Graduate Student Handbook
Department of Physics
Columbia University

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February 18, 2026

Abstract

This handbook presents in one place much of the information needed to pursue a Ph.D. in Physics at Columbia. In the case of inconsistency with other sources of the same information, it is intended to supersede similar material on the Physics Department website. However, in the case of conflict with information provided by the website of the Graduate School of Arts and Sciences (GSAS), the information on that website should take precedence. Please send corrections or suggestions for improvements to the authors.

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1 Introduction

The Columbia Ph.D. degree is awarded based on a high level of proficiency in core topics in physics, experience in teaching at the undergraduate level and the successful completion of significant, original research in experimental or theoretical physics. We divide the information presented here into four categories: course work, research, teaching and financial support. Each of these sections describes important elements of the Columbia Ph.D. program including the sequence of degrees to be obtained, courses to be taken, minimum grades to be earned and presentations to be made. These are all necessary steps along the path leading to the Ph.D. degree. Each student is required to demonstrate satisfactory progress in each area; a student whose progress is insufficient may at any time be put on probation, requested to withdraw, or see their appointment be terminated.

2 Course work

Academic progress in completing the course work required for the Ph.D. is demonstrated by the receipt of two academic degrees that lead up to the Ph.D. No student may become a candidate for the Doctor of Philosophy (Ph.D.) degree without first fulfilling the requirements for the Master of Arts (M.A.) in Physics and Master of Philosophy (M.Phil.) in Physics degrees at Columbia.

2.1 M.A. Degree in Physics

This degree is a prerequisite for the M.Phil. and Ph.D. degrees, unless a student has been awarded two Residence Units of advanced standing. The M.A. degree requirements are:

Points of letter-grade credit: 30 points with at least 24 point coming from courses within the department.
Program of study: 15 points of physics courses numbered 6000 or higher, with an overall performance satisfactory to the Committee on Graduate Work (aka Graduate Advising Committee). The courses are to be chosen in consultation with the Director of Graduate Studies (DGS) to insure knowledge of classical and quantum physics.
Residence Units: 2 (minimum).

Any student who fails to complete the requirements for the MA degree within four consecutive terms (not counting summer terms) must obtain permission from the Department Chair in order to continue work into a fifth term.

2.2 M.Phil. Degree in Physics

This degree is a prerequisite for the Ph.D. degree and will be conferred upon certification by the department.

Typical length of program: Three to four years, including the time spent for the M.A.degree. This degree must be obtained before the end of the fourth year.
Residence Units: Six full-time, including the two earned for the M.A. degree.

Thesis Proposal: To earn the M.Phil., the thesis proposal presentation must be complete to the satisfaction of the committee (see Section 4.2 below).
Points of credit: 30 earned for the M.A. degree; none if the student has been awarded two Residence Units of advanced standing.
Required courses: See the list of required courses in Table 1.

4 Core Courses*	**1** of the following:	**2** Field-specific Courses**	Additional Courses
PHYS G6092: Electromagnetic Theory	PHYS G6047: Quantum Field Theory	PHYS G6011: Astrophysics I	PHYS G6040: Nuclear Physics
PHYS G6037: Quantum Mechanics I	PHYS G6094: Classical Waves and Fields	PHYS G6012: Astrophysics II	PHYS GR6020: Frontiers of Condensed Matter Physics
PHYS G6038: Quantum Mechanics II	PHYS G6057 Quantum Many-Body Physics	PHYS G6010: Physical Cosmology	PHYS G6070: Biological
PHYS G6036: Statistical Mechanics		PHYS G6060: Atomic Physics	PHYS G6080: Scientific Computing
		PHYS G6082: Condensed Matter Physics I	PHYS G6042: Experimental Methods for Nuclear, Particle and Astrophysics
		PHYS G6083: Condensed Matter Physics II	PHYS G8036: Advanced Statistical Mechanics
		PHYS G6065: Quantum Optics	PHYS G8066: Special Topics: Condensed Matter Physics
		PHYS G6050: Particle Phenomenology	PHYS G8048: Quantum Field Theory II
		PHYS G8069: Particle Physics I	PHYS G8049: Quantum Field Theory III
		PHYS G8040: General Relativity	

Table 1: *A grade of B- or better is required for each of the core courses, see Section 3. **With special permission from the student's PhD advisor and the DGS, the student may if justified substitute *one* of the two field-specific courses with a 6000 level or above course outside this list from Physics or another department, by submitting a request to the DGS.

2.3 Placement exam

A written placement exam is administered to all students at the start of the fall semester of their first year. The purpose of the placement exam is to ensure the success of all students admitted to our Ph.D. program by providing individual guidance on course work during the first years at Columbia. Our experience has been that the admissions process successfully identifies students with the appropriate ability, but does not guarantee uniformity in the academic preparation of the talented individuals admitted to our program.

This exam consists of problems typical of those found in our introductory and advanced undergraduate courses in mechanics, electromagnetism, quantum mechanics and statistical mechanics. The Columbia undergraduate courses matching the material covered by the placement exam and the textbooks typically used in those are as follows:

- Mechanics, Physics UN3003 and GU4003: *Classical Mechanics*, Goldstein, Poole and Safko; *Mechanics*, Landau and Lifshitz.
- Electromagnetism, Physics UN3007-3008: *Introduction to Electrodynamics*, Griffiths.
- Quantum Mechanics, Physics GU4021-4022: *Introduction to Quantum Mechanics*, Griffiths; *A Modern Approach to Quantum Mechanics*, Townsend.
- Statistical Mechanics, Physics GU4023: *An Introduction to Thermal Physics*, Schroeder; *Thermal Physics*, Kittel and Kroemer.

This guidance is intended to be descriptive, not prescriptive. There are many other excellent textbooks for each of these subjects. In addition, copies of past placement exams can be found at https://www.physics.columbia.edu/content/placement-exam. The exam takes place in two 3-hour sessions at the start of the first semester at Columbia. The first session covers classical mechanics and electromagnetism, and the second quantum mechanics, statistical mechanics and thermodynamics. While an effort is made to provide appropriate formulas with each exam, students are allowed to bring one letter-size, double-sided formula sheet to each session.

Following the exam, the results are first discussed by a small faculty group, consisting of members of the placement exam and graduate advising committees; this is followed by individual meetings between each student and the DGS. During that meeting, if the examination identified a likely gap in a student's preparation at a level that would prevent successful completion of one or more of the required graduate courses, the student and the DGS decide on a course of action to remedy the gap. Examples range from student self-study (in case the gap is small) to successfully completing the corresponding undergraduate course(s) before taking the corresponding graduate course(s). The DGS will also review core graduate course midterm scores in the Fall semester and contact students who appear at risk of obtaining a course grade below the required B-.

The results of the placement exam become part of the student's departmental record; they are reviewed in a faculty meeting later in the Fall semester.

2.4 Transfer Credits

In the case of students with advanced preparation who have already mastered the material in some of our graduate courses transfer credits (which counts towards the requirements for the M.A. and M.Phil. degrees) may be granted. This requires that an equivalent graduate level course

has been successfully completed, as well as a passing grade on the relevant part of the placement exam. There are significant restrictions on the courses that can be considered: more detailed information is available at
https://www.gsas.columbia.edu/content/transfer-credit.

3 Student Evaluation

During the first two years, each student's performance is evaluated at the start of each semester by the DGS, and by the full faculty at the start of the second year in the program. At that time the faculty have access to each student's full departmental record. Students whose academic performance does not meet GSAS or departmental performance criteria can be put on probation to ensure the actions required to remain in the program are clear. A grade of B- or better in each of the four core courses, PHYS G6092, PHYS G6037, PHYS G6038 and PHYS G6036 is required for the Ph.D. degree. If a student gets a grade below B- in a core course, the case will be discussed by the graduate committee and any other faculty whose input may be relevant, typically the prospective advisor and/or course instructor. The Committee will decide if the student will be allowed one or more additional attempts. The latter allowance might be made in a case where the grade is far below the student's grades in other core courses, or if there is clear evidence that the grade is due to circumstances external to the course itself. If the committee does not allow more than one additional attempt, the student will be put on probation with the requirement to obtain a grade of B- or better the following year.

Once students move into full-time research, their evaluation is performed by their advisor and thesis proposal committee (see below). The advisor can consult with the DGS on an action path if the student's performance falls below expectations.

4 Research

4.1 Finding a research sponsor

The most critical component of a Columbia Ph.D. in physics is the doctoral research project carried out in most circumstances under the supervision of a member of the Physics Faculty.

The first year of graduate study is usually focused on course work and, especially for theoretical physics, acquiring the background needed to conduct research. However, students frequently begin some degree of informal research either with a prospective sponsor or a faculty member working in a area of interest. The summer of the first year provides a critical opportunity to begin serious research and it is important to lay the ground work for this summer activity during the first two semesters at Columbia. If a potential sponsor has not been pre-arranged during the admission process, it is important to approach faculty members working in an area of interest and discuss possible summer projects and potential sources of long term financial support. The Director of Graduate Studies (DGS) is available to help in this process.

There are occasions when a student's Ph.D. research is carried out with a faculty member not in the Physics Department. While such an external Ph.D. adviser is most often from the Department of Astronomy, sponsors from Chemistry, Applied Physics, Electrical Engineering or even Neuroscience are not uncommon. In these cases, approval from the DGS is required and a faculty member in the Physics Department is identified who agrees to act as an adjunct sponsor to monitor satisfactory progress toward completion of the degree. In unusual circumstances, a

sponsor outside of Columbia may best meet the professional interests of a Ph.D. student while still providing a research topic appropriate for a Physics degree. While such cases merit more intense scrutiny, they are allowed with the approval of the DGS and the appointment of an adjunct sponsor in the Department. In the case of a Ph.D. project sponsored by someone outside of the Department, yearly reports on research progress must be submitted to the DGS. Additional information is available from the GSAS webpage on Faculty Advising.

A Ph.D. student must identify a thesis sponsor by the end of the second year. Whether prearranged before coming to Columbia or decided during the second year, both the student and research sponsor should be committed to this sponsorship (including long-term financial support) and the sponsor should so inform the Director of Academic Administration (DAA). It is the responsibility of each Ph.D. student to find a research sponsor; doing so is an important element of the requirement that all students make satisfactory rate of progress toward the degree. Failing to find a sponsor by the end of the second year will result in termination of the student's appointment at Columbia.

4.2 Thesis proposal presentation

Between the middle of the 3rd year and the end of the 4th year each student will present a thesis proposal to a committee of three faculty members working in fields close to that of the planned research. The 5-10 page thesis proposal should describe the proposed research in some detail including the questions to be addressed and results to be obtained. The proposal should include a description of the broader research area and the importance of the thesis topic to that area of research, as well as methods to be used and a summary of relevant prior research. The Research Proposal Committee will include the thesis adviser and two additional faculty members, normally including both a theoretical and experimental faculty member, chosen by the student in consultation with the thesis adviser. The presentation and ensuing questions and discussion should require approximately two hours. The thesis proposal and a short form completed at the end of the presentation will be submitted to the DGS and become part of the student's record. This is a required step in the process of obtaining the Physics M.Phil. degree at Columbia and also an exciting milestone in the student's progress toward earning the Ph.D. Complementary information is available from the GSAS webpage on the Dissertation Prospectus.

4.3 *Ad hoc* Ph.D. advisory committees

The Department supports the creation of an *ad hoc* Ph.D. advising committee should a student or their adviser wish to obtain advice or suggestions from additional faculty colleagues. The committee would include the Ph.D. adviser and two other faculty chosen by the student in consultation with the adviser. Meetings of the student with this *ad hoc* committee can be arranged by the student, their adviser or the DGS as the circumstances require. Topics that might be addressed include the choice or scope of Ph.D. research topic, the rate of progress in research or other concerns of either the student or their adviser.

4.4 Thesis defense

At least two months before the student expects to defend their advisor should contact the DGS to start the process. Note that per University rules, students are **not** allowed to be involved in choosing the members of the defense committee. This is done by the advisor and the Director

of Graduate Studies, with final sign-off by GSAS. The thesis has to be distributed to the defense committee preferably four weeks, but no later than three weeks before the defense.

The final Ph.D. defense in the Physics Department is divided into two parts. The first part is open to the public and announced on the Department webpage and with other seminar postings a week or more in advance. This part follows the form of a typical seminar with the Ph.D. candidate presenting their Ph.D. research for approximately 45 minutes. This part of the thesis defense is attended by the student's defense committee, other students and faculty and possibly the student's family and friends. The second part of the exam immediately follows the first part and is the formal, University-required thesis defense, attended only by the student and their defense committee. In this second part the Ph.D. candidate might be asked to present some aspects of their research in greater detail and answer further questions posed by the committee. This portion of the final defense typically lasts one hour.

5 Teaching

The experience of teaching as a graduate student is a foundational element of doctoral education, and a significant part of professional apprenticeship. TA duties normally include teaching small laboratory sections or recitation sessions in elementary courses, providing assistance to undergraduate students in the help room, and grading homeworks and exams. Fulfilling pedagogical requirements and responsibilities as designated by the department and GSAS is one of the conditions to maintain good academic standing.

Teaching is also the principal method of support for first and second year graduate students, who are appointed as Teaching Fellows. There are typically limited opportunities to teach in later years for supplemental pay. The Graduate School of Arts and Sciences requires that graduate students teach at least two consecutive semesters in the same academic year.

6 Financial support

Financial support for Ph.D. students in the physics department comes from the Graduate School of Arts and Sciences in the first two years, when students are appointed as Teaching Fellows, and normally from research grants after that. Students are encouraged to apply for external grants, for example the National Science Foundation Graduate Research Fellowship (https://www.nsf-grfp.org/). Columbia will top off the grant to match the standard Ph.D. student pay rate (see below), and, at this time (2023), provides an additional bonus to students who obtain such fellowships. Students who secure external fellowships will have more flexibility in identifying a thesis sponsor as this will reduce the need for research grant funding.

More details on pay rates, fees etc. are available from
https://studentbenefits.provost.columbia.edu/content/compensation-and-student-employee-benefits.