GRADUATE PHYSICS AT CORNELL

This document is written to help the beginning graduate student become acquainted with some aspects of graduate physics at Cornell—matters such as the design of the program, its administration, students' special committees, major and minor subjects, the examination structure, etc. It is also intended as a reference document on policy and procedures for all faculty. In the latter role, it encompasses the "Graduate Conference Agreements" subscribed to by faculty members of the Field of Physics.

I. General Intent and Design of Program

The program is designed for the student who wants to become a professional physicist. It is primarily for the Ph.D. aspirant, but a physics Master's degree may be taken as a terminal degree, and is normally taken as an in-progress degree by students passing the ACE exam. Later sections discuss exams in detail.

Physics at Cornell is nestled among closely allied activities—applied physics, space science, engineering, chemistry, mathematics, biology, history of science, technology and society, etc.—and physics major students are encouraged to broaden their concerns as they wish. It is recognized and accepted that such breadth may dilute or delay a highly-honed physics specialization.

The program has two main ingredients: (a) comprehension of at least a core of advanced general physics, and (b) research experience in some specific area. The large majority of students find the most efficient way to acquire the general comprehension is by the usual route of formal courses, but this formal way is not required and most students should do some of it by independent study. Getting started effectively in independent study, or indeed in research, typically calls forth new initiative and personal responsibility for one's own education.

As to research, students should, during the first year of graduate work, spur themselves (and be encouraged by the faculty) to find out about some of the Cornell research going on around them. By the summer following the first year they should associate themselves personally with the research of some professor or research group, even if this association is only temporary. The normal time for a reasonably firm commitment for a Ph.D. thesis area, and for such an understanding with a supervising professor, is at about the end of the second year.

The general comprehension outlined in Section V of this document should give the physicist an adequate base in advanced physics (a) for gainful and satisfying employment; (b) for keeping up to date in Physics; and (c) for an eventual, possibly early, shift in the area of physics specialization. No physicist should feel trapped in the particular specialization of the thesis.

The program is designed to be flexible but to include, especially in its early part, appropriate checks and balances. It presumes that students will take the initiative in availing themselves of the flexibility offered.

II. Administration

The Graduate Faculty

The Graduate Faculty of the University makes and administers the rules that govern the program, and the Dean of the Graduate School is the Faculty's spokesman. For these rules, each student (and faculty member) should refer to the *Code of Legislation of the Graduate School* and the *Announcement of the Graduate School*. All relevant documents are available online from Graduate School sites; a good starting point is http://www.gradschool.cornell.edu/. The Dean and the committee of the Graduate Faculty administers graduate fellowships, traineeships and other appointments.

The Field of Physics

The Field is the next lower level of administration. There are 96 fields at Cornell; Physics is one of the largest. The faculty of the Field of Physics consists of those members of the Graduate Faculty who serve as physicists on the Special Committee (see Section IV) of one or more students and thus represent the Field in an official capacity. From the student's point of view, his/her Special Committee is the most important part of the Administration; the Committee sets the academic requirements and standards for the student's degree program and judges performance and progress.

An initial Special Committee is assigned to incoming graduate students. This committee helps guide course selection, serves as a resource to guide students towards research groups of interest, and provides support and feedback for the "Q" exam. When a student has been accepted into a research group, prior to the ACE Exam, a student should choose members of his/her own committee to conform to personal interests (with, of course, the concurrence of the members). If those interests change, a student will generally encounter no difficulties in changing the membership of the committee prior to the ACE exam. Such changes are initiated by the student via their Student Center. Changes to the special committee after the ACE exam require a petition of the Graduate School, and for a significant change in research subfield may necessitate a new ACE exam.

Because of its size, the Field of Physics has voluntarily established its own device to coordinate the requirements and standards expected by the 200 or so special committees. This device is called the Physics Graduate Conference (see Appendix). Membership in the Conference includes all those in the Graduate Faculty who are approved to represent the Field of Physics on at least one student's Special Committee. The Conference does not make binding rules, but it does make "agreements" that guide its members; it determines educational policy for the Field and advises its members and others on graduate academic matters concerning the Field. The Conference has no budget and makes no appointments.

The Director of Graduate Studies (DGS) represents the Field of Physics in the Graduate School.

The Department of Physics

The Department of Physics, which is a unit of the College of Arts & Sciences but not the Graduate School, determines what physics courses shall be offered and administers them. The Conference advises on courses in its interest. The Department's budget is almost entirely for instruction, including stipends for teaching assistants in the Department.

Research in physics is administered (and budgeted) almost exclusively by other university units, e.g., by Laboratories (LASSP, LEPP and CLASSE) and Centers (CBB, CCMR, etc.), and research in allied areas by other departments. The stipends of research assistants come directly through the appropriate administrative unit. Because of the need for coordination, the Physics Department Chair, who is also Chair of the Graduate Conference, confers and concurs in the appointment of every physics-major student, whether it be a teaching assistantship, research assistant, fellowship, or scholarship, and in whatever administrative unit.

Graduate Teaching Assistantships

Most incoming graduate students in physics hold teaching assistantships, and the Field of Physics strongly encourages students (even those who hold Fellowships) to serve as a teaching assistant for at least one semester. Teaching assistantships are useful to the student in several ways: 1) in solidifying the student's own knowledge of physics, 2) in furthering graduate education by providing meaningful work in the subject area, and by receiving training as physics instructors through real life teaching experiences that increase the TA's confidence, listening and speaking skills, etc.; 3) in providing financial support for graduate education through the payment of stipends, tuition and health insurance, affording them the opportunity to explore research opportunities; and 4) in supporting the physics teaching program by leading discussion sections and interacting closely with undergraduate students, and by providing the students with a different perspective, personality and teaching style;.

The responsibility for teaching physics, even at the most elementary level, is taken very seriously by the department, which invests in the incoming grads by providing TA training and ongoing support to help ensure success in the classroom. Each year some of our best teachers turn out to be TAs. Learning to be an effective communicator and instructor is a critical component of graduate education whether or not one chooses to follow a career in education. Many of our Ph.D.s recall the time spent teaching undergraduate physics as among their most rewarding graduate experiences.

Students admitted to the graduate program with TA support should plan on teaching for the first two years. A student who finds support as a GRA during the first two years may request to be released from teaching. The request will be granted on a semester-by-semester basis if they are not needed to teach, which is usually the case, but cannot be guaranteed. The request should be made to the department manager at least one month before the start of the semester.

Teaching assignments are made by the department manager in consultation with the DGS, Chair, other appropriate faculty as needed, and with each grad in an ongoing way. An attempt is made to place TAs in courses that they would prefer to teach while considering other important factors such as experience, past performance, special training, course needs, and language ability. Foreign students are evaluated on their language skills and for those who may need a little extra work to improve their English, temporary teaching restrictions are sometimes put in place by Cornell after language assessment by the Center for Teaching Innovation. Ultimately, the top priority is to position instructors in all of our courses to best serve the interests of the undergraduate students.

A full TA work load should be about 15 hours per week, on average, although some inexperienced TAs may take a few weeks to learn how to improve their efficiency. Note that the averaging period, in keeping with Graduate School policy, includes time before and after the

semester to accommodate course preparation and peaks resulting from prelim examinations. TAs will earn a 9-month stipend plus tuition scholarship and university health insurance coverage.

To discuss teaching preferences or any questions about the TA appointment process, contact Craig Wiggers, cww67@cornell.edu . Craig is always interested to speak directly with grads about TAing.

Student Records

All Graduate School forms (Schedule of Exam, Results of Exam, Leave of Absence, etc.) should be given to Kacey Acquilano after the special committee has signed them. Kacey will obtain the approval signature of the Director of Graduate Studies and then submit the completed form to the Graduate School. A copy will be maintained within the department. Kacey keeps, for the convenience of students, a few hard copies of some of the most frequently needed Graduate School forms in her office. Forms can also be obtained at www.gradschool.cornell.edu/forms.

III. Graduate Student Status; Fellowships

The Admissions Committee makes recommendations to the DGS concerning student admissions (including transfers) into the Field of Physics. Final admission decisions are made by the DGS, normally in consultation with the Chair of the Admissions Committee. All admissions are for the PhD program; the Field does not have a Master's program.

Recommendation by the Admissions Committee for admission, or for a change of status, becomes invalid if the applicant has not matriculated in the Cornell Graduate School as a physics-major student within approximately one month after the stated time for admission, or completed the change of status within one semester of the date of the recommendation.

The Director of Graduate Studies (DGS) acquaints her/himself and the Conference with currently available fellowships, traineeships, and scholarships, and brings them to the attention of students and Special Committees. The DGS makes specific recommendations for such awards for new students and consults with the Conference as needed about specific recommendations for continuing students. For Cornell-administered awards, the recommendations are submitted to the Graduate School Office.

IV. Special Committees; Major and Minor Subjects; Thesis Supervision

Each entering graduate student is assigned a temporary Special Committee consisting of three members of the field. This committee guides the student in choosing courses and exploring potential research areas. Its members may, or may not, represent the student's ultimate research interests. The chair is chosen from a group of four "wise people" for each year who help facilitate communication from the Field and Conference.

The temporary committee will last until either the beginning of the fifth semester, or formation of the permanent special committee that will guide the student's research, whichever comes earlier. The field will dissolve this temporary committee during the first week of the fifth semester (third year) if it has not already been replaced. To avoid the Graduate School placing a hold on registration, the student will need to establish a permanent committee by the end of that semester.

Approved major and minor subjects for the Ph.D. degree in the Field of Physics are Physics, Experimental Physics, and Theoretical Physics.

A major or minor in Physics must be accompanied by a minor or major, respectively, outside the Field of Physics; and a major in Experimental or Theoretical Physics must be accompanied by a minor in Theoretical or Experimental Physics, respectively. (For a Ph.D. degree in the Field of Physics it generally suffices to have only one minor subject, either inside or outside the Field, but the student's Special Committee may approve or recommend two minors.)

When students' programs become reasonably firm, they are encouraged to form a permanent Committee (at least three members for Ph.D. programs and at least two for M.S. programs). The permanent committee must be formed by the fifth semester and before the student is ready to take the Admission to Candidacy Exam (A exam). The A exam is normally completed in the third year of study and must be completed before the start of the seventh semester. For each student in Physics' Ph.D. Program, the Special Committee must consist of at least three members, with at least two who hold membership with indefinite tenure in the Field of Physics. Please consult the Physics web site (physics.cornell.edu) or the Graduate Field Assistant (Kacey Acquilano) for current field membership. For students with both major and minor subjects within the Field, there should be three members from the Field of Physics.

The Chair of the permanent Committee represents the major subject and normally also supervises the thesis. Each minor subject must be represented by a member of the Committee; if there is only one minor, the third member has only examining, advising, and form-signing duties. The Ph.D. Committee Chair must be a regular (not *ad hoc*) member of the Field. The Chair must supervise the thesis, and therefore must be, or become, a member of the Field. By the rules of the field, the Special Committee should always include at least one theorist and one experimentalist from within the Field of Physics, and must always include two field members with membership of indefinite tenure.

If your research supervisor is not currently a member of the Field of Physics, they must apply (initially) for a five-year term-limited membership. Your supervisor should consult with the DGS of Physics for the current review requirements for admission to the Field of Physics. The Field strongly recommends that such a review occur before your fourth semester, to allow you sufficient time to pursue other research options in the case that your supervisor is not voted into the Field.

Some sample special committee assignments are as follows:

Major in Experimental Physics	Major in Theoretical Physics
Physics – Experimentalist	Physics - Theorist
Physics – Experimentalist	Physics - Theorist
Physics – Theorist	Physics – Experimentalist
Major in Physics with Minor outside of Physics	
Physics Chair – Experimentalist	Physics Chair – Theorist
Outside Field Member	Outside Field Member
Physics – Theorist	Physics – Experimentalist

(For a minor outside of Physics it is up to the student to speak to the DGS in that particular field to see what the requirements are for them to minor in that field.)

Annual Progress Reports

The Graduate School requires that each student in their second year or beyond complete an Annual Progress Report (APR). Each student will receive a link, along with specific instructions and deadlines, from the DGS regarding the APR each year. Typically, students will complete the APR early in the fall semester. Upon receipt of the instructions from the DGS, each student should schedule a meeting with their advisor (special committee chair) to review the APR. The student should then follow the link to complete their APR form and submit it for review by the advisor at least a week in advance of the meeting. The APR is designed to facilitate discussions between student and advisor on research progress and mentoring. After amending the APR form based on the advisor meeting, the student will electronically submit the form. The advisor will then approve / comment on the form electronically, and submit it to the DGS and Graduate School.***Time to Degree***

The Graduate School requires that students complete their doctoral degree within 7 years of matriculation. Students who will not graduate in this time frame must write a plan for completion of the degree, showing major milestones, in consultation with their advisor. This plan should be provided to the DGS before the start of the 15th semester. At this time, the student must also petition the Graduate School for an extension of the time to degree. Students remaining beyond 8 years will need to provide a new plan and re-petition the Graduate School annually. Please note that the Department will not provide any TA support beyond the seven year deadline.

V. Course Recommendations for Graduate Study in Physics at Cornell

A graduate education in physics should consist of (1) mastery of core subjects that are central to all fields of physics, (2) an in-depth study of at least one specialized sub-field, and (3) some knowledge of at least one area of active research outside a student's thesis area.

Core Subjects:

All students should demonstrate mastery of the following core subject areas:

1. Experimental Physics (at the level of PHYS 510 (6510)).
2. Quantum Mechanics (at the level of PHYS 572 (6572) Quantum Mechanics I, or higher)
3. Statistical Physics (at the level of PHYS 562 (6562) Statistical Physics I, CHEM 796 (7960), or higher)
4. Electricity and Magnetism (at the level of PHYS 561 (6561)).

Physics 6510 should normally be taken within the first year.

Because the Q exam and A exam are not ordinarily designed to test comprehensive knowledge, students are generally expected to demonstrate mastery of core subjects through letter grades in Cornell courses. Students with strong preparation may, with the permission of their Special Committee, be able to forego coursework in one or more core subjects (but not PHYS 6510) in order to focus on more advanced courses. For students with exceptional experimental preparation, the Physics 6510 experience can be customized. However, students who skip

directly to advanced courses should be comprehensively tested on the core material as part of the A exam. An advanced undergraduate laboratory course, including Cornell's Physics 4410 course, does not satisfy the Physics 6510 requirement.

Many students will benefit from courses in mathematical methods and computational techniques, although these subjects are not generally emphasized to the same degree as the core subjects listed above. Options for interested students include: *Mathematical methods* T&AM 610-614 (6100-6140), AEP 321-322 (3210-3220), MATH 472 (4720) (Statistics), MATH 615 (6150) *Computational techniques* PHYS 680 (7680); CIS 401, 402, 403, or 405 (4201-4205); CS 421 (4210); see also courses listed at http://www.cis.cornell.edu/cse/courses.htm .

Students interested in careers that involve teaching may benefit from EDUC 404 (4040) and 405 (4050) "Learning and Teaching I and II", or PHYS 683 (7683) "Physics Learning and Teaching" (when offered).

- **Course Recommendations Beyond the Core Subjects:**
- **Breadth**

It is recommended that all students should acquire some knowledge of at least one current area of active scientific research outside of their thesis area, through study at the level and extent of a graduate-level course in a different sub-field of physics or a graduate-level course in a different science or engineering department. Students should discuss with their Special Committee which courses are acceptable for fulfilling this recommendation.

- **Number of Courses**

For students not engaged in research, the number of courses per semester considered to be full-time is two to three, in addition to work as a teaching assistant. Students with less-rigorous physics backgrounds or those on fellowship or who are engaged in research should consult with their Special Committee about taking fewer or more courses per semester. Most students will find that a full-time load of courses and TA work will require an effort of approximately 60 hours per week. During the transition from coursework to full-time research, the number of courses taken should decrease in concert with the increase in time devoted to research.

The total number of courses to be taken during a graduate career will differ by subfield, but should generally range from 7 to 16 courses.

- **Academic Performance**

To maintain good standing as a graduate student in the Field, students are expected to achieve at least a B grade average. An average of at least a B+ is more the norm, however, and students performing below this level must meet with their special committee chair and the DGS for guidance and support.

- **Colloquia and Seminars:**

Every graduate student is expected to attend the weekly physics colloquium, even when the topic differs from his or her specific field of interest. Special Committees are encouraged to ask questions about the ideas presented in the colloquia during A exams. Students are also

encouraged to attend other more specialized weekly seminars throughout their graduate careers, as an effective way to broaden their understanding of current research areas.

- **Course Recommendations Beyond the Core Subjects, by Sub-Field:**

Accelerator Physics:

Strongly Recommended:
PHYS 656 (7656) Introduction to Accelerator Physics and Technology
PHYS 657 (7657) The Storage Ring as a Source of Synchrotron Radiation
PHYS 574 (6574) Applications of Quantum Mechanics II
PHYS 551 (6551) Classical Mechanics, Nonlinear Dynamics, and Chaos
PHYS 688 (7688) Advanced Topics in Accelerator Technology
Consider:
PHYS 645 (7645) High–Energy Particle Physics I
PHYS 646 (7646) High–Energy Particle Physics II
PHYS 653 (7653) Statistical Physics II
PHYS 680 (7680) Computational Physics
ECE 581 (5810) Introduction to Plasma Physics (=A&EP 606 (6060))
T&AM 578 (5780) Nonlinear Dynamics and Chaos
PHYS 360 (3360) Electronic Circuits
A&EP 711 (7710) Principles of Diffraction
A&EP 440 (4440) Quantum and Nonlinear Optics

Astrophysics Theory: (more detailed course recommendations are available on the web page http://www.astro.cornell.edu/academics/gradrequire.php)

Strongly Recommended:
PHYS 574 (6574) Applications of Quantum Mechanics II
ASTRO 511 (6511) Physics of Black Holes, White Dwarfs and Neutron Stars
ASTRO 560 (6560) Theory of Stellar Structure and Evolution
Consider:
PHYS 553 + 554 (6553 + 6554) General Relativity (=ASTRO 509 + 6510)
ASTRO 516 (6516) Galactic Structure and Stellar Dynamics
ASTRO 530 (6530) Astrophysical Processes
ASTRO 599 (6599) Cosmology
ASTRO 690 (7690) Computational Astrophysics
ASTRO 555 (6555) Theory of the Interstellar Medium
PHYS 635 + 636 (7635 + 7636) Solid State Physics I + II
PHYS 645 (7645) Particle Physics
PHYS 651 + 652 (7651 + 7652) Relativistic Quantum Field Theory I + II
PHYS 680 (7680) Computational Physics
ASTRO 410 (4410) Experimental Astronomy
ASTRO 520 (6520) Radio Astronomy
ASTRO 525 (6525) Techniques of Optical/Infrared and Submillimeter Astronomy
ASTRO 570 (6570) Physics of the Planets
ASTRO 571 (6571) Mechanics of the Solar System (=T&AM 673)

ASTRO 590 (6590) Galaxies and the Universe
A&EP 606 (6060) Introduction to Plasma Physics (=ECE 581 (5810))
A&EP 607 (6070) Advanced Plasma Physics (=ECE 582 (5820))

Condensed Matter Experiment:

Biophysics:

Strongly Recommended:
BIOBM 330 (3300)/331 (3310)/332 (3320) Principles of Biochemistry
Consider:
PHYS 635 (7635) Solid-State Physics I
PHYS 653 (7653) Statistical Physics II
PHYS 330 (3330) Modern Experimental Optics
PHYS 360 (3360) Electronic Circuits
A&EP 470 (4700) Biophysical Methods
A&EP 663 (6630) Nanobiotechnology
BIOBM 432 (4320) Survey of Cell Biology
BIOBM 631 (6310) Protein Structure and Function
BIOBM 632 (6320) Membranes and Bioenergetics
BIOBM 633 (6330) Biosynthesis of Macromolecules
BIOBM 636 (6360) Advanced Cell Biology
BIOBM 638 (6380) Macromolecular Interactions and Cell Function
CHEM 357 + 358 (3570 + 3580) Organic Chemistry for the Life Sciences
CHEM 359 + 360 (3590 + 3600) Honors Organic Chemistry I and II
CHEM 389 + 390 (3890 + 3900) Honors Physical Chemistry I and II

Soft Condensed Matter Physics:

Strongly Recommended:
PHYS 635 (7635) Solid-State Physics I
PHYS 653 (7653) Statistical Physics II
Consider: (see also other courses listed under Biophysics)
PHYS 360 (3360) Electronic Circuits
PHYS 330 (3330) Modern Experimental Optics
PHYS 682 (7682) Computational Statistical Mechanics
PHYS 683 (7683) Basic Training: Tools for Condensed Matter Theory
CHEM 357 + 358 (3570 + 3580) Organic Chemistry for the Life Sciences
CHEM 670 (6700) Fundamental Principles of Polymer Chemistry
CHEM 796 (7960) Statistical Mechanics
CHEME 731 (7310) Advanced Fluid Mechanics and Heat Transfer
M&AE 601 (6010) Foundations of Fluid Dynamics and Aerodynamics
M&AE 737 (7370) Computational Fluid Mechanics and Heat Transfer
MS&E 589 (5890) Colloids and Colloid Assemblies
T&AM 578 (5780) Nonlinear Dynamics and Chaos
T&AM 663 (6630) Solid Mechanics I
T&AM 664 (6640) Solid Mechanics II

T&AM 617 (6170) Advanced Mathematical Modeling--Biological and Fluid Dynamics

Solid State or Low Temperature Physics:

Strongly Recommended:
PHYS 574 (6574) Applications of Quantum Mechanics II
PHYS 635 (7635) Solid-State Physics I
Consider:
PHYS 636 (7635) Solid-State Physics II
PHYS 653 (7653) Statistical Physics II
PHYS 683 (7683) Basic Training: Tools for Condensed Matter Theory
PHYS 360 (3360) Electronic Circuits
PHYS 330 (3330) Modern Experimental Optics
A&EP 440 (4400) Quantum and Nonlinear Optics
A&EP 661 (6610) Nanocharacterization
A&EP 662 (6620) Micro/Nano-fabrication and Processing
A&EP 711 (7710) Principles of Diffraction
MS&E 545 (5450) Magnetic and Ferroelectric Materials
MS&E 585 (5850) Electronic, Magnetic, and Dielectric Properties
CHEM 605 (6050)/606 (6060)/607 (6070) Advanced Inorganic Chemistry
CHEM 629 (6290) Electrochemistry

X Ray Physics:

Strongly Recommended:
PHYS 635 (7635) Solid-State Physics I
A&EP 711 (7710) Principles of Diffraction
Consider: (see also other courses listed under the other sub-fields of Condensed Matter Experiment)
PHYS 574 (6574) Applications of Quantum Mechanics II
PHYS 636 (7635) Solid-State Physics II
PHYS 653 (7653) Statistical Physics II
PHYS 656 (7656) Introduction to Accelerator Physics and Technology
PHYS 683 (7683) Basic Training: Tools for Condensed Matter Theory

Condensed Matter Theory:

Strongly Recommended:
PHYS 635 (7635) Solid-State Physics I
PHYS 636 (7635) Solid-State Physics II (optional for biophysics theory)
PHYS 653 (7653) Statistical Physics II
PHYS 680 (7680) Computational Physics
PHYS 683 (7683) Basic Training: Tools for Condensed Matter Theory
Consider:
PHYS 551 (6551) Classical Mechanics, Nonlinear Dynamics, and Chaos
PHYS 574 (6574) Applications of Quantum Mechanics II

PHYS 651 (7651) Relativistic Quantum Field Theory I
PHYS 652 (7652) Relativistic Quantum Field Theory II
PHYS 654 (7564) Theory of Many-Particle Systems
PHYS 681-689 (7681-7689) Relevant special topics courses
T&AM 578 (5780) Nonlinear Dynamics and Chaos
T&AM 617 (6170) Advanced Mathematical Modeling--Biological and Fluid Dynamics
CHEME 731 (7310) Advanced Fluid Mechanics and Heat Transfer
M&AE 601 (6010) Foundations of Fluid Dynamics and Aerodynamics

Elementary Particle Experiment:

Strongly Recommended:
PHYS 645 (7645) High–Energy Particle Physics I
PHYS 646 (7646) High–Energy Particle Physics II
PHYS 651 (7651) Relativistic Quantum Field Theory I
Consider:
PHYS 574 (6574) Applications of Quantum Mechanics II
PHYS 656 (7656) Introduction to Accelerator Physics and Technology
PHYS 360 (3360) Electronic Circuits
PHYS 652 (7652) Relativistic Quantum Field Theory II
Group Theory for Particle Physicists (new course, number to be assigned)

Elementary Particle Theory:

Strongly Recommended:
PHYS 574 (6574) Applications of Quantum Mechanics II
PHYS 651 (7651) Relativistic Quantum Field Theory I
PHYS 652 (7652) Relativistic Quantum Field Theory II
At least one semester of PHYS 661 (7661) Advanced Topics in High-Energy Particle Theory (Taking PHYS 661 more than once is encouraged, as topics vary from year to year.)
Consider:
PHYS 553 + 554 (6553 + 6554) General Relativity (=ASTRO 509 + 510)
ASTRO 599 (6599) Cosmology
PHYS 645 + 646 (7645 + 7646) High–Energy Particle Physics I + II

Students Conducting Research in Other Sub-Fields should consult regularly with their Special Committee to formulate an appropriate sequence of courses.

Note: If you notice that any of the recommendations require updating, please inform the physics office (Kacey Bray, klb79@cornell.edu).

VI. Major or Minor Outside of Physics—recommended courses

Master's Degree (with thesis)

Physics Major—6510; 6561; 6572; and one additional course >4400 (>3 cr. hrs.).

Physics Minor—Three courses >3300 (each >3 cr. hrs.), at least two of which to be taken as a graduate student at Cornell.

Ph.D. degree_(or Master's without thesis)

Physics Major (with minor outside physics)—The "Breadth" requirement is naturally transferred to the field of the minor.

Physics Minor (with major outside physics)—Four courses (each >3 cr. hrs.) including at least two courses selected from 3323, 3327, 4443, 4444, 4454, >6500 but <7680. At least three of these four should be taken as a graduate student at Cornell.

VII. Examination Requirements

Q Exam

The Qualifying Examination (Q exam) is an oral examination administered on the Friday afternoon of the first week of class in the fall and spring semesters. This examination is required by the Field of Physics and not by the Graduate School. The main purpose of the exam is diagnostic, wherein any gaps in a student's knowledge are identified and remedies suggested. It also serves to identify students who may have difficulty completing a Ph.D. (though it is not designed to build attrition into our admissions process – our default assumption is that every admitted student is capable of passing the Q exam).

Each student will have two ½-hour sessions during the afternoon, each administered by two physics faculty members. One session will focus more on classical / macroscopic phenomena, such as Classical Mechanics, Electricity and Magnetism, Special Relativity, etc.. The other session will focus more on quantum or microscopic phenomena, such as Quantum Mechanics and Statistical Mechanics. In both cases, the level will be at the typical advanced undergraduate level. You should expect many of the questions to take an estimation, *i.e.*, "back of the envelope," style. While completion of the core graduate courses is not required before taking the Q exam, they will help solidify the concepts. Advanced students planning to bypass the core courses should expect the qualifying examination to probe that material.

All students will take the Qualifying Examination in the Spring Semester of their first year, though students who enter with a physics Master's degree, or who appear upon entrance to be otherwise exceptionally well prepared in physics, will be encouraged to take the Qualifying Examination in their first term.

At the conclusion of the Qualifying Examination, the examining committee shall meet to formulate recommendations to each student, which will be one of the following courses of action. The recommendation will be made on the basis of the Qualifying Examination, of performance at Cornell in the core courses, of credentials upon admission, and any other information available to the Committee. The recommended courses of action are:

(1) The student is encouraged to continue in the Ph.D. program, moving as rapidly as possible toward completion of course work, selection of Ph.D. thesis area, and completion of the Admission to Candidacy Examination (an examination mandated by the Graduate School). Even in this scenario, it is not uncommon for a student to receive a recommendation to TA a certain course to help cement a particular core subject.

(2) The student is advised to address broader inadequacies in their preparation, and to repeat the Qualifying Examination the following semester. This recommendation will be made no more than twice. At the third attempt (the Spring Semester of the second year), the committee will recommend either course (1) or (3). Determination of the final course of action for a given

student will be the purview of the DGS, with consideration of recommendation of the Q exam committee and the input of the advisor or special committee chair.

(3) In rare cases, the student is advised to start work immediately toward the Master's degree (with thesis) and to consider the possibility of terminating work at Cornell with the Master's degree. This degree should be completed before the start of the third academic year. At its discretion, the Special Committee may, at the time of the Master's Final examination, agree to consider it as a Qualifying Examination. In this case, the examining Special Committee must have a composition suitable for a continuing Ph.D. Special Committee. If the Committee agrees to continue as a Ph.D. committee, the student would return to the path of recommendation (1) above.

A Exam

Every student who has a Ph.D. major in the Field of Physics must take the Admission to Candidacy exam (ACE or A-exam) before commencing the seventh semester of graduate work. Scheduling of the A-exam after this time is subject to the approval, via general petition, of the Graduate School. In all cases, the timing of this exam is such that the student should have passed the Q exam and completed all of the recommended core courses, or have the equivalent comprehension (see Section V), and at least a substantial part of the work for any outside minor(s). In addition, the student should have begun research with the faculty member with whom he or she expects to carry out their thesis research, and should have formed his or her permanent Special Committee.

Scheduling of the A-exam will not be approved by the Field until the Physics 6510 requirement has been satisfied.

The A-exam usually involves written answers to questions posed by special committee members, followed by an oral examination. It is expected that no more than one month will elapse from the time when the questions are posed until the exam takes place, and to ensure this, many students find it beneficial to schedule the exam before collecting the questions. Alternative formats for the A-exam are acceptable with the consent of all committee members. Upon passing this exam, a student is formally admitted to Ph.D. candidacy status. If the student passes "at the Master's degree level", whether passing or failing at the Ph.D. level, the Special Committee may recommend the award of a Master's degree without thesis. The graduate school requires the completion of at least four registration units before issuing the Master's degree.

Students who fail the A-exam have the following three choices: (1) leave Cornell, perhaps with a Master's degree without a thesis; (2) start work on a Master's thesis which should be completed before the end of the year (normally before the end of the third academic year of graduate work); or (3) with the specific advice of the Special Committee, a re-take shall be allowed.

It is generally expected that each of the questions posed by the faculty member should be structured so that they take no more than 1 week for the student to answer. It is also generally expected that the student has the opportunity to consult with the faculty member involved in formulating the answer. The faculty member may waive the question or ask for a description of thesis topic, or (for example) ask that the student write a referee's report on a published research paper. However, ultimately, the structure of this portion of the A exam is at the discretion of the

committee. The student and committee members should discuss the parameters of the questions so there is a clear understanding of requirements.

The candidate must provide a copy of all answers to each of the committee members at least one week in advance of the A-exam. This may be waived at the discretion of the faculty members, but doing so is not recommended.

The student must file a schedule of A exam with the DGS and the graduate school no less than one week before the exam is to take place.

At the A exam, the student presents the answers to one or more of the posed questions in the form of a PowerPoint or similar presentation. The student should be prepared to address all three questions, with 5 to 10 slides on each. The committee asks questions during and after the presentation. These questions need not be limited to the content of the A-exam questions, and particularly students who have opted out of the core courses should expect questions on those subject areas. Again the structure of this portion of the exam is at the discretion of the committee, but substantial deviations should be made clear to the student in advance so there is a clear understanding of requirements.

The student should also prepare a plan of their thesis topic, which may be a written document, or a presentation. This should be a detailed presentation if a committee member has asked that this serve as their "question". Otherwise, the student should be prepared to present this to the committee as a thesis plan outline of a one page document or 2 slides maximum. This may be waived at the discretion of the committee but doing so is not recommended.

B Exam

The final Ph.D. Examination (B exam) is oral and is conducted by the student's Special Committee after the thesis has been accepted and all other prescribed work has been completed. The student gives a public talk lasting about 30-45 minutes, followed by a closed door session with the special committee. The exam is limited to the thesis and related subject matter. The student should prepare a poster one week before the exam to advertise the public talk and should see Kacey Acquilano for poster requirements. This satisfies the Graduate School requirement that the exam be posted a minimum of 7 days in advance.

The Physics Department recommends that the thesis be circulated to the student's Special Committee, in a form already suitable for submission, at least two weeks in advance of the B exam. The Graduate School mandates circulation at least one week in advance. The Physics DGS will sign the scheduling form, which must be submitted at least one week in advance of the exam, upon circulation of the thesis to the Committee.

Master's Final Exam

Graduate students who decide not to pursue the doctoral degree may earn a Master's degree without thesis by completing four registration units (semesters). Candidates for the degree must have passed the Q exam, demonstrated mastery of the four core subjects (see p. 6) and pass a final exam for the degree. Research is not required. The final exam may either be a special

Master's Final Exam or an A exam passed at the Master's level or better. Students who take the special exam or pass the A exam only at the Master's level do not continue in the PhD program.

The Master's final exam is generally an oral exam administered by the special committee. For students who have already demonstrated mastery of the four core subjects (see page 6) through satisfactory completion of the relevant courses, the exam may start with a presentation by the student on a topic agreed to in advance by the committee. If the student has not previously shown mastery of the core subjects, the exam should focus on these. In order to pass the exam, the student must demonstrate comprehension at the level of a grade of "Satisfactory". Before the examination, the student should request a change of status to Master's candidacy. This request can be made conveniently by the formal reorganization of his or her Special Committee.

Foreign Language Examinations

No foreign language is required for either a Master's or a Ph.D. degree with a major in the Field of Physics.

-Lawrence Gibbons (2018)

Appendix: The Graduate Conference in Physics

This Appendix is mainly for reference by faculty.

Membership in the Conference consists of two categories:

(1) regular members of the Field of Physics. This category includes all members of the Physics Department faculty who have been approved for membership in the Graduate Faculty. It also includes a small number of faculty not in the Department of Physics who have been specifically approved for regular membership in the Field.

(2) *ad hoc* members of the Conference. These are people who are currently teaching a graduate physics course, and people who are currently serving as *ad hoc* members on Physics Special Committees.

All Ph.D. members of the Physics staff (including LASSP and LEPP) who are not members of the Conference are invited to attend Conference meetings and to participate in the discussions. Inquiries about possible membership should be addressed to the Conference Chair.

The Conference frequently solicits the opinions of Physics graduate students on matters of general education policy, either informally through its individual members or formally by the appointment of students to committees that report to the Conference. The student members of such committees, appointed by the Chair, participate in the report and in the ensuing Conference discussions.

The Chair of the Physics Department serves *ex officio* as Chair of the Graduate Conference.

The Director of Graduate Studies (DGS) represents the Field of Physics in the Graduate School and serves as the official link between the Field and the Dean of the Graduate School. The DGS is appointed by the Chair and normally serves, subject to ratification by the Conference, for a period of three years. The DGS is automatically a member of the Admissions Committee.

Meetings are held several times each year upon call by the Chair. At any meeting any member may bring up for discussion any graduate academic business, including discussion of the performance and progress of individual students.

Standing Committees: (1) The Admissions Committee consists of the eight to ten faculty members appointed by the Chair. Appointments are normally made in September for three-year staggered terms. The Conference Chair designates one of the experienced appointed members to become the Chair of the Admissions Committee. (2) Four or five faculty members serve as an Advisors' Group for each entering class of graduate students, remaining associated with the students through their second year. (By the end of the second year, the students will normally have chosen their permanent special committees.) This group is informally known as the "Wise People". A new group of faculty is assigned to each incoming class. The advisors' group is appointed during the summer by the Chair for the two-year term. One of the members of the advisors' group is assigned as Chair of the temporary special committee of each incoming student by the Conference Chair. Students may not remove the Wise Person from their committee until after passing the Q exam.

Ad hoc committees are formed at the discretion of the Conference or of the Chair.

Agreements of the Conference express the educational policy of the Field. They are written in the minutes of the meetings, and the agreements to date are summarized in this document.

Any significant exception to any agreement or requirements proposed for any student by the special committee should be brought to the Conference for discussion and possible approval as a special case.

Minutes of each meeting are recorded by the Administrative Assistant to the Chair. The minutes of all meetings are on file in the Department Office and are open to any member of the Conference. At the discretion of the Chair or by direction of the Conference, appropriately edited parts of the minutes of any meeting may be posted or otherwise made available to others, especially to Physics graduate students.