

4 Preliminary Examination

4.1 Description

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

The exam consists of three parts, each administered separately:

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

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

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

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

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

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

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

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

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

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

4.2 Timeline

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

First administration. The first administration of the Preliminary Examination will be before the start of the fall semester, in August. This administration will be after the end of the Review of Physics summer course but before the start of classes (typically the week before the Graduate School’s orientation week). All students are expected to arrange to be on campus in time to take all exam parts. Failure to take the exam counts as failure of the exam (see “Special circumstances” below).

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

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

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

the preceding summer, the student is still welcome to optionally retake this part, but the student will *not* be paid to do so.

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

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

4.3 Policies

4.3.1 Problem preparation

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

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

4.3.2 Administration and format

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

4.3.3 Grading

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

The Preliminary Examination Committee chair will review the scores of both graders. If the committee chair judges that the scores differ significantly (*e.g.*, by more than 1 point) or otherwise require further review, the committee chair may convene the graders to review and reevaluate the scores. If this does not resolve the concern, then a third grader will be called upon for that problem, and the three grades will be averaged. Grading will be blind, *i.e.*, identifying information will not be released to the Preliminary Examination Committee.

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

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

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

4.3.4 Extraordinary performance in coursework

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

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

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

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

4.3.5 Special circumstances

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

Inability to take the exam due to illness must be supported by medical documentation. It is important to notify the department, via the graduate administrator and/or DGS as soon as

possible and, barring extreme emergencies, before the exam is administered.

Excused postponements for other extraordinary (nonmedical) circumstances, such as family crisis, should again be requested in advance of the exam and must likewise be supported by documentation. These cases must be considered and approved by a committee constituted and operating according to the department's formal Appeal Process (Section 12).

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

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

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

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

4.4 Exam-day guidelines

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

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

(1) *Mathematical Handbook*. You will be expected to bring a copy of the *Mathematical Handbook of Formulas and Tables*. Reserve copies are available for you to check out from the Chemistry Physics Library. (You may alternatively use your personal copy, if you prefer. However, you may not have any notes in the *Handbook*. Therefore, be sure to look to see if your personal copy has any markings. If so, be sure to check out an unmarked reserve copy to bring to the exam instead.) If you are not already proficient with using the *Mathematical Handbook*, it is strongly recommended that you familiarize yourself with the organization of information in advance, so you can find information (identities, integrals and derivatives, special functions and polynomials) quickly, when needed.

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

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

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

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