What Every Successful Physics Graduate Student Should Know

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This text is written to be a guide for students considering graduate school in physics. I choose the title, "What Every Successful Physics Graduate Student Should Know" because I honestly believe that if you want to be successful in a graduate physics program, you need to know the information contained in these pages. I believe that I am qualified to write this because, while I wasn't a perfect graduate student (I was not a straight A student and had to take the candidacy exam twice), I was a successful graduate student because I did finish the program with a Ph.D. and found a job in physics. After finishing graduate school, I joined the faculty of the University of Houston Clear Lake (UHCL) where I founded a graduate physics program. I am writing this text based on a suggestion from one of my students who felt that this could provide a useful guide to people who are interested in pursuing a graduate-level physics degree. I try to write this text in such a way that it applies to graduate physics programs in general and not just to the UHCL Physics program.

Basic Preparation for a Graduate Physics Degree

Before you start graduate school in Physics, or any other field, there are certain things that you need to know. The first thing you need to know is, what are the basic requirements for joining the program. While some graduate schools require that you have an undergraduate degree in physics, the UHCL program requires specific classes to prepare for the program. These courses are:

University Physics I & II (Calculus-Based Physics) with Laboratory
Modern Physics
Calculus I, II
Calculus III
Differential Equations
Complex Variables
Linear Algebra
Probability and Statistics
Advanced Undergraduate Mechanics
Advanced Undergraduate Electromagnetism
Advanced Undergraduate Quantum Mechanics
Advanced Undergraduate Thermodynamics

Some schools, like UHCL, offer an undergraduate Mathematical Methods sequence that can replace Calculus III, Differential Equations, Complex Variables, Linear Algebra and Probability & Statistics. I find a student's mathematics background is the most important part of this preparation. Some graduate schools (also like UHCL) admit students who have not completed all the basic preparation courses and allow them to take these courses as a graduate student. You should always check with the program to see specifically what they require. Also note that the courses listed above make up the core of most undergraduate physics programs and are lower-level versions of the core graduate-level physics courses. Additional requirements may consist of the Graduate Records Exam (GRE) and the Test of Standard Written English (TSWE) for international students. Every graduate level physics program at an accredited institution requires at least the general GRE exam. Most, if not all, Ph.D. Physics programs also require the Physics GRE subject test. These test requirements can be waived under certain circumstances. What is an acceptable grade or score depends on the department. I suggest that anyone considering applying to a physics graduate program to contact faculty in that program before submitting an application.

Admissions

Every graduate school has a clearly defined admissions policy. At UHCL, students must submit an application, transcripts from all undergraduate and graduate courses taken and their test scores directly to our admissions office through an online form (https://www.applytexas.org/adappc/gen/c_start.WBX). The admissions office collects all this information and forwards it to the physics faculty for review. The package never gets forwarded until ALL the required documents have been submitted. A faculty committee then decides whether or not a student is admitted into the program. Students may be admitted unconditionally, with certain conditions or denied. Typically a student is admitted conditionally if they are missing one or two of the required courses or has low grades (C's or D's) in some courses. If a student has significant deficiencies, they will be advised on how to correct these before reapplying.

Sometimes students may temporarily bypass the admissions process by registering as non-degree seeking students. A non-degree seeking student at UHCL does not have to be admitted by the faculty admissions committee and therefore they can start their graduate work sooner. This is useful for students who only need to take a specific class or want to "test" their ability to handle graduate-level courses. The downside to this is that non-degree seeking students may be under-prepared for graduate-level courses. These students may be scared off from taking additional courses or working to complete the degree. I suggest that anyone considering joining a physics program, as a non-degree seeking student should first talk to the faculty before taking courses. Please don't abuse the system. Courses taken as a non-degree seeking student do not necessarily count towards graduate credit after a student is admitted into the program. I've had students wait until their last semester to convert from non-degree seeking to degree seeking status. This is a gamble, which does not always work out.

Masters verses Ph.D. Programs

One of the first things that you have to do in choosing where to pursue a graduate-level physics degree is whether you want to go to start at a masters or Ph.D. level program. This depends a lot on the individual and their situation. If you know that you want a Ph.D. and are a traditional student with a strong background in the basic preparation courses, I would suggest going to a Ph.D. level program. These programs focus heavily on research and tend to be excellent in training students to become researchers. In deciding which program to apply to, look for departments, which are strong (have several researchers) in your area of interest. Because you never know when a faculty member will leave their academic appointment, you should never choose a program based on the promise of working with one person. The drawback to these programs is that students who need more time to catch-up with the fundamentals and are not ready to produce cutting edge research may find the environment uncomfortable. If you leave a Ph.D. program with a master's degree it is often seen as a consolation prize within the physics community. It is usually better to get a masters degree from a small relatively unknown program that grants a masters as its highest degree than a large well-known Ph.D. program.

Masters degree programs in physics are not as common as Ph.D. programs but they can hold several advantages to the right students. They tend to have better student to faculty ratios so students get more individual attention. The focus tends to be more on teaching than research so students can work more on learning the fundamentals. Masters programs are often more professionally focused and accepting of nontraditional students. I suggest that if you don't feel prepared to pursue a Physics Ph.D. because of your undergraduate preparation, time since you were last in school or your uncertainty about quitting your job to pursue a physics degree full-time, you should apply to a Master's level physics program. A good masters degree program should prepare students to pursue the Ph.D. anywhere in the country.

Other options for students include Collaborative Physics Ph.D. programs and Professional Science Masters (PSM) Degrees in Physics. UHCL offers both such programs. The Collaborative Physics Ph.D. program gives you the advantages of both the Masters and Ph.D. level programs. You can pass Ph.D. candidacy as a part-time graduate student but if you leave before finishing the Ph.D., your MS won't look like a consolation prize. Our program is done in collaboration with the Ph.D. program at the University of Houston (UH). The PSM is a new type of degree that using the core science curriculum to train students specifically for jobs in industry. Our program combines the core physics curriculum with courses in systems engineering and management to train students as technical managers.

Time Requirements

The time required to be successful in a graduate-level physics course depends on many variables. A student's level of preparation, their ability to focus on the course, their level of maturity, and their ability to work in groups, all factor into how much time a student will need to spend on a course. A typical graduate-level physics course for at UHCL requires about 15-20 hours per week for a well-prepared student.

A full-time student should expect to spend about 45-60 hours per week on his or her courses. A part-time student, who works full-time, should only take 1 or 2 courses per semester. We sometimes see students who work full-time and attempt to take 3 courses. These students are rarely successful. Online courses will require about the same time commitment. On the positive side, most students have the freedom to choose when to devote time to their studies. Graduate school requires excellent time-management skills. I recommend using an electronic calendar to schedule time devoted to research and study in addition to class time.

Student research should take about the same amount of time per Semester Credit Hour (SCH) as face-to-face courses. A typically independent study or thesis could take anywhere from 15-60 hours per week depending on how many credits the student registers for. Thesis work, whether for a Bachelors, Masters or Ph.D., typically requires more time and focus than students think. Before considering doing a thesis, try to imagine how may hours you think the project will require per week and multiply that by two or three. If you cannot devote that much time, you may want to reconsider the project.

Full-time verses part-time

Most universities don't give students the choice to pursue a graduate physics education part-time. UHCL, however, does give this option so I feel confident in discussing it. Traditional physics graduate students may devote over 80 hours per week to study, teaching and research. This allows students to become fully emerged in their subject, which has a net positive impact on learning. Most graduate physics programs only accept full-time students and most physics faculty will not work with part-time students.

I feel that part-time students bring a lot to the table. They tend to be more mature, they have more practical work experience and they tend to be more organized with their time. When deciding whether to pursue graduate education full-time or part-time, one must weigh several items: time to complete the degree, economic situation, chance of success and career goals. Full-time students complete degrees in less semesters and they have a better chance of getting good grades. However, not all students can go to school full-time. Many of my students have families and have already made significant progress in their careers. They can't afford to go to school full-time.

Ultimately, this decision comes down to time. To attend graduate school part-time, especially in physics, often means spreading a 2-year degree over 3 years or a 6-year degree over 10 years. It means that you may need to work harder to finish your degree before time runs out. Not only do part-time students take fewer classes and miss out on many valuable opportunities such as teaching undergrads, they also often have to work full-time outside of the university. For them, time management is even more critical.

Teaching part-time non-traditional students also requires a significant effort on the part of the faculty. Part-time students tend to miss classes for extremely valid reasons. I've had many students tell me that they had to miss class because they are scheduled to work in mission control, how can I argue with that? Fortunately there are now several new technologies available to record lectures. Working with part-time students in research is also a challenge. You have to push them to make progress, but you must understand that your class or research project is not the most important thing in their lives. This is not an easy thing for a physics professor to accept.

Financial Aid and Assistantships

Full-time traditional students, especially those in Ph.D. departments, are normally given assistantships and never see a tuition bill. Assistantships typically come in two types, teaching assistantships and research assistantships. Some schools require students to apply for these. Most assistantships require students to work about 20 hours per week and are designed to teach students skills that they need later on in their careers. Since most physics majors never receive an formal training in teaching, Teaching Assistantships may prove especially valuable for students considering a career in academia.

Part-time students are not normally given assistantships. These students are typically expected to find their own way to pay for their education. Whether a student is full-time or part-time, they still have several options for paying for their education. Students may apply for fellowships or scholarships from either the university or outside organizations. Grants and student loans also provide an option for students. At UHCL, nontraditional students also tend to have the option of having their employer pay. Many companies have educational plans, which can support an employee's goal of obtaining a higher degree. The employee gets the degree they want and the employer gets a more valuable employee. These plans are especially common among engineering firms where employees need to constantly update their skills.

Core Courses

Physics is an incredibly traditional discipline. Although there is no national accrediting agency for physics, most graduate level physics programs have incredibly similar curriculums. Many of these programs use the same textbooks and design their syllabi to focus on the same core material. Many of these classes look similar to the undergraduate basic preparation courses. That is not an accident. Students learn the basics at the undergraduate level then they re-learn everything in more depth at the graduate level. These courses are offered regularly (at least once per year) and it is expected that students complete these courses before attempting more advanced graduate level courses. In the following sections I will review each of the core classes and what students are expected to learn in each. UH and UHCL use these core courses to determine Ph.D. candidacy. Students need to get a B or better in the class and on the final exam in order to pass candidacy. Some programs require 3 credit hour core courses but UH and UHCL require Ph.D. candidates to also complete a 1 credit hour recitation course.

Mathematical Methods

About 54% of Ph.D. level physics departments require at least one semester of Mathematical Methods. I feel that Mathematical Methods is the most important of the core physics courses. I normally advise my part-time students to take this course first before attempting any of the other core courses. The purpose of this course is to prepare students to complete the other graduate-level courses by reviewing and teaching the mathematics that are needed for the other classes. I view this course primarily as a review; so don't expect to learn all the material if this is the first time you are seeing these topics. The material, which is covered in this course, depends primarily on the preference of the professor and background of the students but the curriculum often consists of the following topics:

- Ordinary Differential Equations
- Infinite Series
- Integration Techniques (how to use a mathematical handbook)
- Fourier (and other integral) Series and Transforms
- Complex Variables and Contour Integration
- Linear Algebra
- Tensors
- Eigenvalue Problems
- Green's Functions
- Partial Differential Equations
- Probability & Statistics
- Non-linear Dynamics
- Special Functions (Legendre Polynomials and Bessel Functions)

- Variational Calculus
- Group Theory

Textbooks typically used for graduate-level Mathematical Methods courses are:

1) Mathematical Methods for Physicists by Arfken and Weber
2) Mathematical Methods of Physics by Mathews and Walker
3) Mathematical Methods of Physics and Engineering by Riley, Hobson and Bence
4) Mathematical Physics by Hassani
5) A Course of Mathematical Analysis by Whittaker and Watson
6) Mathematics of Classical and Quantum Physics by Bryon and Fuller
7) Mathematical Physics by Butkov
8) Mathematical Methods for Scientists and Engineers by McQuarrie
9) Mathematical Methods in the Physical Sciences by Boas
10) Introduction to Solid State Physics by Kittel

Classical Mechanics

About 77% of Ph.D. level Physics departments require at least one semester of Classical Mechanics. Classical Mechanics based primarily on pre-twentieth century physics first developed by Newton hundreds of years ago. The mathematics used in this course is primarily calculus of variations and differential equations although many of the other Mathematical Methods topics are also used. Typical topics include:

1. Survey of Elementary Principles
    - Mechanics of a system of particles
    - Constraints
    - D'Alembert's Principle and Lagrange's Equations
    - Velocity Dependent Potentials and the Dissipation Function
    - Simple applications of the Lagrangian formulation
2. Variational Principles and Lagrange's Equations
    - Hamilton's Principle
    - Some techniques of the calculus of variation
    - Derivation of Lagrange's equations from Hamilton's principle
    - Extending Hamilton's principle to systems with constraints
    - Advantage of Variational Principle formulation
    - Conservation theorem and symmetry properties
3. The Central Force Problem

- Reduction to the equivalent one body problem
- The Viral theorem
- Differential equation for orbits and integrable power law potentials
- Bertrand's Theorem
- Kepler's Problem
- Scattering in a central force field
- Three body problem

4. The Kinematics of Rigid Body Motion
    - Independent coordinates of a rigid body
    - Orthogonal transformation
    - Euler angles
    - Finite rotations
    - Coriolis force
5. The Rigid Body Equations of Motion
    - Angular momentum and kinetic energy of motion about a point
    - Torque free motion
    - Motion of a symmetric top
6. Oscillations
    - Eigenvalue equations and the principal axis of transformation
    - Forced vibrations and the effect of dissipative forces
    - Beyond small oscillations
7. The Hamilton Equations of Motion
    - Legendre transformation and the Hamilton equations
    - Cyclic coordinates and conservation theorem
    - Derivation of Hamilton's equations from Variational Principle
    - The principle of least action
8. Canonical Transformations
    - Equations of canonical transformations
    - Harmonic Oscillator
    - Poisson brackets and other canonical invariants
    - Conservation theorems in Poisson bracket formulation
    - Hamilton-Jacobi theory
    - The action angle variables

Textbooks typically used for graduate-level Classical Mechanics courses are:

1) Classical Mechanics by Goldstein, Poole & Safko

2) Theoretical Mechanics of Particles and Continua by Fetter and Walecka

3) Classical Dynamics by Jose and Saletan

4) The Classical Theory of Fields by Lifschitz and Landau

5) Classical Mechanics by Taylor

6) Differential Forms and Connections by Darling

7) Calculus of Variations by Formin and Gelfand

Electrodynamics

About 89% of Ph.D. level Physics departments require at least one semester of Electrodynamics. This course is based partially on the work of Maxwell in the mid 19th Century but also includes topics from 20th Century research. The mathematics used in this course primarily consists of vector calculus, differential equations, Green's functions, Fourier transforms, complex variables, special functions and tensors so a good understanding of mathematical methods is essential here. The most popular textbook used in this class is the one originally written by J.D. Jackson in 1962. Topics typically include:

- Electrostatics and Magnetostatics and Potentials
- Gauge Invariance
- Boundary-Value Problems
- Multipoles
- Tensors and Relativity
- Dynamics of Particles and Lagrangians
- Dynamic Fields and Electromagnetic Waves
- Waveguides
- Radiation and Radiating Systems
- Scattering and Damping
- Magnetohydrodynamics

Textbooks typically used for graduate-level Electrodynamics are:

1) Classical Electrodynamics by Jackson
2) Classical Theory of Fields by Lifshitz and Landau
3) Modern Problems in Classical Electrodynamics by Brau
4) Notes for a Course on Classical Electrodynamics by Goldstein
5) Electrodynamics of Continuous Media by Lifshitz, Landau and Pitaevskii
6) Electromagnetism by Pollack and Stump
7) Introduction to Electrodynamics by Griffiths

8) Classical Electromagnetic Theory by Vanderlinde

9) Classical Electrodynamics by Greiner

Quantum Mechanics

About 91% of Ph.D. level Physics departments require at least one semester of Quantum Mechanics. Most programs require two semesters. The mathematics used in Quantum Mechanics typically consists of differential equations, linear algebra, tensors, probability & statistics and Fourier transforms. The material consists mostly of physics developed during the mid-twentieth century. Topics typically include:

Quantum Mechanics I

1. Introduction to Quantum Mechanics
    - Structure of matter
    - Classical and quantum physics
    - Wave-particle duality
    - Energy levels
2. Methematics of Quantum Mechanics
    - Hilbert Space of finite dimensions
    - Spectral decomposition of Hermitian operators.
    - Infinite dimension
3. Polarization: Photons and spin ½ Particles
    - Photon polarization
    - Quantum Cryptography
    - Angular Momentum and Magnetic moment in classical physics
    - Rotation of Spin ½
    - Dynamics and time evolution
4. Postulates of Quantum Mechanics
    - State vectors and physical properties.
    - Concept of the wave-function and the probability.
    - Superposition principle.
    - Heisenberg Inequalities
    - Schrodinger and Heisenberg pictures.
    - Time Evolution
5. Symmetries in Quantum physics
    - Transformation of a state in symmetric operation
    - Infinitesimal generators
    - Canonical commutation Relations
    - Galilean Invariance
6. Wave Mechanics
    - Diagonalization of X and P and wave functions
    - The Schrodinger Equation
    - Solution of time-independent Schrodinger equation
    - Potential scattering
    - The periodic potential

- Wave mechanics in three dimensions

Quantum Mechanics II

7. Wave Mechanics
    - Diagonalization of X and P and wave functions
    - The Schrodinger Equation
    - Solution of time-independent Schrodinger equation
    - Potential scattering
    - The periodic potential
    - Wave mechanics in three dimensions
8. Angular Momentum
    - Diagonalization of J^2 and J_z
    - Rotation matrices
    - Orbital angular momentum
    - Particle in a central potential
    - Angular distributions in decays
    - Addition of two angular momenta
9. Harmonic Oscillator
    - Simple harmonic oscillator
    - Coherent states
    - Introduction to quantized fields
    - Motion in a magnetic field
10. Elementary Scattering Theory
    - The cross section and scattering amplitude
    - Partial waves and phase shifts
    - Born approximation
    - Inelastic scattering
    - Scattering of a wave packet
11. Perturbation Theory
    - Time independent non-degenerate perturbation theory
    - Time independent degenerate perturbation theory
    - Magnetic moment calculation
    - Time dependent perturbation theory
    - Harmonic perturbation
12. Identical Particle Systems
    - Bosons and fermions
    - Scattering of identical particle
    - Approximation methods
    - One-electron atom

The same text is normally used for both semesters. Some textbooks include:

1) Quantum Mechanics – Concepts and Applications by Zettili
2) Quantum Mechanics by Le Bellac

3) Elementary Theory of Angular Momentum by Rose

4) Quantum Mechanics by Schiff

5) Modern Quantum Mechanics by Sakurai

6) Principles of Quantum Mechanics by Shankar

7) Quantum Mechanics Vol. 1 and 2 by Cohen-Tannoudji

8) Quantum Mechanics by Merzbacher

9) Quantum Mechanics by Messiah

10) Quantum Mechanics by Abers

11) Introductory Quantum Mechanics by Liboff

12) Lectures on Quantum Mechanics by Baym

13) Quantum Mechanics by Gasiorwicz

14) Introduction to Quantum Mechanics by Griffiths

15) Quantum Mechanics by Bransden

16) Quantum Mechanics by Lifshitz and Landau

17) An Introduction to Quantum Physics by French and Taylor

18) Quantum Mechanics: Fundamentals by Gottfried and Yan

19) Quantum Mechanics, 2nd Edition by Goswami

20) Intro to Theory and Applications in Quantum Physics by Yariv

21) Principles of Quantum Mechanics by Dirac

Some of the good Quantum Mechanics websites

http://info.phys.unm.edu/~ideutsch/Classes/Phys521F02/Phys521.html
http://info.phys.unm.edu/~ideutsch/Classes/Phys522S03/Phys522_S03.html
http://www.faculty.uaf.edu/ffraw1/651.html http://www.physics.ohio-state.edu/~perry/p632/
http://www.vanderbilt.edu/A&S/physics/volker/p330b/course_content.html
http://www.pas.rochester.edu/~orr/p246.html#homework

Links and Animations

http://www.falstad.com/mathphysics.html#qm
http://lectureonline.cl.msu.edu/~mmp/kap13/cd361a.htm
http://home.mesastate.edu/~dacollin/teaching/2007Fall/Phys321/

Statistical Mechanics

About 85% of Ph.D. level Physics departments require at least one semester of Statistical Mechanics. Statistical Mechanics is essentially a generalization of Thermodynamics, which seeks to understand the behavior of more particles than can be understood using classical or quantum mechanics. It mostly utilizes probability & statistics and differential equations. The material ranges from classical gas dynamics developed prior to the 20th century and quantum statistics developed during the 20th century. Topics typically include:

- Statistical Description of Systems of Particles
- Statistical Thermodynamics
- 4 Laws of Thermodynamics
- Equations of State
- Thermodynamic Potentials
- Classical Ideal Gases
- Entropy of Mixing and Gibb's Paradox
- Ensemble Theory
- Microcanonical Ensemble
- Canonical Ensemble
- Viral Theorem
- Paramagnetic Systems
- Grand Canonical Ensemble
- Density Matrix
- Quantum Ensembles
- Maxwell-Boltzmann, Bose-Einstein, and Fermi-Dirac Statistics

Typical textbooks include:

1) Statistical Mechanics by Pathria

2) Statistical Mechanics by Huang
3) Fundamentals of Statistical and Thermal Physics by Reif
4) Statistical Physics by Landau and Lifshitz
5) Introduction to Statistical Physics by Salinas
6) Statistical Mechanics and Thermodynamics by Garrod
7) A Modern Course in Statistical Mechanics by Reichl
8) Fundamentals of Statistical Mechanics by Bloch and Walecka
9) Thermodynamics and an Introduction to Thermodynamics by Callen
10) Thermal Physics by Kittel and Kroemer
11) Statistical Mechanics Made Simple by Mattis
12) Statistical Mechanics by McQuarrie
13) Equilibrium Statistical Physics by Plischke and Bergerson
14) Introduction to Modern Statistical Mechanics by Chandler

Other required courses

Some departments also require other courses such as Laboratory Techniques, Astronomy, Computational Physics, Optics, Elementary Particle Physics, Condensed Matter, Astrophysics, Modern Physics or various advanced topics courses. I suspect that the choice of required courses depends a lot on the research focus of the department. These requirements should be well documented in the department's literature. The UHCL program only requires the five basic core courses; Mathematical Methods in Physics I, Classical Mechanics, Electrodynamics, Quantum Mechanics I and Statistical Mechanics (in addition to advanced elective courses chosen by the student) for its MS program. In addition Quantum Mechanics II and the recitation courses are required for students pursuing the Ph.D. at UH or UHCL.

Choosing an Advisor

Choosing an Advisor is one of the most important decisions that a graduate student can make. In most programs, new graduate students are assigned temporary advisors or mentoring committees until they have completed the core courses and/or passed Ph.D. candidacy. For masters degree programs, students may have two advisors, an academic advisor and a thesis (or research project) advisor. In choosing an advisor, there are several things to keep in mind. First try to choose an advisor who has research interests similar to your own. If you aren't interested in your research advisor's work, graduate school won't be very fun.

Second, choose someone who communicates well with you. Graduate school in physics is more like an apprenticeship than anything else. In order to get the most out of it, you need to know very clearly from your advisor what you need to do and how well you are doing. Finally, if your relationship with your advisor isn't working out, you should check with your department chair as to your options. It is sometimes better to start over with a new thesis or research project than to continue in a dysfunctional advisor/advisee relationship. In addition to choosing an advisor, students completing a thesis are also required to select a thesis committee to help oversee their work.

Advanced Electives

The purpose of advanced electives is to prepare students to work on research projects. These courses are not offered as regularly as the core courses (usually only once every two or three years at best) so a student who has completed all the required courses and needs to take a specific advanced elective should signup when the course is offered and not wait until next time. I recommend that students choose advanced electives in consultation with their advisor or the faculty member that they wish to do research with. I've had students choose their electives based purely on their interests at the time without regard to their research goals, but this is not advisable. Advanced electives are typically courses like Astroparticle Physics, Computational Physics, Quantum Field Theory, General Relativity, Plasma Physics, Condensed Matter Physics, Particle Physics, Planetary Science, Astronomy, Cosmology or other advanced topics. These courses typically require knowledge of the core courses so any student who has completed the core should be ready to take advanced electives regardless of there background before starting graduate school. Time requirements vary as some advanced electives take less time than core courses and some can take much more.

Thesis verses Non-thesis Masters Degrees

Many physics departments offer both thesis and non-thesis options for completing the master's degree while the Ph.D. can only be completed with a thesis. The non-thesis option usually consists of a research project that may be as simple as assisting a faculty member with his or her work, but sometimes leads to a publishable research. I find that the non-thesis option works better for part-time students. Thesis work tends to be much more involved and the time commitment is more than most part-time students can handle. The advantage of the thesis is that the work can sometimes be extended into Ph.D. research. The thesis also gives the student time to become much more focused on a specific research interest. A good master's thesis can usually be published.

Colloquia

An important and but often overlooked part of any physics department is the colloquia. This is often called a speaker or seminar series. These are probably the easiest part of a physics graduate student's education, they simply need to show up and occasionally ask questions. The value of the colloquia is that it: 1) introduces students to current physics research, 2) it teaches students how to give talks by watching others, 3) it gives students a chance to meet researchers who may not be at their university and 4) it gives students a chance to ask questions to about current research. At UHCL, the physics colloquia are given in combination with our non-thesis capstone course every spring. Attendance is not limited to students taking the course and is encouraged for all graduate students.

Choosing a Research Project

Students should choose a research project based on their interests, abilities and time restrictions. Theoretical research projects tend to require a much more sophisticated mathematics background than experimental research. Computational work is often placed in the same category as theoretical research. The advantage of theoretical (or computational) research for some students is that work can be more easily scheduled than experimental work. Experimental work requires a physical laboratory, and almost all work must be completed in the lab. This makes experimental work difficult for many part-time students. I recommend that non-traditional students work on either theoretical research of try to find a project that can be completed at their work. There are many interesting problems that can be solved on a computer (in astrophysics for example) that could never be solved experimentally. Data analysis projects are another alternative for part-time students but may not be significant enough for Ph.D. level work.

Ph.D. Work

Masters and Ph.D. programs are structured in a similar way. Both utilize core courses, advanced electives and a research capstone. The difference is that for the Ph.D., the research capstone is much more involved. There is a rule in Ph.D. programs that the degree must be completed within 10 years or 100 credit hours. This clock starts as soon as the student is accepted into the Ph.D. program. The rule puts pressure on part-time students to make as much progress as possible as soon as possible. Traditional Ph.D. students typically take 5-7 years to complete their degree. The Ph.D. in physics is not like may other degrees; there is no clear completion time and you are not handed a degree after completing all the coursework. Students finish the degree when their advisor feels that they are done and no sooner.

Ph.D. Exams

Ph.D. programs typically require students to pass several exams as they progress through the program. The first test is referred to as the candidacy exam or qualifying exam. These tests are normally written but sometimes have an oral component. Most departments allow students two attempts to pass this test. At UHCL and UH, the candidacy exam is built into the core courses. Students are required to get a B or better in each of the core courses and on the various final exams in order to pass. In addition, students are required to take the 1 credit hour recitation section associated with each core course. Once a student passes the candidacy exam he or she is officially considered a Ph.D. candidate.

The second test is sometimes referred to as the qualifier or oral exam. This exam covers the material that the student is expected to know after completing the advanced electives. Students are required to pass this exam before officially beginning their Ph.D. thesis work. The student's thesis committee often gives this as an oral exam. The final exam is the thesis defense. Normally a student is not allowed to defend their dissertation until their advisor believes they are ready. Few people ever fail this test but many never make it this far. Once the defense is complete, you are officially a doctor, the final version of the dissertation is signed by the committee and placed in the university's library.

What to do after the degree

People pursue graduate level physics degrees for many reasons. It compliments engineering degrees, broadens the knowledge base of practicing engineers and gives the student the background needed to participate in advanced research. Students who want to pursue careers in higher education teaching need at least a master's degree. Whatever your motivation, just getting the degree is not always enough to achieve your goals. After finishing an advanced degree in physics, students have several options. They may choose to complete another degree in a similar area such as engineering, chemistry or biology in order to learn more about a specific interdisciplinary research interest. They may choose to complete a degree in a seemingly unrelated area such as business or law, in order to develop the unique background needed for their chosen career path. Many students go on from the masters to Ph.D. and then postdoctoral positions in order to focus on a specific physics related problem. I choose to go directly from the Ph.D. to a faculty position at a small university so I could pursue my interests in curriculum development.

Which path to choose depends a lot on the student. The great thing about physics is that it opens lots of doors for whatever your ultimate goals are. It can be used as a liberal arts degree, which enhances the knowledge base of the student no matter what their career path. Some also see it as a training degree to prepare students for a specific job. However you choose to use your degree keep one thing in mind, getting an advanced degree in physics is not easy and may be considered impossible for most people. If you only want the degree to put a Ph.D. behind your name, look elsewhere. If you really want to learn physics, even if don't know what you would use it for, this is the degree for you. If you have questions about what you can do with the degree you should talk to some physics faculty members. They may not have all the answers (some many still think that becoming a professor is you only career option) but they could provide a few ideas. Physics is a good major for someone who wants a career, not just a job, because you can learn important skills like: how to solve complex problems, how to program computers, the effective use of mathematics, how to build and work with machines, how to use high-performance computers, how to teach a class, how essentially any system works, how to manage projects, how to give presentations, how to write technical papers and most importantly, how to think critically. For example, one of the many skills that I learned doing computational physics was how to program using parallel processors. I learned this before the invention of cheap multicore processors when there was no demand for this skill. Now this skill is in high demand as many software developers are now working to parallelize their code to take advantage of the new hardware.

My advice here is that you don't need to know specifically what your job will be after you finish graduate school in physics. Physicists are smart and have a lot of marketable skills, there will always be jobs for smart people. I wish I could list every job that an advanced degree in physics qualifies you for but there just isn't enough room. For information on what physicists do after graduation and how much they get paid for doing it, check out the American Institute of Physics website http://www.aip.org/statistics/trends/emptrends.html.

For more information on the University of Houston Clear Lake and University of Houston Physics Programs go to:

UHCL Physics Department: http://sce.uhcl.edu/physics

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