REQUIREMENTS FOR THE M.S. AND Ph.D. DEGREES
DEPARTMENT OF PHYSICS AND ASTRONOMY
UNIVERSITY OF PITTSBURGH

(Revised: November 13, 2018)

The requirements for the Master of Science (MS) and Doctor of Philosophy (PhD) degrees as described here supersede all previous versions. University requirements are described in detail in the University of Pittsburgh Graduate and Professional Bulletin, which is available under Bulletins/Courses at http://www.pitt.edu/~graduate/.

The graduate degrees offered by the Department of Physics and Astronomy are PhD in Physics (see Part A below) and MS in Physics (see Part B below).

Part A. THE PHD DEGREE IN PHYSICS

A.1 REQUIRED COURSES

Except for students on a directed study plan, each PhD candidate is normally expected to take the following physics courses for credit preferably in the first year of graduate study, but certainly within the first two years of graduate study. All incoming graduate students that do not test out of PHYS 2513 (Dynamical Systems), must enroll in Physics 2513 during their first year of study in the Department of Physics and Astronomy at the University of Pittsburgh.

Core Courses (3 credits each unless noted otherwise)

PHYS 2373 Mathematical Methods in Physics
PHYS 2513 Dynamical Systems (**MUST TAKE IN FIRST YEAR**)
PHYS 2541 Statistical Mechanics & Thermodynamics
PHYS 2555 Classical Electricity & Magnetism (**4 credits**)
PHYS 2565 Non-relativistic Quantum Mechanics I
PHYS 2566 Non-relativistic Quantum Mechanics II

Courses Required for Acceptance to Candidacy:

PHYS 2997 Teaching of Physics (1 credit)
PHYS 2998 Teaching of Physics (or Astronomy) Practicum
PHYS 2999 Physics and Astronomy Colloquium

A minimum of 72 credits is required for the PhD degree, including any credits transferred. As part of these 72 credits, all students must take at least four advanced level (3000-level) graduate courses offered within our Department as described below in Section A.6.

A.2 *POSSIBLE EXEMPTIONS FROM THE CORE PHYSICS COURSES*

A.2.a *WRITTEN ADVANCEMENT EXAMS FOR NEW PHD STUDENTS*

New graduate students, entering our program for the first time, may elect to take a written advancement exam in order to earn exemption from any (or all) of the six core physics courses. Each exam will be set at a level comparable to the level of the Comprehensive Examinations in each of the courses (see Section A.5) below. The exams will take place during the orientation period prior to the start of the fall semester each academic year. In order to earn exemption from a course and pass the Comprehensive Examination in that course, a student must earn a grade of 60% or higher in the examination. Any student earning a grade below 60% in an advancement exam will be required to take the corresponding course and pass the Comprehensive Examination in that course during their first academic year in the program.

The following rules shall apply to all advancement examinations.

1. **Exams will be written, administered, and graded by a member of the faculty that has taught the relevant course within the 10 years immediately preceding the exam. This will be the faculty member that last taught the course unless unusual circumstances render this impossible.**
2. **Exam results will be final and will not be subject to appeal.**
3. **Students must notify the Department (via email to the Director of Graduate Studies and the Graduate Administrator) of their intent to take an advancement exam prior to 1 August of the year of their first entry into the graduate program.**
4. **Students attempting an advancement exam may not enroll in the undergraduate-level course in that same core subject area.**
5. **An attempt at a written advancement exam is a "free shot" at passing the Comprehensive Examination in Physics and does not count toward the two attempts students are given to pass the Comprehensive Examination.**

A.2.b *ORAL ADVANCEMENT EXAMS FOR STUDENTS ENTERING WITH A M.S. DEGREE IN PHYSICS OR ASTRONOMY*

New graduate students entering our program for the first time that have earned a M.S. degree in physics or astronomy may be eligible to take an oral examination to earn exemption from the core courses in physics and pass the Comprehensive Examination. In order to be eligible for an oral test out exam, the student must have earned an M.S. degree in physics or astronomy at another

institution. The oral exam is designed to streamline the transition into PhD research for those students that have taken their M.S. coursework elsewhere.

The following rules shall apply to all oral advancement exams.

1. **Only students with an M.S. degree may attempt an oral exam. In some cases, international students are admitted with a Bachelor's equivalency. This is typically a combination of a 3-year B.S. and a 2-year M.S. The Dietrich School does not recognize such degrees as M.S. degrees. A student with a Bachelor's equivalency is <u>not</u> eligible for the oral exam option.**
2. **Students intending to take an oral advancement exam must notify the Department (via email to the Director of Graduate Studies <u>and</u> the Graduate Administrator) of their intent to take an oral advancement exam prior to 1 August of the year of their first entry into the graduate program.**
3. **The oral exam will be administered by an ad hoc committee of three (3) faculty members who have taught one or more of the core subjects within the past ten years. Other faculty, not on the ad hoc committee, may sit in on the exam if desired. The exam will take place prior to the end of the second week of the fall semester, at a mutually agreeable time, and will not exceed two hours. Students will be expected to attend the respective course(s) until the results of the oral exam(s) are known.**
4. **The ad hoc oral exam committee may recommend that the student pass any, or all, of the core physics courses. Such a recommendation will exempt the student from the course(s) and constitutes passing of the Comprehensive Examination(s) (See Section A.5 below) in the course(s).**
5. **The ad hoc oral exam committee may recommend that the student fail any, or all, of the core physics courses. Such a recommendation will require the student to enroll in the relevant course and to pass the Comprehensive Examination in that course during the first academic year in the program.**
6. **Oral advancement exam results are final and are <u>not</u> subject to appeal.**
7. **Students attempting an oral advancement exam may <u>not</u> enroll in the undergraduate course in that same core subject area.**
8. **An attempt at an oral advancement exam will be a "free shot" at passing the Comprehensive Examination in Physics and will <u>not</u> count toward the two attempts**

that each student is given to pass the Comprehensive Examination.

A.3 ***PRETESTS AND ADVISING; QPA REQUIREMENT***

The department requires that prior to the start of Fall classes the instructors for the first-year graduate core courses PHYS 2513, PHYS 2541, PHYS 2555, and PHYS 2565 test the incoming students on their mastery of the undergraduate physics prerequisites for these courses. This pre-test is used for **diagnostic purposes only** and does not bear on the standing of the student in the program. The student's academic advisor, in consultation with the core course instructor(s), may advise students who do not perform well on the pre-test(s) to enroll in the advanced undergraduate version(s) of the course(s) before taking the graduate-level core course(s) the following year. In exceptional cases in which the student's academic advisor deems the student to lack sufficient undergraduate background to be in a position to succeed in the graduate courses, the student's academic advisor may **require** the student to take the advanced undergraduate version of the course before taking the graduate version of the course in order to remain in good academic standing. This decision will be based on the student's performance on the diagnostic pre-test and an interview with the student and will be made in consultation with the core course instructor(s).

Graduate students must maintain a QPA of at least 3.00 for all required core courses and for all graduate courses overall. PHYS 1341, 1370, 1371, and 1372 are considered to be substitute core courses for the purpose of QPA calculations and are acceptable for satisfying a portion of the MS course requirement. (For QPA calculations letter grades are assigned the following values: D– = 0.75, D = 1.00, D+ = 1.25, C– = 1.75, C = 2.00, C+ = 2.25, B– = 2.75, B = 3.00, B+ = 3.25, A– = 3.75, A = 4.00, A^+ = 4.00.) The Graduate Bulletin describes the University's regulations regarding grades.

Students testing out of all core courses based on the provisions of Section A.2 above will not be subject to the core course QPA requirement, but will still be subject to the overall QPA requirement.

A.4 ***PRELIMINARY EVALUATION***

All graduate students must pass the "Preliminary Evaluation" at the end of their first academic year in the program. As outlined in the "Regulations Governing Graduate Study at the University of Pittsburgh," the decision whether or not a student has passed the Preliminary Evaluation is based on the student's performance in courses taken during the first two terms of study. A graduate student is deemed to have passed the Preliminary Evaluation if he/she has met the QPA requirement (QPA > 3.0) and has obtained final examination scores of at least **50%** in graduate-level (2000-level) courses or at least **75%** in the 1300-level, advanced undergraduate courses in each of the following core subject areas: Dynamical Systems, Statistical Mechanics, Quantum Mechanics, and Electricity and Magnetism. The same standard for final exam performance applies to those students who were exempted from the course. A graduate student who passes the Preliminary Evaluation is also considered to have passed the Comprehensive Examination for the MS degree and may apply for that degree as soon as all other requirements for the MS have been satisfied.

Review process: The Graduate Committee meets at the end of the Fall term to evaluate the course performance of the first-year students during their initial semester. If the Committee finds that a student has failed to perform adequately, it will propose remedial steps to be taken during the second term. The Graduate Committee reviews the performance of all first-year graduate students again at the end of the Spring term to determine whether or not they have passed the Preliminary Evaluation and possibly also the Comprehensive Examination. In making its decision in the event of an inadequate final examination score the Committee may consider all aspects of a student's academic record including other measures of competence. If the Committee concludes that a student has not passed the Preliminary Evaluation at the end of the first year, the Committee may grant that student a time extension of no more than one additional year; in that event the Committee will set specific conditions that the student must fulfill during that time. If the Committee determines that the student has not passed the preliminary evaluation and is not eligible to continue toward the M.S. or Ph.D. degrees, the student is entitled to appeal that decision. In order to appeal the decision, the student must submit a request in writing to the Graduate Committee to reconsider its evaluation within **two weeks** of receiving written notification of the decision of the Graduate Committee. The request must state specifically which decision is being appealed and give detailed reasons why the appeal should be considered. The Graduate Committee is **not** obligated to consider petitions received after this two-week period has expired and will consider such requests at its discretion.

A.5 ***COMPREHENSIVE EXAMINATION REQUIREMENT***

All doctoral students must pass the Comprehensive Examination by the end of their second academic year. As outlined in the "Regulations Governing Graduate Study at the University of Pittsburgh," the decision whether or not a student has met the criteria for passing the Comprehensive Examination is based on the student's performance on the final examinations in the six required graduate core courses listed in Section A.1. A graduate student is deemed to have passed the Comprehensive Examination if the student has met the QPA requirement (**QPA > 3.0** in all classes **and** in the core physics classes) **and** has obtained a final examination score of at least **60%** in each of the **six core courses**. As the Comprehensive Examination must be passed by the end of the second year, this means that each student gets two attempts to pass the Comprehensive Examination. The same standard for final examination grades applies to students who were exempted from the particular course.

Review process: During its meeting at the end of every Spring term, the Graduate Committee reviews in particular the performance of all second-year students who have not yet have passed the Comprehensive Examination. In making its decision in the event of an inadequate final examination score the Committee may consider all aspects of the student's academic record including other measures of competence. If the Graduate Committee concludes that a student has not passed the Comprehensive Examination by the two-year deadline, the Committee may grant that student a time extension of no more than one additional year; in that event the Committee may place the student on probation and it will set specific conditions that the student must fulfill during that time. The Committee will review that student's performance again at the end of that time extension to determine whether or not he/she has passed the Comprehensive Examination. If the Committee determines that the student has not passed and must leave the Ph.D. program, the student is entitled to appeal that decision by promptly submitting a written request along with a statement of the reasons. If the Committee determines that the student has not passed and must leave the Ph.D. program, the student is entitled to appeal that decision. In order to appeal the decision of the Graduate Committee, the student must submit a request in writing to the Graduate Committee to reconsider its evaluation within **two weeks** of receiving written notification of the Graduate Committee's. The request must state specifically which decision is being appealed and give detailed reasons why the appeal should be considered. The Graduate Committee is **not** obligated to consider petitions received after this two-week period has expired and will consider such requests at its discretion.

A.6 ***ADVANCED TOPICS COURSES***

All students must take at least four 3000-level courses offered in our Department to earn the PhD degree. It is expected that the vast majority of students will take all four of these courses in the Department of Physics and Astronomy. In some instances, graduate courses taught by other departments may align better with the research of a student and may be substituted for a course in the Department of Physics and Astronomy. Students may take courses outside of the Department of Physics and Astronomy to satisfy their requirement for advanced courses subject to the following regulations.

1. Students are expected to take all advanced courses in Physics and Astronomy that are directly relevant to their research. Relevance will be determined in consultation with the thesis advisor and the thesis committee. The thesis committee will report on the appropriateness of the coursework of the student.

2. Students must take a minimum of 2 advanced courses taught by the Department of Physics and Astronomy.

3. Students may substitute an advanced graduate course taught outside the Department of Physics and Astronomy for an advanced course with approval of the Graduate Curriculum Committee or if the course is among those courses listed for standing approval by the Graduate Curriculum Committee. The approved list is below.

4. Faculty and/or students may petition the Graduate Curriculum Committee to add courses to the standing list of approved courses. In order to do so, the Graduate Curriculum Committee must be provided with, minimally, a course syllabus, a justification for the course in the student's field of specialty, a textbook (if used), and a statement from a recent instructor of record addressing the general level (M.S. or Ph.D.) of the course and the degree of commitment required by the course.

Course Selection. The 3000-level courses currently being offered are listed below; there will be additions, substitutions, and special courses over time. The choice of courses should be made in consultation with the student's research advisor who may recommend or require additional courses. Curriculum recommendations may be found in Appendix II.

3000-Level Courses

3274	Computational Methods
3542	Advanced Statistical Mechanics
3580	Galactic and Extragalactic Astronomy
3705	Astronomical Techniques
3707	Intro to Many Body Physics
3715	Solid State Physics
3716	Advanced Solid State Physics
3717	Particle Physics
3718	Advanced Particle Physics
3725	General Relativity I
3726	General Relativity II
3750	Stellar Structure
3765	Field Theory 1
3766	Field Theory 2
3770	Topics in Quantum Physics
3785	Cosmology
3790	Particle Astrophysics

Courses Outside of Physics and Astronomy Approved for 3000-level Advanced Course Credit

PSYCH 2477	Design of Educational Systems
PSYED 2030	Experimental Design
PSYED 3472	Causal Inference in Educational Research
MATH 2301	Analysis I
MATH 2302	Analysis II

A **Directed-Study** (PHYS or ASTRON 3902) or **Directed-Research** (PHYS or ASTRON 3907) plan must be supervised by a faculty member. Registering for unsupervised **Independent Study** will be interpreted as registering to study for formal exams.

Students supported with departmental Teaching, Research or Fellowship funds are expected to complete the core course requirements before taking optional or elective courses in other departments. Requests to register for courses outside of the department must be approved by the student's academic advisor in addition to satisfying the regulations stipulated above. Students supported by Research funds while completing degree requirements must also receive written approval from their research advisor in order to register for courses outside of the department. A copy of this approval must be provided to the Graduate Coordinator for the students' records.

A.7 *RESEARCH AGREEMENT*

Within six months after receiving written notification of having passed the Comprehensive Examination each graduate student must file a completed Research Agreement which indicates that he/she has been accepted as a dissertation student by a research advisor. This form must be filed with the graduate coordinator in accordance with the procedures detailed in Appendix I. The research advisor and the student are jointly responsible for following these procedures. Only graduate students who have a current executed Research Agreement on file may register for PHYS 3000 (dissertation research).

If the chosen research advisor is from another department within the University, a graduate faculty member of the Department of Physics and Astronomy must serve as the co-advisor. (See APPENDIX III)

A.8 *ADMISSION TO CANDIDACY*

A student who has passed the Comprehensive Examination, has satisfied the required teaching courses, and has submitted a completed Research Agreement should, in consultation with his or her research advisor, file an application for admission to candidacy for the Doctor of Philosophy (PhD) degree. All students must be admitted to candidacy at least eight months before the defense of their dissertation.

A.9 *THE DISSERTATION COMMITTEE*

Once the Research Agreement has been executed, the research advisor and the graduate student should discuss the membership of the student's Dissertation Committee, which must be finalized within eight months after the graduate student has received written notification of having passed the Comprehensive Examination. The composition of the Dissertation Committee must be as follows:

- It consists of five faculty members, at least four of whom must be members of the Graduate Faculty.
- Four of the Dissertation Committee members must hold a primary, joint, or secondary faculty appointment in the Department of Physics and Astronomy. This departmental core group must include the student's research advisor (or co-advisor, see Appendix III), who serves as Committee Chair, two other members who work in the same major research area (astrophysics/cosmology, condensed matter physics, particle physics, and physics education research) in which the dissertation research falls, and one member who works in a different major research area. One of the two other members working in the same major research area as the dissertation must be a theorist and the other

an experimentalist; if that is not possible, then the group of three members other than the Chair must include both theoretical and experimental expertise. (Since the Dissertation Committee of a student in the area of physics education research cannot meet all of these conditions, the student's research advisor should first consult with the Director of Graduate Studies and/or the Department Chair regarding the membership of the departmental core group.)

- The fifth member of the Dissertation Committee must be a faculty member with science expertise whose primary appointment is in a department other than Physics and Astronomy. (If this member is from outside the University of Pittsburgh, the proposed individual must be approved in advance by the Department Chair and the Assistant Dean of A&S Graduate Studies. Typically the Assistant Dean requests a current CV and a letter from the student's research advisor explaining the reason for proposing this individual. This proposed individual must have publications, supervised graduate student(s), and taught graduate course(s). Essentially the equivalent of our Graduate Faculty.
- In order to comply with the Graduate Program Assessment Matrix, Committee members complete an individual evaluation form at each doctoral committee meeting. (see Appendix IV)

The first meeting of the Dissertation Committee must be held within <u>twelve months</u> after the student has received written notification of having passed the Comprehensive Examination. The University requires that the Committee meets with the student at least once every twelve months after that to assess his/her progress toward the PhD. The Committee has the authority to recommend or deny any extension of the statute of limitations, to require supplementary research, or the rewriting of any portion or all of the dissertation, among other actions, and shall conduct the final oral examination (dissertation defense). (Refer to Appendix I for further details regarding the function of Dissertation Committees.)

A.10 ***<u>TEACHING, THE TEACHING REQUIREMENT, AND PRESENTATIONS</u>***

Teaching is an essential element of graduate education. As such, **all graduate students are required to serve as Teaching Assistants** for either two regular academic terms or one regular term plus one six-week summer session. Qualified teaching activities must include contact with students such as teaching in a laboratory course or as recitation instructor. In order to satisfy the teaching requirement, the teaching assistant must have student contact hours (as in a recitation) for at least one semester. The teaching requirement cannot be satisfied under any circumstances through teaching responsibilities that consist entirely of grading (e.g., homework/exam/lab grading). Exemptions from the teaching

requirements may be granted in special cases (for instance, if a graduate student can document substantial prior teaching experience). Students should familiarize themselves with the University's Teaching Support (available through Center for Instruction Development and Distance Education, CIDDE) and the following departmental documents which may be found at the Department's web site under Graduate Program:

"Responsibilities of Teaching Assistants and Teaching Fellows"

"Guidelines for Proctoring Exams"

"Resource Room Guidelines"

"Guidelines of Financial Support"

"Contractual Obligations"

Students will be graded on their teaching performance. A committee comprised of the Associate Chair of the Department, the Chair of the Graduate Admissions Committee, and the Director of Graduate Studies will determine teaching grades. Teaching grades will be based upon the recommendations of the professor/instructor in charge of the course(s) in which the teaching assistants are employed **and** the student reviews of TA performance. Credit toward fulfillment of the teaching requirement of the Department of Physics and Astronomy will only be awarded to teaching assistants that receive a teaching grade of **B or better** for the semester or summer session. Repeated, unexcused failure to show up for classes prepared and on time **alone** suffices for teaching assistants to earn a grade below the **B** threshold without regard to any other considerations of teaching performance. Failure to receive a grade of B or better suffices for the Graduate Committee to find the student to not be in good academic standing. The consequences of being in poor academic standing include forfeiture of any funding guarantees, especially through teaching support, made to the student as part of their admissions offer and, possibly, not being permitted to continue in the graduate program in the Department of Physics and Astronomy at the University of Pittsburgh. The Graduate Committee will review such cases individually to render a final decision on the academic status of any student that has not performed teaching duties at an acceptable level. All aspects of the academic record of the student, especially past teaching performance, will be considered during the deliberations of the Graduate Committee. Teaching Assistants are notified and encouraged to review the results of the Teaching Evaluations at the end of the term.

Students that have exhibited exceptional teaching performance, as determined by the TA Grading Committee discussed in the previous paragraph, may be deemed, by the TA Grading Committee, to have satisfied their teaching requirement after only a single semester of teaching. In these cases, teaching assistant must have had considerable contact with students and cannot fulfill the teaching requirement if

their responsibilities were exclusively grading activities. The decisions of the TA Grading Committee are final and are not subject to appeal.

Faculty supervisors are strongly encouraged to arrange for their graduate students to prepare and deliver a variety of presentations as they progress, from journal club discussions to informal talks at group meetings and formally announced departmental seminars. Advanced students should be encouraged to present results from their dissertation research at professional meetings.

A.11 *ELECTRONIC DISSERTATION*

Information about preparing the dissertation electronically may be found on the Graduate Studies webpage at http://www.pitt.edu/~graduate/dissertation.html.

A.12 *STATUTE OF LIMITATIONS*

All requirements for the PhD degree must be completed within a period of ten years from the student's initial registration, or within eight years if the student was admitted with a Masters degree.

Under exceptional circumstances a candidate may apply for an extension of the statute of limitations. The request form must be approved by the Graduate Committee (currently we have the DGS or Assoc. Chair approve such requests) and submitted to the dean for final action. Requests for an extension must be accompanied by a departmental assessment of the work still required of the student to complete the degree as well as documented evidence of the extenuating circumstances leading to the request for an extension. Students who request an extension of the statute of limitations must demonstrate proper preparation for the completion of all current degree requirements. Arts & Sciences does not extend the seven-year statute of limitations of the Comprehensive Examination for the PhD under any circumstances.

A.13 *LANGUAGE*

There is no foreign language requirement, but the student must demonstrate English language proficiency in compliance with university policy as described in the University's Graduate Bulletin.

A.14 *PETITION PROCEDURE*

The Graduate Committee consists of the academic advisors, the core course instructors, the admissions committee, the director of graduate studies, and the department chair. It, or an appropriate

subcommittee, is empowered to make reasonable modifications to these requirements on a case-by-case basis in response to a petition by a graduate student. A committee meets to consider proposals for directed study or research, to receive petitions to modify or set aside rules, and/or to redress grievances.

Part B. THE MS DEGREE IN PHYSICS

Any student admitted to the MS or PhD program in Physics and Astronomy prior to Spring 2017 may earn a MS under the previous 24 credit guidelines. See the Graduate Administrator or Director of Graduate Studies for questions.

A minimum of 30 credits (3.0 GPA) is required for the MS for both thesis and non- thesis options. The student must be in compliance with all of the University's degree requirements. At least four physics courses (12 credits) at the graduate 2000-level must be completed with a grade of B (3.00). A 3000-level course can be substituted for one of these, but only with the Academic Advisor's approval. At most, up to 12 credits of 1300-level undergraduate coursework listed in the "Advising" section of this document as acceptable for graduate credit may also be used to satisfy the department's 30-credit requirement. No more than six credits of graduate work completed at another institution may be accepted by the Graduate Committee toward the completion of the residence requirement. Credits earned for PHYS 2997 and PHYS 2998 may not be used to satisfy this requirement. No more than two non-physics graduate-level courses, *approved in advance by the Director of Graduate Studies*, will be considered for credit for the MS degree.

B.1 COURSES:

There are three ways to earn an MS degree:

(1) Submit a thesis and complete at least six courses. Four courses must be at the 2000- level each with a grade of B or better. Courses and directed study/research credit must be accrued to reach the minimum 30 credit hours. Courses may include up to four 1300-level undergraduate classes and/or any number of 3000-level advanced graduate courses.

(2) Submit no thesis and complete at least eight courses. Courses and directed study/research credit must be accrued to reach the minimum 30 credit hours. Four courses must be at the 2000-level each with a grade of B or better. Courses needed to accrue the necessary credit hours may include no more than four 1300-level

undergraduate classes and/or any number of 3000-level advanced graduate courses.

(3) Submit no thesis and complete at least six courses at the 2000-level or beyond. In order to accrue the requisite 30 credits for graduation, the student may engage in Directed Study, Directed Research, or take additional, approved courses at the 3000-level.

B.2 GRADES:

The candidate must maintain a GPA of at least 3.00 for all core courses and for all courses overall.

B.3 COMPREHENSIVE EXAMINATION:

The Comprehensive Examination for MS students is equivalent of the Preliminary Evaluation for PhD students. Refer to Section A.3, Preliminary Evaluation.

B.4 THESIS AND THESIS ORAL EXAMINATION:

A thesis for the MS degree must represent either an original research project or a significant survey of some topic of current interest in physics. A student should find it possible, while carrying some course work, to complete the MS thesis in one term. A copy of the final draft of the thesis must be submitted to the department chair, and copies of the thesis must be distributed to the members of the Master's Committee, a group of at least three members of the graduate faculty recommended by the professor guiding the student's research and approved by the department chair.

Information about preparing the thesis electronically may be found on the Graduate Studies webpage at http://www.pitt.edu/~graduate/dissertation.html.

A final oral thesis examination to determine the ability of the student to comprehend and to organize the materials of his or her field will be conducted by the Master's Committee. In addition to the content of the thesis, the examination may cover the subject matter of the courses taken.

B.5 STATUTE OF LIMITATIONS:

All requirements for the MS must be completed within a period of 4 calendar years from the student's initial registration for graduate study.

B.6 LANGUAGE:

There is no foreign language requirement, but the student must demonstrate English language proficiency in compliance with University policy.

B.7 PETITION PROCEDURE

The Graduate Committee consists of the academic advisors, the core course instructors, the admissions committee, the director of graduate studies, and the department chair. It, or an appropriate subcommittee, is empowered to make reasonable modifications to these requirements on a case-by-case basis in response to a petition by a graduate student. The Graduate Committee also meets to consider proposals for directed study, to receive petitions to modify or set aside rules, and/or to redress grievances.

APPENDIX I

NORMAL PROGRESSION BEYOND THE COMPREHENSIVE EXAMINATION

(Revised Version Approved by the Graduate Committee on Aug. 28, 2007)
(PK/DT clarifications Jan. 2009, PK/AL/DT clarifications July 2009)

The majority of the students admitted to our PhD program now satisfy all of the requirements for passing the Comprehensive Examination by the end of their first year. All of them must do so by the end of their second year. This Appendix describes in detail the benchmarks that our PhD students must achieve after passing the Comprehensive Examination and the time scale they are expected to adhere to in order to make satisfactory progress towards the completion of their degree objective.

1. Finding a Research Advisor:

It will generally take time to find a faculty member in the Department who does research in an area that is of interest to a particular graduate student, is willing to serve as that student's research advisor, and is able to support the student. Therefore all PhD students are urged to begin this search as soon as possible and certainly within the first or second month after their arrival. (If you want to request permission to perform your PhD research under the primary guidance of a faculty member outside the Department of Physics and Astronomy, please see Appendix III.)

The decision to work together on a significant research project represents a long-term commitment for both the faculty member and the graduate student and therefore should not be taken lightly. Thus it is standard practice for the faculty member to "try out" the student by assigning some kind of experimental or theoretical project. This trial period will also give the student the opportunity to discover what it is like to work with that faculty member in that specialty area. Graduate students are encouraged to begin research **as soon as possible** after arriving on campus, so long as this work does not compromise performance in the core graduate courses and the Comprehensive Examination. At minimum, all graduate students who complete the first two semesters in good standing should use the summer months following their first year as an opportunity for working in a research group on a trial basis. If necessary, they should continue to search actively for a research advisor during the early part of the fall term of their second year.

Many of our graduate students are supported by the Department through the first two academic years, typically as Teaching Assistants (TAs), enabling the faculty members to "try out" the students who are interested in working with them for a term without having to support them financially. But all graduate students are expected to be supported as a Graduate Student Researcher (GSR) by their research advisor beginning with the summer that follows their fourth semester in our program. Therefore any student who has not found a research advisor by that time is in danger of being **without financial support**.

2. Executing a Research Agreement:

As soon as a faculty member and a graduate student have reached a mutual agreement to work together as research advisor and dissertation student, this understanding must be formalized by the execution of a Research Agreement (Part A of the Post-Comps Progress Form which is available from the Department's graduate secretary). The upper section of Part A must be completed and signed by both the research advisor and the graduate student. **The graduate student is responsible for filing the completed Research Agreement with the graduate secretary within six (6) months after receiving written notification of having passed the Comprehensive Examination. Only graduate students who have a current executed Research Agreement on file may register for PHYS 3000 (dissertation research).**

Once it has been executed, the Research Agreement should be regarded as binding on both parties. Should unforeseen circumstances arise subsequently that preclude a continuation of productive collaborative research work, the Research Agreement must be formally terminated using the lower section of Part A of the student's Post-Comps Progress Form; a reason must be given and all parties must sign. When a research advisor concludes that a Research Agreement needs to be terminated, it is very important that the affected graduate student be notified in writing as early as possible, especially if the student will lose financial support.

3. Forming a Dissertation Committee:

Soon after the Research Agreement has been executed, the research advisor and the graduate student should begin to discuss the membership of the student's Dissertation Committee. (See Section A.9 of the **Requirements for the MS and PhD Degrees** for the rules regarding the composition of Dissertation Committees.) When all members of the Dissertation Committee have been identified and contacted, and have indicated their willingness to serve, Part B of the graduate student's Post-Comps Progress form must be completed and submitted, along with any required supporting documentation, to the Department Chairperson for review and approval. **The graduate student is responsible for filing her/his PCP Form with Part B completed and approved with the departmental graduate secretary within eight (8) months after receiving written notification of having passed the Comprehensive Examination.**

If it becomes necessary subsequently to change the membership of a Dissertation Committee, a Change in Dissertation Committee form (available from the graduate secretary) must be filled out and submitted by the graduate student.

4. Dissertation Committee Meetings:

Collectively the members of a Dissertation Committee have two principal responsibilities: (1) they serve as a broadly knowledgeable review and advisory board for the purpose of assisting the dissertation research project to progress at a reasonable pace from its beginning stage all the way through to its completion; and (2) they help maintain departmental quality standards in the level of dissertation research.

The first meeting of a graduate student's Dissertation Committee must be held within twelve (12) months after the student received written notification of having passed the Comprehensive Examination. The graduate student is responsible for seeing to it that this is done. The research advisor must remind the student of this responsibility. At the first meeting of the Dissertation Committee the graduate student is expected to make a presentation which demonstrates that he/she has acquired an appropriate level of understanding of the physics concepts and the current state of knowledge in the specific research specialty area of the dissertation and, in that context, of the significance of the question that the dissertation research is setting out to answer. (The material presented by the student at this meeting could later be part of the introductory chapter of the dissertation.) The graduate student will also be expected to present a well-thought-out proposal of how the dissertation research is to be carried out. The proposal should include time estimates for achieving a series of clearly defined milestones that can be used in subsequent meetings to monitor the progress of the project. (The above scenario assumes that the student's dissertation research consists of a single extended project. In dissertations where this is not the case, the graduate student's presentation should be appropriately changed to reflect this difference.) At least one week prior to the meeting the graduate student must furnish each member of her/his Dissertation Committee with a brief written document (3-5 pages of text, not in power point "bullet" format) that summarizes the proposed research project, explains its significance, and provides milestones and time estimates for carrying it out; a copy of this document must also be given to the graduate secretary at that time for inclusion in the graduate student's file. **Within 7 days after the meeting each member of the Dissertation Committee must complete a "Member's Report of Dissertation Committee Meeting" (blue form) and transmit it to the Chair of the student's Dissertation Committee. Based on this input the Chair must then prepare a "Summary Report of Dissertation Committee Meeting" (green form) and use it as the basis of a follow-up meeting with the graduate student which must take place within 2 weeks of the Dissertation Committee meeting. The graduate student's signature on this Summary Report indicates that he/she has received a copy and has had the follow-up meeting with the Committee Chair. The research advisor is responsible for completing the appropriate section of the student's PCP form and returning it to the Department's graduate secretary along with the green form and all of the blue forms. (The PCP form and the green form will be placed in the student's file; all blue forms will be collected by the Department's graduate secretary for future statistical analysis by the Graduate Program Assessment Committee.) The graduate student is responsible for filing an application for Admission to Candidacy for the PhD degree with the Department's graduate secretary at that time.**

In order for a student's Dissertation Committee to be able to meet its mandate, the University of Pittsburgh requires that it is reconvened at least once every 12 months after the first meeting. The graduate student is responsible for seeing to it that this is done. The research advisor must remind the student of this responsibility. At each of these meetings the graduate student is expected to summarize the work that he/she has accomplished since the previous meeting, discuss any significant unanticipated difficulties that have been encountered, review the rate of progress in terms of milestones met and unmet, and identify goals and milestones for the year ahead. **At least one week prior to each meeting the graduate student must furnish each member of her/his Dissertation Committee with a brief written report on the progress of the research project (3-5 pages of text, not in power point "bullet" format) that highlights milestones achieved and problems encountered, discusses actions taken in response to any shortcomings identified by the Dissertation Committee in a prior meeting and, if appropriate, provides a revised set of goals and milestones for the project. The student should also use this write-up to inform the Committee of the titles and status of any papers submitted and of any research talks presented, both within the department and at scientific meetings; a copy of this document must also be given to the graduate secretary at that time for inclusion in the graduate student's file. Within 7 days after the**

meeting each member of the Dissertation Committee must complete a "Member's Report of Dissertation Committee Meeting" (blue form) and transmit it to the Chair of the student's Dissertation Committee. Based on this input the Chair must then prepare a "Summary Report of Dissertation Committee Meeting" (green form) and use it as the basis of a follow-up meeting with the graduate student which must take place within 2 weeks of the Dissertation Committee meeting. The graduate student's signature on this Summary Report indicates that he/she has received a copy and has had the follow-up meeting with the Committee Chair. The research advisor is responsible for completing the appropriate section of the student's PCP form and returning it to the Department's graduate secretary along with the green form and all of the blue forms. (The PCP form and the green form will be placed in the student's file; all blue forms will be collected by the Department's graduate secretary for future analysis by the Graduate Program Assessment Committee.)

At the final meeting of the Dissertation Committee the graduate student reports on the completed dissertation project and is examined on the details of her/his work. In contrast to all of the preceding meetings, the date, time, and place of the dissertation defense must be publicly posted in advance and the meeting is open until the Dissertation Committee begins its final deliberation.

No written progress report needs to be prepared prior to the final meeting of the Dissertation Committee, but the graduate student must strictly adhere to the rule that **each member of the Dissertation Committee must be provided with a hard copy of the dissertation (complete with all indexes, chapters, figures, tables, equations, and appendixes) at least four (4) weeks in advance of the meeting date.** Likewise, neither the blue forms nor the green form need to be completed following the final meeting of the Dissertation Committee.

POST-COMPS PROGRESS FORM

Name of Graduate Student: _____

Graduate Study Initiation Date: _____ Date Passed Comprehensive Examination: _____

PART A: RESEARCH AGREEMENT

I, _____, hereby agree to serve as Research Advisor for _____

I expect to support this student financially: Yes / No If no, please explain _____

Area of Research: _____

Preliminary Title of Project: _____

Signature of Research Advisor_____ Date _____

Signature of Student_____ Date _____

Signature of Co-Advisor (if applicable) _____ Date _____

Signature of Dept. Chairperson_____ Date _____

TERMINATION OF RESEARCH AGREEMENT:

In the event that the above agreement is terminated, the advisor and student must complete this section.

Signature of Research Advisor_____ Date _____

Signature of Student_____ Date _____

Signature of Co-Advisor (if applicable) _____ Date _____

Reason for termination:

Signature of Dept. Chairperson _____ Date _____

Signature of Dept. Chairperson_____ Date _____

PART B: PROPOSED DISSERTATION COMMITTEE

(Department Chairperson's Approval Required)

	Name	Theorist or Experimentalist	Subfield of Physics	Department (if other than Physics and Astronomy)
1				
2				
3				
4				
5				

Approved by Dept. Chairperson: _____Date:_____

FIRST MEETING OF DISSERTATION COMMITTEE

Meeting Date _____ Expected date of dissertation defense_____

Changes in Committee ? yes / no If yes, elaborate _____

Members Present_____

_____

Comments _____

_____

_____

Signature of Student _____ Date _____

Signature of Research Advisor _____ Date _____

Signature of Co-Advisor (if applicable) _____ Date _____

SECOND MEETING OF DISSERTATION COMMITTEE – DUE DATE _____

Meeting Date _____ Expected date of dissertation defense_____

Changes in Committee? yes / no If yes, elaborate _____

Members Present_____

_____

Comments _____

_____

_____

Signature of Student _____ Date _____

Signature of Research Advisor _____ Date _____

Signature of Co-Advisor (if applicable) _____ Date _____

THIRD MEETING OF DISSERTATION COMMITTEE –DUE DATE _____

Meeting Date _____ Expected date of dissertation defense_____

Changes in Committee? yes / no If yes, elaborate _____

Members Present_____

_____

Comments _____

_____

_____

Signature of Student _____ Date _____

Signature of Research Advisor _____ Date _____

Signature of Co-Advisor (if applicable) _____ Date _____

FOURTH MEETING OF DISSERTATION COMMITTEE – DUE DATE _____

Meeting Date _____ Expected date of dissertation defense_____

Changes in Committee ? yes / no If yes, elaborate _____

Members Present_____

_____

Comments _____

_____

_____

Signature of Student _____ Date _____

Signature of Research Advisor _____ Date _____

Signature of Co-Advisor (if applicable) _____ Date _____

FIFTH MEETING OF DISSERTATION COMMITTEE – DUE DATE _____

Meeting Date _____ Expected date of dissertation defense_____

Changes in Committee? yes / no If yes, elaborate _____

Members Present_____

_____

Comments _____

_____

_____

Signature of Student _____ Date _____

Signature of Research Advisor _____ Date _____

Signature of Co-Advisor (if applicable) _____ Date _____

FINAL MEETING OF DISSERTATION COMMITTEE (DEFENSE)

Meeting Date _____

Changes in Committee? yes / no If yes, elaborate _____

Members Present_____

_____

Comments _____

_____

_____

Signature of Student _____ Date _____

Signature of Research Advisor _____ Date _____

Signature of Co-Advisor (if applicable) _____ Date _____

CHANGE IN DOCTORAL DISSERTATION COMMITTEE

Graduate Studies, Arts & Sciences, 5141 Sennott Square

Student: _____

Campus Address: _____

Department: Department of Physics and Astronomy Social Security Number: _____

Major Advisor: _____

Requested Change(s) in Dissertation Committee: _____

_____

_____

_____

_____

_____

Reasons for Change(s): _____

_____

_____

_____

_____

_____

Signature of Student_____

Approval of Research Advisor_____

Approval of Graduate Director _____

Approval of Dept. Chairperson _____

APPENDIX II (HISTORICAL REFERENCE)

University of Pittsburgh

School of Arts and Sciences
Department of Physics and Astronomy

Pittsburgh, PA 15260

412-624-9000
Fax: 412-624-9163
www.phyast.pitt.edu

TO: Graduate Students, Graduate Student Advisors, and Other Department Faculty

FROM: David Turnshek, Department Chair

DATE: 25 August 2010

SUBJECT: Curriculum Recommendations by Research Specialty from the Graduate Curriculum Committee (Tony Duncan, Committee Chair, David Jasnow, Rainer Johnsen, Arthur Kosowsky, Adam Leibovich, Vittorio Paolone)

During the last academic year (2009/2010) the department's Graduate Curriculum Committee provided me with curriculum recommendations for our graduate students according to eight different research specialties. This memo summarizes the Committee's recommendations. It is important for graduate students and advisors to be aware of these recommendations. By following these recommendations a student will become well-prepared for a future career in their chosen specialty area. In addition, within the various specialties, there are ample opportunities for students to take possible elective/special topics courses to further deepen their graduate education.

Another reason for this memo is to clarify, as much as possible, the schedule for offering courses, which can be confusing. Some recommended 3000-level courses are offered only every other year. Other 3000-level courses are shared with CMU, so students would have to put up with the minor inconvenience of making the short walk to CMU to take a particular course. With regard to courses offered at CMU, students should know that eventually the course will be offered in this department, but it is often not wise to wait for that to happen, and it is usually better for a student to take recommended courses on schedule. In addition to some courses, the Monday Colloquia and many seminars are also shared between the Pitt and CMU departments.

Example recommended schedules for eight research specialties are given for "first-year" students entering our graduate program in the fall 2010 term (i.e., the 2010/2011 academic year). For courses offered every other year, "second-year" students, who entered in the fall 2009 term, will have to adapt their schedules by substituting appropriate courses to take this year, etc. Please pay close attention to these recommendations.

The course schedule for each graduate student in the department is generally unique during their graduate career, and it is understood that it is often not possible to rigorously follow recommended schedules on a term-by-term basis. However, graduate students should understand that the role of graduate student advisors is to work with students to settle on an appropriate schedule each term, so that students can become proficient in their chosen specialties.
DT/ms

Department of Physics and Astronomy, University of Pittsburgh

Recommended Non-Core Graduate Courses for Department Specialty Areas

August 2010

1 Areas of Research Specialization in the Department of Physics and Astronomy

1. Astronomy/Astrophysics/Cosmology.
2. Elementary Particle Experiment.
3. Elementary Particle Theory.
4. Condensed Matter/Nano Experiment.
5. Condensed Matter Experiment/Soft Condensed Matter.
6. Biophysics.
7. Condensed Matter Theory.
8. Physics Education.

2 Standard Post-Core 3000-level Courses in Physics and Astronomy

For a graduate degree in physics, students are required to complete those 2000-level courses designated as core courses. Also, the Physics & Astronomy Colloquium Course (Phys 2999) has been added to the schedules of first-year graduate students to facilitate students' decisions about their future research specialty. Two terms of Teaching Practicum (Phys 2998 and/or Astron 2998) are required for graduation. In the second year, Computational Methods (Phys 2274) and Research Internship (Phys 2900) are usually recommended. In addition to the 2000-level courses, the following 17 3000-level courses will be offered with regularity. Some will be offered yearly and others will be offered every other year. Some of the courses are shared with CMU, but decisions on which department will teach a course in a given year are usually only made in the year before courses are offered. Various subsets of the 3000-level courses are recommended to students, depending on their desired areas of research specializations. Special Topics courses are also occasionally offered. Advanced students may take Directed Study (Phys 3900 or Astron 3900), Research & Dissertation (Phys 3000), and/or FTDS (Full-time dissertation study).

1. Astron 3550: Stellar Structure (co-listed as Phys 3550) – Spring 2011, 2013, …outdated
2. Astron 3580: Galactic & Extragalactic Astronomy (co-listed as Phys 3580) – Fall 2011, 2013, …
3. Astron 3705: Astronomical Techniques – Fall 2010, 2012, …
4. Astron 3785: Cosmology (co-listed as Phys 3785) – Spring 2012, 2014, …

5. Phys 3540: Introduction to Astrophysics & Cosmology – Spring 2011 (CMU), 2012, …
6. Phys 3542: Advanced Statistical Physics – Spring 2012, 2014, …
7. Phys 3707: Introduction to Many-Body Physics – Fall 2010, 2011, …
8. Phys 3715: Solid State Physics – Fall 2010, 2011, …
9. Phys 3716: Advanced Solid State Physics – Spring 2011, 2013, …
10. Phys 3717: Particle Physics – Fall 2010, 2011, …
11. Phys 3718: Advanced Particle Physics – Spring 2011, 2012, …
12. Phys 3725: Introduction to General Relativity – Fall 2011, 2013, …
13. Phys 3726: General Relativity 2 – Spring 2012, 2014, …
14. Phys 3730: Introduction to Biophysics – Spring 2011 (CMU), 2012, …
15. Phys 3765: Field Theory 1 – Fall 2010 (CMU), 2011, …
16. Phys 3766: Field Theory 2 – Spring 2011 (CMU), 2012, …
17. Phys 3790: Particle Astrophysics – Fall 2010 (CMU), 2012, …

In addition, in two specialty areas (Biophysics and Physics Education) we recommend courses outside of the department. These courses are not on the above list.

3 Recommendations for Individual Research Areas

3.1 Area 1: Astronomy/Astrophysics/Cosmology

1. Astron 3550 (Stellar Structure)
2. Astron 3580 (Galactic & Extragalactic Astronomy)
3. Astron 3705 (Astronomical Techniques)
4. Astron 3785 (Cosmology)
5. Phys 3540 (Introduction to Astrophysics & Cosmology)
6. Phys 3725 (Introduction to General Relativity)
7. Phys 3790 (Particle Astrophysics)

3.2 Area 2: Elementary Particle Experiment

1. Phys 3717 (Particle Physics)
2. Phys 3718 (Advanced Particle Physics)
3. Phys 3765 (Field Theory 1)

and one of the following four courses:

1. Phys 3725 (Introduction to General Relativity)
2. Phys 3766 (Field Theory 2)
3. Phys 3785 (Cosmology)
4. Phys 3790 (Particle Astrophysics)

3.3 Area 3: Elementary Particle Theory

1. Phys 3717 (Particle Physics)
2. Phys 3718 (Advanced Particle Physics)
3. Phys 3725 (Introduction to General Relativity)
4. Phys 3726 (General Relativity 2)
5. Phys 3765 (Field Theory 1)
6. Phys 3766 (Field Theory 2)
7. Phys 3785 (Cosmology)
8. Phys 3790 (Particle Astrophysics)

3.4 Area 4: Condensed Matter/Nano Experiment

1. Phys 3542 (Advanced Statistical Physics)
2. Phys 3707(Introduction to Many-Body Physics)
3. Phys 3715 (Solid State Physics)
4. Phys 3716 (Advanced Solid State Physics)

and two of the following four courses:

1. Phys 3540 (Introduction to Astrophysics & Cosmology)
2. Phys 3717 (Particle Physics)
3. Phys 3725 (Introduction to General Relativity)
4. Phys 3730 (Introduction to Biophysics)

3.5 Area 5: Condensed Matter Experiment/Soft Condensed Matter

1. Phys 3542 (Advanced Statistical Physics)
2. Phys 3707 (Introduction to Many-Body Physics)
3. Phys 3715 (Solid State Physics)
4. Phys 3730 (Introduction to Biophysics)

and two of the following four courses:

1. Phys 3540 (Introduction to Astrophysics & Cosmology)
2. Phys 3716 (Advanced Solid State Physics)
3. Phys 3717 (Particle Physics)
4. Phys 3725 (Introduction to General Relativity)

3.6 Area 6: Biophysics

1. Phys 3542 (Advanced Statistical Physics)
2. Phys 3707 (Introduction to Many-Body Physics)
3. Phys 3715 (Solid State Physics)
4. Phys 3730 (Introduction to Biophysics)

and two of the following four courses:

1. Biosc 1290 (Genetic Engineering Lab) – usually offered in the spring
2. Biosc 1470 (Biological Chemistry) – usually offered in the spring
3. Biosc 1540 (Computational Biology) – usually offered in the fall
4. Biosc 1940 (Molecular Biology) – usually offered in the fall

3.7 Area 7: Condensed Matter Theory

1. Phys 3542 (Advanced Statistical Physics)
2. Phys 3707 (Introduction to Many-Body Physics)
3. Phys 3715 (Solid State Physics)
4. Phys 3716 (Advanced Solid State Physics)
5. Phys 3765 (Field Theory 1)
6. Phys 3766 (Field Theory 2)

and two of the following four courses:

1. Phys 3540 (Introduction to Astrophysics & Cosmology)
2. Phys 3717 (Particle Physics)
3. Phys 3725 (Introduction to General Relativity)
4. Phys 3730 (Introduction to Biophysics)

3.8 Area 8: Physics Education

Three of the following five courses:

1. Phys 3540 (Introduction to Astrophysics & Cosmology)
2. Phys 3542 (Advanced Statistical Physics)
3. Phys 3715 (Solid State Physics)
4. Phys 3717 (Particle Physics)
5. Phys 3730 (Introduction to Biophysics)

and two of the following three courses:

1. PsyEd 2019 (Stat2: Analysis of Variance)
2. PsyEd 2030 (Experimental Design)
3. Psy 2476 (Seminar in Cognitive Psychology)

Recommended Curriculum for a Specialization in Astronomy/Astrophysics/Cosmology[#]

Year 1 (e.g., 2010/2011)	
Fall	**Spring**
Phys 2373: Math Methods in Physics (3 cr) Phys 2513: Dynamical Systems (3 cr) Phys 2565: Non-Rel Quantum Mech 1 (3 cr) Phys 2997: Teaching of Physics (1 cr) Phys 2999: Phys & Astron Colloq (1 cr)	Phys 2541: Thermo & Stat Mech (3 cr) Phys 2555: Adv Electricity & Magnetism (4 cr) Phys 2566: Non-Rel Quantum Mech 2 (3 cr) Phys 2999: Phys & Astron Colloq (1 cr)
Year 2 (courses noted with a * are offered every other year and might be taken in Year 3)	
Phys 2274: Computational Methods (3 cr) *Phys 3725: Intro to General Relativity (3 cr) *Astron 3580: Gal & Extragal Astron (3 cr)	Astron 2900: Research Internship (3 cr) *Astron 3785: Cosmology (3 cr) Phys 3540: Intro to Astrophysics & Cosmo (3 cr)
Year 3 (courses noted with a * are offered every other year and might be taken in Year 2)	
*Astron 3705: Astronomical Techniques (3 cr) *Phys 3790: Particle Astrophysics (3 cr) Astron 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3 cr)	*Astron 3550: Stellar Structure (3 cr) Optional Elective/Special Topics Course (3 cr) Astron 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)
Year 4	
Optional Elective/Special Topics Course (3 cr) Optional Elective/Special Topics Course (3 cr) Astron 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)	Optional Elective/Special Topics Course (3 cr) Optional Elective/Special Topics Course (3 cr) Astron 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)
Year 5	
Phys 3000: Research & Dissertation (3-6 cr) **OR** FTDS (Full-time dissertation study)	Phys 3000: Research & Dissertation (3-6 cr) **OR** FTDS (Full-time dissertation study)

#Two terms of Astron 2998 and/or Phys 2998 (Teaching Practicum) are required for graduation.

Recommended Curriculum for a Specialization in Elementary Particle Experiment[#]

Year 1 (e.g., 2010/2011)	
Fall	**Spring**
Phys 2373: Math Methods in Physics (3 cr) Phys 2513: Dynamical Systems (3 cr) Phys 2565: Non-Rel Quantum Mech 1 (3 cr) Phys 2997: Teaching of Physics (1 cr) Phys 2999: Phys & Astron Colloq (1 cr)	Phys 2541: Thermo & Stat Mech (3 cr) Phys 2555: Adv Electricity & Magnetism (4 cr) Phys 2566: Non-Rel Quantum Mech 2 (3 cr) Phys 2999: Phys & Astron Colloq (1 cr)
Year 2	
Phys 2274: Computational Methods (3 cr) Phys 3717: Particle Physics (3 cr) Phys 3765: Field Theory 1 (3 cr) Elective Courses (0-3 cr)+ (Phys 3725: Intro to General Relativity, Phys 3790: Particle Astrophysics, both offered in alternate yrs)	Phys 2900: Research Internship (3 cr) Phys 3718: Adv Particle Physics (3 cr) Elective Courses (0-3 cr)+ (Astron 3785: Cosmology, offered in alternate yrs, or Phys 3766: Field Theory 2)
Year 3	
Optional Elective/Special Topics Course (3 cr) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)	Optional Elective/Special Topics Course (3 cr) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)
Year 4	
Optional Elective/Special Topics Course (3 cr) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)	Optional Elective/Special Topics Course (3 cr) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)
Year 5	
Phys 3000: Research & Dissertation (3-6 cr) **OR** FTDS (Full-time dissertation study)	Phys 3000: Research & Dissertation (3-6 cr) **OR** FTDS (Full-time dissertation study)

#Two terms of Astron 2998 and/or Phys 2998 (Teaching Practicum) are required for graduation.
+At least one of four specific courses is recommended during a student's graduate career.

Recommended Curriculum for a Specialization in Elementary Particle Theory[#]

Year 1 (e.g., 2010/2011)	
Fall	**Spring**
Phys 2373: Math Methods in Physics (3 cr) Phys 2513: Dynamical Systems (3 cr) Phys 2565: Non-Rel Quantum Mech 1 (3 cr) Phys 2997: Teaching of Physics (1 cr) Phys 2999: Phys & Astron Colloq (1 cr)	Phys 2541: Thermo & Stat Mech (3 cr) Phys 2555: Adv Electricity & Magnetism (4 cr) Phys 2566: Non-Rel Quantum Mech 2 (3 cr) Phys 2999: Phys & Astron Colloq (1 cr)
Year 2 (courses noted with a * are offered every other year and might be taken in Year 3)	
Phys 2274: Computational Methods (3 cr)§ Phys 3717: Particle Physics (3 cr) Phys 3765: Field Theory 1 (3 cr)	Phys 3718: Adv Particle Physics (3 cr) Phys 3766: Field Theory 2 (3 cr) *Astron 3785: Cosmology (3 cr)§
Year 3 (courses noted with a * are offered every other year and might be taken in Year 2)	
*Phys 3790: Particle Astrophysics (3 cr) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3 cr)	Optional Elective/Special Topics Course (3 cr) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)
Year 4 (courses noted with a * are offered every other year)	
*Phys 3725: Intro to General Relativity (3 cr) § Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)	*Phys 3726: Adv Gen Relativity, if offered (3 cr)§ Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)
Year 5	
Phys 3000: Research & Dissertation (3-6 cr) **OR** FTDS (Full-time dissertation study)	Phys 3000: Research & Dissertation (3-6 cr) **OR** FTDS (Full-time dissertation study)

#Two terms of Astron 2998 and/or Phys 2998 (Teaching Practicum) are required for graduation.
§Depending on the students' experience and interests Phys 2274 (Comp Meth) and Astron 3785 (Cosmology) in Yr 2 might be switched with Phys 3725 (Intro to Gen Relativ.) and Phys 3726 (Adv Gen Relativ.) in Yr 4.

Recommended Curriculum for a Specialization in Condensed Matter/Nano Experiment[#]

Year 1 (e.g., 2010/2011)	
Fall	**Spring**
Phys 2373: Math Methods in Physics (3 cr) Phys 2513: Dynamical Systems (3 cr) Phys 2565: Non-Rel Quantum Mech 1 (3 cr) Phys 2997: Teaching of Physics (1 cr) Phys 2999: Phys & Astron Colloq (1 cr)	Phys 2541: Thermo & Stat Mech (3 cr) Phys 2555: Adv Electricity & Magnetism (4 cr) Phys 2566: Non-Rel Quantum Mech 2 (3 cr) Phys 2999: Phys & Astron Colloq (1 cr)
Year 2 (courses noted with a * are offered every other year and might be taken in Year 3)	
Phys 2274: Computational Methods (3 cr) Phys 3707: Intro to Many-Body Physics (3 cr) Phys 3715: Solid State Physics (3 cr)	Phys 2900: Research Internship (3 cr) *Phys 3542: Adv Statistical Physics (3 cr) Elective Course (0-6 cr)+ (Phys 3730: Intro to Biophysics, Phys 3540: Intro to Astrophysics & Cosmology)
Year 3 (courses noted with a * are offered every other year and might be taken in Year 2)	
Elective Course (0-6 cr)+ (Phys 3725: Intro to General Relativity, offered in alternate yrs, Phys 3717: Particle Physics) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)	*Phys 3716: Adv Solid State Physics (3 cr) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)
Year 4	
Optional Elective/Special Topics Course (3 cr) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)	Optional Elective/Special Topics Course (3 cr) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)
Year 5	
Phys 3000: Research & Dissertation (3-6 cr) **OR** FTDS (Full-time dissertation study)	Phys 3000: Research & Dissertation (3-6 cr) **OR** FTDS (Full-time dissertation study)

#Two terms of Astron 2998 and/or Phys 2998 (Teaching Practicum) are required for graduation.

+At least two of four specific courses are recommended during a student's graduate career.

Recommended Curriculum for a Specialization in Condensed Matter Experiment/Soft Condensed Matter

Year 1 (e.g., 2010/2011)	
Fall	**Spring**
Phys 2373: Math Methods in Physics (3 cr) Phys 2513: Dynamical Systems (3 cr) Phys 2565: Non-Rel Quantum Mech 1 (3 cr) Phys 2997: Teaching of Physics (1 cr) Phys 2999: Phys & Astron Colloq (1 cr)	Phys 2541: Thermo & Stat Mech (3 cr) Phys 2555: Adv Electricity & Magnetism (4 cr) Phys 2566: Non-Rel Quantum Mech 2 (3 cr) Phys 2999: Phys & Astron Colloq (1 cr)
Year 2 (courses noted with a * are offered every other year and might be taken in Year 3)	
Phys 2274: Computational Methods (3 cr) Phys 3707: Intro to Many-Body Physics (3 cr) Phys 3715: Solid State Physics (3 cr)	Phys 2900: Research Internship (3 cr) *Phys 3542: Adv Statistical Physics (3 cr) Phys 3730: Intro to Biophysics (3 cr)
Year 3	
Elective Courses (0-6 cr)+ (Phys 3725: Intro to General Relativity, offered in alternate yrs, Phys: 3717 Particle Physics) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)	Elective Courses (0-6 cr)+ (Phys 3716: Adv Solid State Physics, offered in alternate yrs, Phys 3540: Intro to Astrophysics & Cosmology) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)
Year 4	
Optional Elective/Special Topics Course (3 cr) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)	Optional Elective/Special Topics Course (3 cr) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)
Year 5	
Phys 3000: Research & Dissertation (3-6 cr) **OR** FTDS (Full-time dissertation study)	Phys 3000: Research & Dissertation (3-6 cr) **OR** FTDS (Full-time dissertation study)

#Two terms of Astron 2998 and/or Phys 2998 (Teaching Practicum) are required for graduation.
+At least two of four specific courses are recommended during a student's graduate career.

Recommended Curriculum for a Specialization in Biophysics

Year 1 (e.g., 2010/2011)	
Fall	**Spring**
Phys 2373: Math Methods in Physics (3 cr) Phys 2513: Dynamical Systems (3 cr) Phys 2565: Non-Rel Quantum Mech 1 (3 cr) Phys 2997: Teaching of Physics (1 cr) Phys 2999: Phys & Astron Colloq (1 cr)	Phys 2541: Thermo & Stat Mech (3 cr) Phys 2555: Adv Electricity & Magnetism (4 cr) Phys 2566: Non-Rel Quantum Mech 2 (3 cr) Phys 2999: Phys & Astron Colloq (1 cr)
Year 2 (courses noted with a * are offered every other year and might be taken in Year 3)	
Phys 2274: Computational Methods (3 cr) Phys 3707: Intro to Many-Body Physics (3 cr) Phys 3715: Solid State Physics (3 cr)	Phys 2900: Research Internship (3 cr) *Phys 3542: Adv Statistical Physics (3 cr) Phys 3730: Intro to Biophysics (3 cr)
Year 3	
Elective Courses (0-6 cr)+ (Biosc 1540: Computational Biology, Biosc 1940: Molecular Biology) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)	Elective Courses (0-6 cr)+ (Biosc 1290: Genetic Eng Lab, Biosc 1470: Biological Chemistry) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)
Year 4	
Optional Elective/Special Topics Course (3 cr) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)	Optional Elective/Special Topics Course (3 cr) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)
Year 5	
Phys 3000: Research & Dissertation (3-6 cr) **OR** FTDS (Full-time dissertation study)	Phys 3000: Research & Dissertation (3-6 cr) **OR** FTDS (Full-time dissertation study)

#Two terms of Astron 2998 and/or Phys 2998 (Teaching Practicum) are required for graduation.
+At least two of four specific courses are recommended during a student's graduate career.

Recommended Curriculum for a Specialization in Condensed Matter Theory

Year 1	
Fall	**Spring**
Phys 2373: Math Methods in Physics (3 cr) Phys 2513: Dynamical Systems (3 cr) Phys 2565: Non-Rel Quantum Mech 1 (3 cr) Phys 2997: Teaching of Physics (1 cr) Phys 2999: Phys & Astron Colloq (1 cr)	Phys 2541: Thermo & Stat Mech (3 cr) Phys 2555: Adv Electricity & Magnetism (4 cr) Phys 2566: Non-Rel Quantum Mech 2 (3 cr) Phys 2999: Phys & Astron Colloq (1 cr)
Year 2 (courses noted with a * are offered every other year and might be taken in Year 3)	
Phys 2274: Computational Methods (3 cr) Phys 3707: Intro to Many-Body Physics (3 cr) Phys 3715: Solid State Physics (3 cr)	Phys 2900: Research Internship (3 cr) *Phys 3542: Adv Statistical Physics (3 cr) Elective Course (0-6 cr)+ (Phys 3730: Intro to Biophysics, Phys 3540: Intro to Astrophysics & Cosmology)
Year 3 (courses noted with a * are offered every other year and might be taken in Year 2)	
Phys 3765: Field Theory 1 (3 cr) Elective Course (0-6 cr)+ (Phys 3725: Intro to General Relativity, offered in alternate yrs, Phys 3717: Particle Physics) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)	*Phys. 3716: Adv. Solid State Physics (3 cr) Phys 3766: Field Theory 2 (3 cr) Optional Elective/Special Topics Course (3 cr) **OR** Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)
Year 4	
Optional Elective/Special Topics Course (3 cr) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)	Optional Elective/Special Topics Course (3 cr) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)
Year 5	
Phys 3000: Research & Dissertation (3-6 cr) **OR** FTDS (Full-time dissertation study)	Phys 3000: Research & Dissertation (3-6 cr) **OR** FTDS (Full-time dissertation study)

#Two terms of Astron 2998 and/or Phys 2998 (Teaching Practicum) are required for graduation.

Recommended Curriculum for a Specialization in Physics Education Research[#]

Year 1	
Fall	**Spring**
Phys 2373: Math Methods in Physics (3 cr) Phys 2513: Dynamical Systems (3 cr) Phys 2565: Non-Rel Quantum Mech 1 (3 cr) Phys 2997: Teaching of Physics (1 cr) Phys 2999: Phys & Astron Colloq (1 cr)	Phys 2541: Thermo & Stat Mech (3 cr) Phys 2555: Adv Electricity & Magnetism (4 cr) Phys 2566: Non-Rel Quantum Mech 2 (3 cr) Phys 2999: Phys & Astron Colloq (1 cr)
Year 2 (courses noted with a * are offered every other year and might be taken in Year 3)	
Phys 2274 Computational Methods (3 cr) Elective Courses (0-6 cr)+ (Phys 3717:Particle Phys, Phys 3715:Solid State Phys) Elective Course (3-6 cr)$ (Psy 2476: Seminar in Cognitive Psychology, PsyEd 2019: Analysis of Variance)	Phys 2900: Research Internship (3 cr) Elective Courses (0-9 cr)+ (Phys 3540: Intro to Astrophys & Cosmo, *Phys 3542: Adv Statistical Physics, Phys 3730: Intro to Biophys) Elective Course (0-3 cr)$ (PsyEd 2030: Experimental Design)
Year 3	
Optional Elective/Special Topics Course (3 cr) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)	Optional Elective/Special Topics Course (3 cr) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)
Year 4	
Optional Elective/Special Topics Course (3 cr) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)	Optional Elective/Special Topics Course (3 cr) Optional Elective/Special Topics Course (3 cr) Phys 3900: Directed Study (3 cr) **OR** Phys 3000: Research & Dissertation (3-6 cr)
Year 5	
Phys 3000: Research & Dissertation (3-6 cr) **OR** FTDS (Full-time dissertation study)	Phys 3000: Research & Dissertation (3-6 cr) **OR** FTDS (Full-time dissertation study)

#Two terms of Astron 2998 and/or Phys 2998 (Teaching Practicum) are required for graduation.

+At least three of five specific courses are recommended during a student's graduate career.

$At least two of thee specific courses are recommended during a student's graduate career.

Short Course Descriptions for
Regularly Offered 3000-level Graduate Courses

The courses below generally have the department's core courses, or the equivalent, as a pre-requirement. If you are interested in taking a 3000-level course, but have not yet finished all the core courses, please contact the course instructor for permission.

1. Astron 3550/Phys 3550: Stellar Structure (every odd year - Spring)
Stars are the most common astrophysical objects. They create most of the atomic elements and most of the observable optical light in the sky. This class provides an overview of the physics of stars and the interstellar medium. Topics will include hydrostatic equilibrium, nuclear processes, radiative transfer, metallicity and opacity, convection, stellar evolution, stellar explosions, properties of the interstellar medium, and energy feedback from stars.

Preparation: Some prior knowledge of astronomy/astrophysics will be useful. For students without this prior knowledge, this could be obtained by serving as an astronomy TA (Astron 2998: Teaching Practicum), or concurrently taking Phys 3540: Introduction to Astrophysics & Cosmology.

2. Astron 3580/Phys 3580: Galactic and Extra-galactic Astronomy (every odd year - Fall)
Galaxies are the fundamental building blocks of the present Universe. This class will give an overview of galaxies, their properties, and their formation and evolution with an emphasis on current research areas. Topics will include observational properties (morphology, masses, colors, concentrations), scaling relations, evolution with redshift, stellar populations, gas and dust, dynamics and dark matter, evolution and mergers, and active galaxies.

Preparation: Some prior knowledge of astronomy/astrophysics will be useful. For students without this prior knowledge, this could be obtained by serving as an astronomy TA (Astron 2998: Teaching Practicum), or concurrently taking Phys 3540: Introduction to Astrophysics & Cosmology.

3. Astron 3705: Astronomical Techniques (every even year - Fall)
This class will expose students to the basics of astronomical data analysis, with an emphasis on statistical techniques and the development of practical programming skills. Topics may include the nature of random and systematic errors, fitting and likelihood techniques, hypothesis testing, astronomical instrumentation and data reduction, and the use of large survey data sets.

4. Astron 3785/Phys 3785: Cosmology (every even year - Spring)
This class will give an overview of the standard cosmological model and the wide range of observational tests. Topics include the expansion history of the Universe, thermodynamic history, nucleosynthesis, recombination, inflation, perturbations and the microwave background, structure formation, evidence for dark matter and dark energy, and future probes of dark energy.

Preparation: Some prior knowledge of astronomy/astrophysics will be useful. For students without this prior knowledge, this could be obtained by serving as an astronomy TA (taking Astron 2998: Teaching Practicum), or concurrently taking Phys 3540: Introduction to Astrophysics & Cosmology.

5. Phys 3540: Introduction to Astrophysics and Cosmology (every year - Spring)
This class will provide a broad overview of the physical principles important for astrophysics, and applications to a range of astrophysical phenomena. Concepts covered will include gravitation, radiative processes, radiative transport, fluid dynamics, and nuclear, atomic, and molecular processes. Sample applications might include extrasolar planets, gravitational collapse, stellar structure, star formation, galaxy evolution, accretion disks, compact objects, galaxy clusters, and topics in cosmology.

6. Phys 3542: Advanced Statistical Physics (every even year - Spring)
This course is aimed at a wide audience of primarily second year (and more senior) graduate students with interests in experimental or theoretical physics and astrophysics/cosmology. The aim is to provide a broad perspective of the concepts and techniques of statistical physics, which cut across many areas of active research. Depending on the composition and areas of interest of a particular class, an attempt will be made to include some examples from different disciplines. For example, potential topics to be covered include: white dwarf stars; fluctuations and response; phase transitions and critical phenomena; mean field theories; Landau theory; order parameters; scaling, fluctuations, response, universality; broken symmetry; renormalization group; interacting systems; weakly interacting Bose gas; excitation spectrum; superfluidity; BCS as a mean field theory; and nonequilibrium stochastic processes.

7. Phys 3707: Introduction to Many-Body Physics (every year - Fall)
This is a one-term nuts-and-bolts introduction to the quantum physics of interacting, many-particle systems. The course includes second quantization, many body physics, and a brief introduction to relativistic quantum mechanics and the Dirac equation.

Throughout there will be discussion of applications of the techniques and concepts in various subfields of physics. The approach will generally be intuitive and hands-on. The course typically will begin with second quantization for fermionic and bosonic systems, with examples typically involving electrons, phonons and photons, arising from the quantization of the electromagnetic field. Applications will typically include the interacting electron gas and plasmons; the interaction of the radiation field and matter; electron-phonon interactions; and dressed electrons and the polaron problem. There will typically be some discussion of condensation phenomena and superfluidity (typically Bogoliubov theory, broken symmetry and Goldstone bosons) and superconductivity (pairing, BCS and Landau-Ginzburg theories). There will generally be some exposure to Greens functions and Feynman diagrams.

8. Phys 3715: Solid State Physics (every year - Fall)
This is a one-term course on solid-state physics, which emphasizes the special ways one must think about crystalline materials. The course will allow students emphasizing this area to enhance their own research efforts, and it will permit other students to have an appreciation for an extremely large part of current research activity in physics. Roughly speaking, there will be three parts to the course. Some variation on emphasis can be expected depending on the instructor and on the interests of the class. (i) Phonons: Crystal lattices; diffraction and scattering; reciprocal lattice; lattice vibrations, quantization; thermal properties. (ii) Electrons: Free electron model; density of states; thermal properties; Bloch's theorem, electron states and energy bands; semiconductor statistics; quasi-classical electron dynamics; Boltzmann equation and transport. (iii) Additional topics: Electron-electron and electron-phonon interactions; Hall effect; Landau levels; superconductivity; electromagnetic response.

9. Phys 3716: Advanced Solid State Physics (every odd year - Spring)
This is a second, graduate-level solid state physics course. The topics will be adjustable given the cross section of students taking the course and topical developments in the field. Topics suitable for this course include: a brief exposure to "practical" group theory; optics and spectroscopy relevant to the solid state including linear and non-linear response and complex dielectric constant; coherence and correlation including the density matrix Bloch equations, and optics; introduction to NMR; superconductivity beyond the Ginsburgh-Landau theory; advanced topics in magnetism; advanced topics in transport theory.

Pre-requirement: Phys 3715, Solid State Physics

10. Phys 3717: Particle Physics (every year - Fall)
This is the first term of a two term sequence exposing the student to basic methods and recent developments in high energy physics. The first term of the sequence is suitable as a one-term course for students not specializing in high-energy physics. Particle physics involves completely relativistic phenomena and requires the generalization of non-relativistic quantum concepts to the relativistic regime in order to develop the phenomenological and calculational methods suitable for relativistic processes in which the number and type of particles can change. The course examines experimental and phenomenological foundations of particle physics. The known particles and fundamental interactions are investigated. Modern experimental techniques of particle physics are discussed (including basic properties of particle interactions with matter). General features of electromagnetic, weak, and strong interactions, and their associated symmetries, are explored.

11. Phys 3718: Advanced Particle Physics (every year - Spring)
This is the conclusion of the 2-term sequence Phys 3717/3718, which should be taken in order. This course covers the Standard Model in detail and includes: the phenomenology of weak interactions; group theory and the quark model; the parton model for deep inelastic scattering and other high energy processes; an introduction to gauge theories of electroweak and strong interactions. Various topics of current interest in particle physics beyond the Standard Model will also be discussed.

Pre-requirement: Phys 3717, Particle Physics

12. Phys 3725: Introduction to General Relativity (every odd year - Fall)
This course covers the basic conceptual foundations of general relativity starting from the special theory, with applications, calculational techniques and discussions of current observational probes. Topics include the equivalence principle, geodesic deviation, tidal forces, the description of gravitation as geometry, Schwarschild space time. Also covered are: solar system tests and post-Newtonian parameters; gravitational lensing; micro and macrolensing as probes of dark matter; observations; vacuum Einstein's Equations and Schwarschild solution.

13. Phys 3726: Advanced General Relativity (every even year - Spring)
The advanced course begins with a derivation of Einstein's equations and energy momentum tensors.The following are studied: stellar evolution, gravitational collapse, compact stars and black holes; gravitational radiation sources and detection; cosmology; the Friedmann-Robertson-Walker metric; the Standard Big Bang; successes and problems; inflation; dark energy and observations; cosmic microwave background and observations.

Pre-requirement: Phys 3725, Introduction to General Relativity

14. Phys 3730: Introduction to Biophysics (every year - Spring)
In this course we will review useful physical ideas and techniques that have contributed significantly to recent developments in biophysical research. This includes: the use of statistical approaches for understanding gene regulation and signal transduction in biological and chemical networks; nonlinear dynamics for understanding biological pattern formation, ecology, and population dynamics; hydrodynamics for understanding cell motility and taxis; and information theory for signal processing in neuronal networks. The course will also introduce basic concepts in biology that range from molecular to cellular biology. Specific topics to be covered include: introduction to biology; microscopy techniques; basics of cell biology; genetics (the genetic code, gene replication, gene expression, genetic networks); molecular biology techniques; energy in biological systems and the statistical view of biological dynamics; entropy and free energy in biology; two-state models in biology and neurobiology.

15. Phys 3765: Field Theory 1 (every year - Fall)
This is the first semester of a graduate course in Quantum Field Theory. The course develops the perturbative approach to relativistic field theory. The topics covered will be: Lorentz and Poincare groups; method of second quantization; free scalar field theory; free spin-1/2 field theory; field quantization; symmetries and conservation laws; interacting scalar field theories, Yukawa theory; perturbation theory and Feynman rules; elementary renormalization theory; quantum electrodynamics.

16. Phys 3766: Field Theory 2 (every year - Spring)
This is the second semester of a graduate course in Quantum Field Theory. It builds on the material covered in Phys 3765 (Field Theory 1), which is a prerequisite. The course further develops the techniques of relativistic quantum field theory, covering the path integral approach to field theory, additional topics in quantum electrodynamics, symmetry breaking, non-abelian gauge theories, and the Standard Model. In more detail, the topics covered will be: Green's functions, asymptotic scattering theory, and the LSZ formalism; functional integration and the path integral; quantization of abelian (QED) and non-abelian (Yang-Mills) fields; the renomalization group; spontaneous symmetry breaking of global and local symmetries; the Standard Model.

Pre-requirement: Phys 3765, Field Theory 1

17. Phys 3790: Particle Astrophysics (every even year - Fall)
Particle physics plays an increasingly important role in astrophysics. This class will cover areas of common interest between these fields. Topics may include dark matter (particle abundances, particle candidates, direct and indirect detection), neutrino masses and oscillations, high energy cosmic rays and detection schemes, high density matter in neutron stars, models for inflation, baryogenesis, cosmological phase transitions, and models for dark energy.

APPENDIX III

TO: Faculty and Graduate Students

FROM: David Jasnow, Chairperson, Department of Physics and Astronomy

DATE: June 4, 2004

SUBJECT: PhD research conducted outside the department

This document replaces the previous statement on this subject published in December 2002.

The Department of Physics and Astronomy has faculty engaged in internationally recognized programs of research in a wide range of fields. Research activities are described in our brochure, on the departmental web site and through links to material maintained by our individual faculty members and/or groups. Graduate students can also learn about current research activities through the "research talks" which take place during the academic year.

Students entering our program, after completing their "core" education requirements, are expected to find a research advisor within the department and to form a graduate committee to guide their PhD research. The graduate advisor has prime responsibility for mentoring the student and supervising the research. The chairperson of the department as well as the Associate Dean for Graduate Studies must both approve the selection of all graduate thesis committees.

In rare occasions a student, to satisfy specific research goals or interests, may request permission to perform PhD research under the primary guidance of a faculty member outside the Department of Physics and Astronomy. The chairperson of the Department of Physics and Astronomy will consider such requests on a case-by-case basis in consultation with the Director of the department's graduate program and others. Below are some guidelines the chairperson may use in deciding whether or not to approve the formation of a particular thesis committee when the primary research advisor is not in the Department of Physics and Astronomy.

GUIDELINES

- The "primary" research advisor from another department or school within the University will serve as co-chair of the thesis committee. He or she must be a member of the graduate faculty, must have substantial training in graduate-level physics or astronomy, and must have a record of physics or astronomy related research activities.
  - A member of the graduate faculty within the Department of Physics and Astronomy must agree to serve as co-chair of the thesis committee.
  - It is essential that the departmental co-chair of the thesis committee takes an active interest and commits to active participation and, ideally, collaboration in the research project.
  - Thesis committees will not be approved if the departmental co-chair acts merely as a "formal" advisor without active involvement.
  - The department chairperson may limit the number of students working outside the department if, in his or her judgment, a further increase is inconsistent with the research goals of the department.
  - The "primary" research advisor takes primary responsibility for the financial support of the student. Any GSR contract should conform to university policies described at http://www.pitt.edu/~graduate/gsr.html. Before signing, it is the student's responsibility to bring a copy to the graduate secretary in the Department of Physics and Astronomy to initiate the appropriate review.

PROCEDURES

- A graduate student wishing to conduct his or her PhD research under the supervision of a primary advisor outside the department should inform the Graduate Secretary as soon as possible of intentions. After discussions with the respective faculty members, the student should identify the proposed primary advisor from outside the department and the proposed co-advisor from within the Department of Physics and Astronomy. The student will be informed in writing if there are potential problems based on the guidelines above.

- In consultation with the primary advisor and the departmental co-chair, the student must submit a written proposal describing the nature of his or her anticipated PhD research as soon as possible, but no later than 4 months after the beginning of an arrangement for joint supervision. A provisional thesis committee must approve the proposed research as suitable for a PhD issuing from the Department of Physics and Astronomy. The primary advisor may be requested to submit a CV and list of publications.

- It will be expected that the primary advisor and the departmental co-chair submit a brief statement outlining the plan for advising and mentoring the student and the nature of the anticipated research collaboration.

(original document Dec., 2002)

APPENDIX IV
MEMBER'S REPORT OF DISSERTATION COMMITTEE MEETING

Name of Committee Member:_____Chair? YES NO

Name of Graduate Student: _____Meeting Date:_____
Dissertation Topic: _____

Meeting Number: 1 2 3 4 5 6 Expected date of dissertation defense (MM/YYYY):____/_____

Rate the student's performance in the following five categories on a scale of 1 (very low) to 5 (very high):	
1. Did the student display an appropriate general understanding of how the dissertation topic addresses broader physics questions?	1 2 3 4 5
2. Did the student display an appropriately detailed understanding of the physics (experiment and theory) involved in the dissertation topic?	1 2 3 4 5
3. Did the student display appropriate mastery of the technical skills (theoretical, experimental, computational) needed to carry out this project?	1 2 3 4 5
4. How do you rate the student's progress on the dissertation project relative t the goals/milestones stated at the previous meeting? (Skip for 1st meeting)	1 2 3 4 5
5. How do you rate the student's oral communication skills as displayed during this meeting?	1 2 3 4 5
6. How do you rate the student's written communication skills as displayed in the materials the student prepared for this meeting?	1 2 3 4 5
7. If you have additional comments/concerns regarding the student's progress, express them here:	
8. If you think the student should address certain items/issues before the next meeting, specify them here:	
9. Is it possible that the <u>next committee meeting</u> can be the thesis defense? *(Note: if more than 1 committee member answers "no" to this question, another committee meeting must take place prior to the defense.)*	

Signature of Committee Member: _____Date _____

Q9 – added January 2013

SUMMARY REPORT OF DISSERTATION COMMITTEE MEETING

Name of Graduate Student: _____Meeting Date:_____

Dissertation Topic: _____

Meeting Number: 1 2 3 4 5 6 Expected date of dissertation defense (MM/YYYY):____/_____

Name of Dissertation Committee Chair: _____

The Dissertation Committee rated your performance as follows, on a scale of 1 (very low) to 5 (very high):	
1. Did the student display an appropriate general understanding of how the dissertation topic addresses broader physics questions?	1 2 3 4 5
2. Did the student display an appropriately detailed understanding of the physics (experiment and theory) involved in the dissertation topic?	1 2 3 4 5
3. Did the student display appropriate mastery of the technical skills (theoretical, experimental, computational) needed to carry out this project?	1 2 3 4 5
4. Was the student's progress on the dissertation project consistent with the Goals/milestones stated at the previous meeting? (Skip for 1st meeting)	1 2 3 4 5
5. Did the student display appropriate oral communication skills in her/his presentation during the meeting?	1 2 3 4 5
6. Did the student display appropriate written communication skills in the materials he/she prepared for this meeting?	1 2 3 4 5
7. Additional comments/concerns expressed by the Committee regarding your progress (use back if needed):	
8. Specific items/issues identified by the Committee that you need to address before the next meeting: 9. Is it possible that the next committee meeting can be the thesis defense? *(Note: if more than 1 committee member answers "no" to this question, another committee meeting must take place prior to the defense.)*	

Signature of Committee Chair: _____Date _____

Signature of Graduate Student: _____Date _____

(Q 9 added January of 2013)