTE) Offers Certificate in Teaching and Learning, TEACH workshops, TA training, teaching consultations, reading groups, and various teaching, learning, and technology workshops: https://cte.rice.edu/.

Children - campus resources for students with children: Resource compilation for parents https://graduate.rice.edu/resources/families

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/

Forms - common graduate student forms: The Graduate and Postdoctoral Studies Office maintains a library of commonly used forms here (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 page.

Graduate Student Association: There is a global graduate student association for all of Rice. They are a terrific resource with lots of information about getting settled at Rice : https://gsa.rice.edu/

Graduate Student Association for Physics and Astronomy (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 listed in the PAGSA website: http://pagsa.rice.edu/

Graduate and Postdoctoral Studies: See https://graduate.rice.edu/ or graduate@rice.edu. It is a great resource for all things related to general graduate study at Rice not particular to the P&A department.

Medical Services: Some medical assistance is available through Student Health Services. For emergencies, call 713-348-6000 on campus, or 911 off-campus.

Wellbeing: The Wellbeing and Counseling Center supports student development and success by providing a good first point of contact for students who want to talk to someone about solutions to their wellbeing and mental health concerns.

International student issues: When in doubt, please consult with the Office of International Students and Scholars https://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 https://oiss.rice.edu/forms

Laboratory safety: Laboratory safety is a very serious issue and should not be treated lightly. General information about laboratory safety may be found at https://safety.rice.edu/ . 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.

Maintenance issues on campus: 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.

LGBTQ+: Resources for students and allies of the LGBTQ+ community can be found on the Rice Pride webpage.

Harassment, Title IX issues: Rice encourages any student who has experienced an incident of sexual, relationship, or other interpersonal violence, harassment or gender discrimination to seek support. There are many options available both on and off campus for all graduate students, regardless of whether the perpetrator was a fellow student, a staff or faculty member, or someone not affiliated with the university.

If you are in need of assistance or simply would like to talk to someone, please contact Rice Wellbeing and Counseling Center, x3311 / (713) 348-3311. Policies, including Sexual Misconduct Policy and Student Code of Conduct, and more information regarding Title IX can be found at the Safe Office webpage.

Students should be aware when seeking support on campus that most employees are required by Title IX to disclose all incidents of non-consensual interpersonal behaviors to Title IX professionals on campus who can act to support that student and meet their needs. The therapists at the Rice Counseling Center and the doctors at Student Health Services are confidential, meaning that Rice will not be informed about the incident if a student discloses to one of these Rice staff members. Rice prioritizes student privacy and safety, and only shares disclosed information on a need-to-know basis.

How to be a good graduate student:

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.

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.

Appendix: Selected graduate courses

Courses listed here may be used in fulfillment of the course requirement for the MS and PhD degrees. A student may petition the Graduate Program Committee to use courses outside of this list to satisfy the requirement.

ASTR 451	Astrophysics I: sun and stars
ASTR 452	Astrophysics II: galaxies and cosmology
ASTR 508	Statistical methods in physics and astronomy
ASTR 542	Nebular astrophysics
ASTR 554	Astrophysics of the sun
ASTR 555	Protostars and planets
ASTR 565	Compact objects
ASTR 570	Solar system physics
ASTR 600	Advanced topics in astrophysics

PHYS 510	Magnetospheric physics
PHYS 512	Quantum materials engineering
PHYS 513	Introduction to general relativity
PHYS 515	Classical dynamics
PHYS 516	Mathematical methods
PHYS 517	Computational physics
PHYS 519	Plasma kinetic theory
PHYS 521	Quantum mechanics I
PHYS 522	Quantum mechanics II
PHYS 526	Statistical physics
PHYS 532	Classical electrodynamics
PHYS 533	Nanostructure and nanotechnology I
PHYS 534	Nanostructure and nanotechnology II
PHYS 535	Crystallography and diffraction
PHYS 541	Radiative processes
PHYS 542	Introduction to nuclear and particle physics
PHYS 543	Physics of quarks and leptons
PHYS 549	Projects in data-enabled physics through data science and machine learning
PHYS 551	Biological physics
PHYS 552	Topics in biological physics
PHYS 561	General relativity
PHYS 563	Introduction to solid-state physics I
PHYS 564	Introduction to solid-state physics II
PHYS 567	Quantum materials
PHYS 568	Quantum phase transitions
PHYS 569	Ultrafast optical phenomena
PHYS 571	Modern atomic physics
PHYS 572	Fundamentals of quantum optics
PHYS 580	Introduction to plasma physics

PHYS 600	Advanced topics in physics
PHYS 605	Computational electrodynamics and nanophotonics
PHYS 622	Quantum field theory
PHYS 663	Condensed matter theory: applications
PHYS 664	Condensed matter theory: many-body formalism
PHYS 665	Topology in quantum physics

Appendix: Course Recommendations by Research Specialty

Astrophysics of star and planet formation

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 variety of research topics are available within the general area of star and planet formation, some more computational and theoretical, while others are driven by data science or new observations. The best courses for each student will vary depending upon the background of the student and the recommendations of the adviser. As many as 12 graduate courses in physics and astronomy often serve the student well by exposing them to a broad range of applications within astronomy and its related fields.

Recommended core courses are:

- ASTR 451 Astrophysics I: Sun and Stars
- ASTR 452 Astrophysics II: Galaxies and Cosmology

Most research projects require:

- ASTR 508 Statistical Analysis in Physics and Astronomy
- ASTR 555 Protostars and Planets

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

In addition, students typically take several of the following:

- ASTR 542 Nebular Astrophysics
- ASTR 554 Astrophysics of the Sun
- ASTR 570 Solar System Physics
- PHYS 541 Radiative Processes

Other useful courses include:

- ASTR 565 Compact Objects
- PHYS 521/PHYS 522 (Quantum Mechanics I and II)
- PHYS 561 General Relativity
- PHYS 580 Introduction to Plasma Physics

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

Students who want to specialize in numerical simulations will probably want to take PHYS 516 (Mathematical Methods) and advanced computation courses in the Computational Mathematics and Operations Research 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 following core courses are recommended for most students interested in research in AMO physics:

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

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 517 Computational Physics
- PHYS 563 Introduction to Solid State Physics I
- PHYS 567 Quantum Materials
- PHYS 568 Quantum Phase Transitions
- PHYS 622 Quantum Field Theory
- PHYS 664 Condensed Matter Theory: Many-Body Formalism

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

Biological 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.

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

The core courses recommended for Biological Physics are:

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

Students also typically take

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

Other valuable courses are

- PHYS 533/534 Nanostructure and Nanotechnology I and II
- PHYS 551 Biological Physics
- PHYS 552 Topics in Biological Physics

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

Condensed matter 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. electron charge and spin in metals and insulators) where many- body phenomena play an important role, resulting in new phases of matter such as 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 following core courses are recommended for most students interested in research in CM and Nanoscale physics:

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

Most students also take:

- PHYS 522 Quantum Mechanics II
- PHYS 563 Introduction to Solid State Physics I
- PHYS 564 Introduction to Solid State Physics II

Courses with an emphasis on theory include:

- PHYS 664 Condensed Matter Theory: Many-body Formalism
- PHYS 665 Contemporary Topics in Theoretical Condensed Matter Physics

Other valuable courses are:

- PHYS 516 Mathematical Methods
- PHYS 533/534 Nanostructures and Nanotechnology I and II
- PHYS 566 Surface Physics
- PHYS 567 Quantum Materials
- PHYS 568 Quantum Phase Transitions

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

Relativistic astrophysics and cosmology (RAC)

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.

Most RAC students take these classes:

- ASTR 452 Galaxies and Cosmology
- PHYS 515 Classical Dynamics
- PHYS 521 Quantum Mechanics I
- PHYS 526 Statistical Physics
- PHYS 532 Classical Electrodynamics
- PHYS 622 Quantum Field Theory

Depending on their supervisor, many RAC students also take some of these classes:

- ASTR 451 Sun and Stars
- ASTR 565 Compact Objects
- PHYS 513 Introduction to General Relativity
- PHYS 516 Mathematical Methods
- PHYS 517 Computational Physics
- PHYS 541 Radiative Processes
- PHYS 542 Introduction to Nuclear and Particle Physics
- PHYS 543 Physics of Quarks and Leptons
- PHYS 561 General Relativity

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 recommended for research in nuclear and particle physics are:

- PHYS 521 Quantum Mechanics I
- PHYS 542 Introduction to Nuclear and Particle Physics
- PHYS 543 Physics of Quarks and Leptons

Other valuable courses depending on student interests and focus are:

- PHYS 513 Introduction to General Relativity
- PHYS 516 Mathematical Methods
- PHYS 517 Computational Physics
- PHYS 522 Quantum Mechanics II
- 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 570 Solar System Physics
PHYS 532 Classical Electrodynamics
PHYS 580 Introduction to Plasma Physics

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 CMOR 520 Computational Science, and CMOR 521 High Performance Computing.

Other courses:
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: Candidacy Exam Topics by Research Specialty

Astrophysics of star and planet formation

The following list of topical areas and subtopics covers the areas of broader astronomy and astrophysics which students are expected to have some mastery of as well as more focused topics relevant to star and planet formation. This is a very broad research area and examinees are not expected to be deeply knowledgeable in all topics. They should be somewhat knowledgeable of topics well removed from their research area(s), and fully knowledgeable about topics of close relevance to their research. 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

Stellar atmospheres:
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. Heating of protoplanetary disks. Hydrostatic equilibrium solution for protoplanetary disks. Interferometry basics. Gas-dust dynamics. Planet orbital migration. Planetary detection techniques. Stellar initial mass functions

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, onset of degeneracy pressure and its role in the structure of white dwarfs, neutron stars, brown dwarfs and giant planets, mass-radius relationships, Chandrasekhar and Oppenheimer-Volkov stellar mass limits, pulsars and spin-down, Schwarzschild radius, gravitational waves

Binaries and Variable Stars: Statistics of binaries, types of eclipsing systems, symbiotic stars, cataclysmic variables and other mass-transfer systems, stellar oscillations, pulsating variables, instability strip, starspots and active chromospheres, flare stars

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, overall spectrum, temperature, abundances, photoionized globules and photodissociation regions

Molecular Clouds: Chemistry and molecules in dark clouds. Extinction and dust grain properties, filaments, turbulence, gravitational collapse, stellar jets and molecular outflows

Planetary Nebulae: Formation, excitation, spectrum

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

ISM: Phases of the ISM, heating and cooling, dispersion and rotation measures, chimneys, magnetic fields in the galaxy

Supernova remnants: evolution, Sedov phase, cosmic ray production

Radiation processes

Definitions and Basic Equations: 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

Spectra and Plasma Properties: Power emitted from accelerated charges (amount, angular pattern, and polarization), free-free emission (bremsstrahlung), 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, plasma effects of rotation measure and dispersion measure

Atomic and Molecular Physics: 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, detection methods of molecular and atomic lines at various frequencies in astrophysical objects

Normal and active galaxies:
Galaxy phenomenology: Discovery of galaxies, Shapley-Curtis debate, Hubble's classification scheme, dwarf galaxies, stellar content and metallicities

Milky Way and Spiral galaxies: Milky Way – stellar populations, clusters, the Galactic center region, molecular ring, thin and thick disk, halo, Magellanic stream, satellite galaxies. External galaxies – velocity dispersions, rotation curves, dark matter inferences, Tully-Fisher relation, spiral structure, density wave theory

Ellipticals: Faber-Jackson relation, relaxation, massive black holes, cooling flows

Active Galaxies: Starburst galaxies, Seyfert galaxies, broad and narrow emission-line regions and unification schemes, reverberation mapping, AGN jets

Cosmology:
Observational cosmology: Olber's paradox, the cosmological principle, Microwave background, distance ladders and the use of supernovae, Hubble's Law, galaxy distributions, galaxy clusters, supernova surveys, large scale structure, Lyman-alpha forests, gravitational lensing, evidence for dark energy

Theoretical Cosmology: Friedmann's equation and solutions, critical density, matter-dominated universes, Robertson-Walker metric, radiation and cosmological constant in Friedmann's equation, particle horizons, matter/radiation eras, nucleosynthesis

Atomic/molecular/optical physics

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 $\hbar$, e, c, m_e; numerical values for length and energy; the fine structure constant.

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

Atoms: Spectroscopic notation (term and configuration); Bohr atom; one electron atom (energy hierarchy, non-relativistic limit, fine structure, hyperfine structure); Rydberg atoms; multi-electron atoms (Hund's rules).

Atoms in Static Fields: Magnetic field: Basic interaction, (anomalous) Zeeman effect, Paschen-Bach decoupling. Electric Fields: Polarizability, linear regime, field ionization, Stark shift.

Atom-Light Interaction: Electric dipole approximation, Bloch equations, Rabi oscillation, Ramsey spectroscopy, AC-Stark shift, Raman process, Jaynes-Cummings model, dressed states, selection rules, spontaneous emission, Landau-Zener tunneling.

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

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, Born approximation), inelastic scattering, effects of identical particle symmetry and ultracold temperatures, Feshbach resonances

Quantum Gases: Ideal Bose and Fermi gas, thermal de Broglie wavelength, Bose-Einstein condensation, weakly interacting Bose condensate (Gross-Pitaevskii equation, Thomas-Fermi approximation, elementary excitations), Cooper pairing, BCS-BEC crossover

Biological physics

This list covers many topics in biological physics and the student is not expected to master them all. The student will agree on relevant topics to be covered in the exam with their 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

The following list of topical areas and subtopics covers the broad field of 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. Unit conversions (eV, K, T, cm^{-1})

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

Basic quantum mechanics: Bohr atom, one electron atom (Lande g factor); hyperfine structure, , 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-Ginsburg theory of phase transitions

Solid state physics:

Basic concepts: Tight binding, nearly-free electron picture, band structure, reciprocal space, diffraction, Bloch states, crystal momentum, acoustic vs. optical phonons, semiconductors, quasiparticles, holes, 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, Curie and Curie-Weiss laws, local vs. itinerant magnetism, Stoner criterion, Bohr-Van Leeuwen theorem

Thermodynamic and transport properties: heat capacity, resistivity (different contributions in metals, semiconductors etc.)., Wiedemann-Franz Law, Nernst effect

Dielectric and optical properties: Kramers-Kronig relations, piezoelectricity, Clausius-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),

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, muSR

Electronic methods: two-terminal vs. four-terminal measurements, lock-in techniques, van der Pauw technique, Hall resistance, 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.

Optical effects emphasis:
Plasmonics: Localized Surface Plasmon, Surface Plasmon-Polariton, Plasmon Hybridization, Quantum Plasmonics, Nonlocal screening, Surface Enhanced Raman Scattering, Surface Enhanced Infrared Absorption,

LSPR sensing, Dark-field scattering spectroscopy, Cathodoluminescence, EELS, Plasmonic Fano resonances, Chirality

Electromagnetics: Purcell effect, superradiance, subradiance

Photonics: Photonic bandgap, Photonic crystals, Metamaterials

Excitonics: Exciton, Quantum Dots, Quantum Confinement effect, Luminescence

Computational: Finite Difference Time-Domain method, Finite Element Method, Mie theory, Discrete Dipole Approximation

Relativistic astrophysics and cosmology (RAC)

Students working with RAC faculty typically study an array of topics in elementary particle physics, astrophysics, and cosmology. Since this is a broad research area, examinees are not expected to be deeply conversant with all topics. Typically they should be roughly conversant with topics well removed from their research area, and very knowledgeable about all subtopics of close relevance to this area. The adviser and examinee may, after consultation, alter this list.

Fundamentals

Classical particle mechanics (basics): equations of motion, harmonic oscillator, Newton's law of gravitation, escape velocity, nonrelativistic Lagrangian/Hamiltonian mechanics, symmetry and Noether's theorem, conserved quantities (linear momentum, angular momentum, energy)

Electrodynamics (basics): Coulomb's Law, Biot-Savart Law, Lorentz force, Maxwell's equations, electromagnetic waves, electromagnetic radiation, electric and magnetic potentials, gauge freedom

Special relativity (basics): time dilation, length contraction, spacetime intervals, boost factor, energy-momentum relation, kinematics, Lorentz transformations, spacetime diagrams, worldlines

Quantum mechanics (basics): Heisenberg uncertainty principle, incompatible observables and commutation relations, wavefunction, Schrodinger equation, intrinsic angular momentum (spin)

Statistical mechanics (basics): temperature, thermal kinetic energy, pressure, ideal gas law, blackbody, random walks, entropy, equilibrium, mean free path

Astrophysics (basics): Hertzsprung-Russell diagram, main sequence, Newtonian gravity, binary orbits, virial theorem, high-energy radiation (cosmic rays, gamma rays, X-rays, neutrino), black holes, compact objects, gravitational waves, multi-messenger astronomy

Cosmology (basics): the cosmological principle, cosmological length and time scales, cosmological expansion and redshift, Hubble's law, cosmological composition, cosmic microwave background radiation, evidence for dark matter and dark energy

Particle physics (basics): antimatter, Feynman diagrams / rules, Fermi's Golden Rule, scattering cross section / lifetime / interaction rates, Thomson / Coulomb scattering, Standard Model particles (name, mass, spin), force carriers, nuclei / pions, Higgs boson / origin of mass, neutrino flavor oscillations

Experimental emphasis

Electrodynamics (advanced): EM fields in medium, permittivity, permeability, index of refraction

Astrophysics (advanced): gamma/cosmic rays, air shower, spatial/energy resolution of detectors

Particle physics (advanced): nuclear form factor, charged/neutral current weak interactions, neutrino flavor oscillations (evidence/history/detectors), dark matter (evidence/history/detectors)

Instrumentation: passage of particle through matter (e.g., PDG 34. Particle Detectors at Accelerators), Bethe-Bloch formula (dE/dx), particle identification, photomultiplier tubes (PMTs), bubble/time projection chamber (TPC), scintillation, ionization, overburden/shielding, sources of noise, radioactivity

Data analysis and statistics: Poisson statistics (counting), chi-squared distribution, confidence intervals, Bayes theorem, machine learning (supervised and unsupervised), signal-to-noise ratio

Theoretical emphasis
Classical mechanics (advanced): phase space, adiabatic invariants, relativistic dynamics, fluid dynamics

Electrodynamics (advanced): relativistic formulation, Green's functions, Larmor formula

Quantum mechanics (advanced): simple harmonic oscillator, Hydrogen atom, square well, addition of angular momentum, perturbation theory (WKB), bra-ket notation, quantum mechanical pictures

Statistical mechanics (advanced): phase space distribution function (BE, FD, MB), quantum statistics (bose/fermi), free energy, partition function, chemical potential and conserved quantities, detailed balance

Astrophysics (advanced): white dwarf stars, neutron stars, quantum degeneracy pressure, mass-radius relationship, Chandrasekhar and neutron star mass limits, Eddington luminosity and mass accretion limit, Bondi accretion, simple accretion disk models, AGNs, relativistic jets, dynamical friction

Cosmology (advanced): distance ladder, FLRW spacetime, Friedmann's equations, cosmological inflation, primordial nucleosynthesis (BBN), cosmic microwave background radiation, relic neutrino background, baryon acoustic oscillations, dynamics of large-scale structure, galaxy surveys, reionization

Particle physics (advanced): Dirac equation, spinors, Lorentz-invariant matrix element, draw and label Feynman diagrams, link between gauge forces and symmetry groups, Standard Model U(1) x SU(2) x SU(3), spontaneous symmetry breaking, Higgs mechanism, Goldstone's theorem and Goldstone bosons

Quantum field theory: canonical / path integral quantization, correlators, propagators, loops, RG flow

General relativity: equivalence principle, curvature, geodesics, classic experimental tests, Schwarzschild spacetime, Kerr metric, gravitational waves, gravitational lensing

Nuclear and particle physics

This list covers many topics in nuclear and particle physics and the student is not expected to master them all. The student will agree on relevant topics to be covered in the exam with their committee.

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.

Specifically for Heavy Ion students:
Basics of Thermodynamics

Basics of Hydrodynamics

Phenomena at Heavy Ion experiments

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 plasma physics

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.

Fundamentals:

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: Plasma frequency, Debye length, Coulomb collision frequencies, Spitzer resistivity

Particle motion in electric and magnetic fields: Drifts, adiabatic invariants, waves in plasmas, cold unmagnetized and magnetized plasma waves

Magnetohydrodynamic description of plasma: MHD approximation, frozen-in-flux, MHD equilibria, waves, instabilities, shocks, force and motion in MHD

Magnetic reconnection: Basic features, MHD models

Kinetic Description of plasma: Vlasov theory, Landau damping, basic kinetic instabilities, the Fokker-Planck equation and binary coulomb collisions

Solar physics

Basic Information About the Sun: Radius, mass, and luminosity, structure of the interior, structure of the atmosphere

EUV & X-Ray Radiation: Coronal model approximation, collisional and radiative bound-bound transitions, ionization and recombination, non-equilibrium ionization, spectroscopic diagnostics

Observations: Imaging instruments, spectroscopic instruments, imaging versus spectroscopic, remote sensing versus in-situ measurements

Coronal Heating: DC mechanisms, AC mechanisms

Coronal Hydrostatics: Basic properties of hydrostatic equilibrium, isothermal and non-isothermal solutions, scaling Law, instabilities

Coronal Hydrodynamics: The hydrodynamic equations, collisionality, coronal heating and cooling cycle, Spitzer-Harm conductivity

Coronal Magnetohydrodynamics: Magnetic fields, open-versus closed-field regions

Solar flares and Coronal Mass Ejections: The "Standard Model", role of magnetic reconnection, particle acceleration and transport, thermal versus non-thermal hard X-ray emission, electron distribution

The Solar Wind: The fast and slow solar wind, Parker model for steady expansion of the solar corona, Parker spiral

Magnetospheric physics

Basic information about the Magnetosphere: Magnetopause, bow shock, plasma sheet, ring current, radiation belts, plasmasphere and associated current systems

Basic information about the Ionosphere: Structure, Chapman Theory, conductances

Solar wind magnetosphere interaction: Energy transfer processes, role of the solar wind and the ionosphere

The aurora: Types of aurora, acceleration processes

Magnetospheric Storms and Substorms: Definition, basic properties, relation magnetic Indices

Magnetospheric Convection: Basic properties, theoretical foundations

Magnetosphere Ionosphere coupling: Basic properties, theoretical foundations

Basic information about the magnetospheres of the other planets: Rotation dominated planets, ionosphere dominated planets