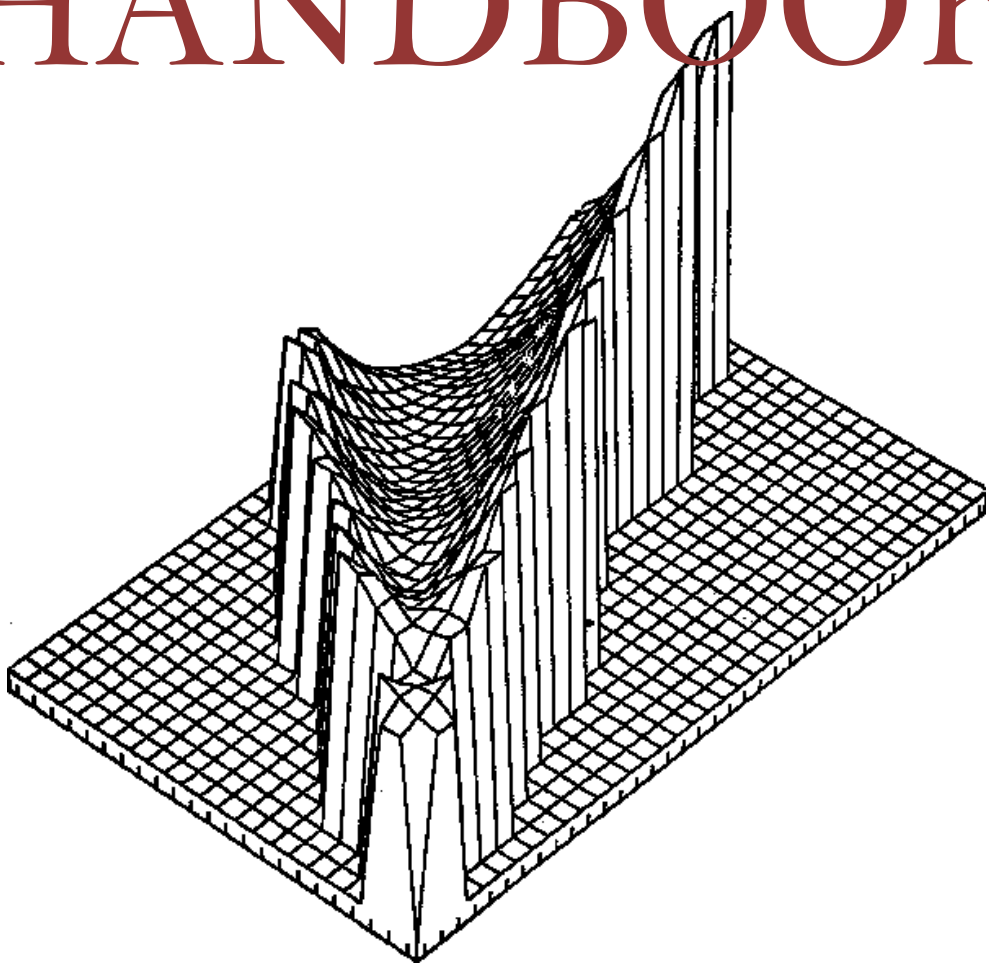
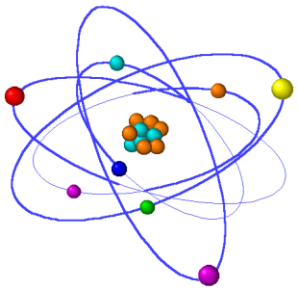
PHYSICS DEPARTMENT

STUDENT HANDBOOK



Gettysburg College
Gettysburg, PA 17325



Dedicated to
All Gettysburg College Students
Engaged in
The Study of the Nature of Matter and Energy

PHYSICS DEPARTMENT

Gettysburg College
Gettysburg, PA 17325

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Gettysburg College Physics Department is online at http://www.gettysburg.edu/academics/physics

FORWARD

"Physics is puzzle solving...." -Maria Goeppert Mayer

"Equipped with his five senses, man explores the universe around him and calls the adventure Science."-Edwin Powell Hubble

For the inquisitive and questioning, the study of physics is a most rewarding pursuit. An inexhaustible search for the fundamental laws and structure of the universe, the nature of matter and energy and the forces by which objects interact, physics is guided by the idea that ultimately these laws and structures are precise, comprehensible, and yes, beautiful. Building descriptions of atoms, organic material, stars and the origin of the universe, scientists and engineers use their understanding of physical principles to solve practical problems in medicine, communications, energy, transportation, computer soft- and hardware design, to name a few. Today's world is complex and often confounding, but physics graduates are well prepared to enter and thrive in it because they have begun to understand the laws that govern the way things work. Products and technology change constantly, but physical principles do not.

The Gettysburg College Physics Department seeks to equip its students with a comprehensive understanding of those physical principles that govern our universe through classes that develop the analytical and quantitative reasoning skills necessary to think critically and creatively. Through classroom lectures, laboratory experiments, independent study, writing, research and discussion with faculty, and talks given by visitors expert in their fields of study, the Department works to provide the training needed for each student to realize his/her career goals.

This Student Handbook introduces the physics, engineering, and astronomy programs and resources available here at Gettysburg College. It is directed to all who seek fundamental knowledge of the wonder-filled world we share, who enjoy questioning, experimentation, discovery, and just plain tinkering. It speaks to those who anticipate becoming professional physicists, astronomers and engineers, as well as to those who seek a stimulating and challenging course of study to prepare themselves for absorbing and interesting careers in a myriad of fields.

In order to help you make the most of your years at Gettysburg, information is provided on the laboratory, shop, library, and computing facilities available to you, as well as brief descriptions of the research activities of our physics faculty. A description of the activities, requirements and expectations of the Gettysburg College Physics Department, including information on courses, the Dual-Degree (3-2) Engineering Program, and opportunities for research will be found here. The

handbook describes some of the opportunities available for careers and graduate study, and outlines what to do to prepare for the years after graduation.

The Gettysburg physics faculty wants to help you assume responsibility for and control of your education by informing you of what demands will be made of you, and what opportunities and rewards to anticipate here and after graduation. You may have a number of questions and we welcome them. We hope to help you make an informed choice of a major - and we hope that it will inspire a positive, enthusiastic decision to declare that major in physics!

INTRODUCTION - THE STUDY OF PHYSICS

"We are just an advanced breed of monkeys on a minor planet of a very average star. But we can understand the Universe. That makes us something very special." –Stephen Hawking

Physics is the most basic of the sciences, dealing with the structure of matter, energy in all its forms, and the interrelationships between matter and energy. If you look around you and start asking questions such as why does that happen or how does that work, and if you probe into those questions to get to the root causes, you are studying physics.

Obviously, there is a difference between a human being and a stone; humans, endowed with constant, immanent movement, communicate with and change the world around them, while stones do not. Still, both are made up of fundamental particles, part of a vast natural universe governed by the same set of physical laws. It is the study of these physical laws that is the field of physics.

The details of what these forces are and how they act cannot be understood at once, even in a concentrated four-year course of study; indeed, it is lifetime pursuit. The basic ideas of physics, however, are all contained in some of the first courses students take at Gettysburg. Mechanics studies how bodies move; electricity and magnetism examine one of the strongest and most important forces of nature; the study of vibrations and waves investigates the behavior of sound and light and fundamental forms of energy; and the studies of atomic and nuclear physics and relativity examine the universe at the scale of the very small and the very large. Students may also take courses that apply fundamental physical principles to the understanding of complex technology, such as microprocessor electronics, lasers, and fiber optics.

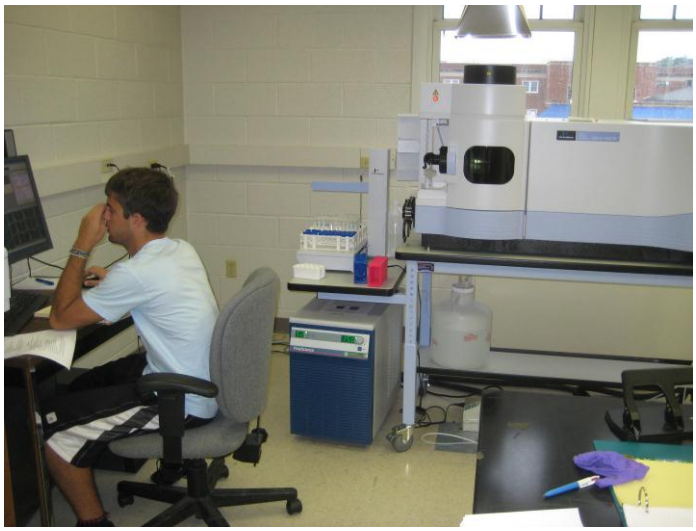
Physics is not learned just in the classroom: careful observation of and insight into nature, experience and experimentation, are as much a part of a physicist's training as are class attendance, discussion and reading. Laboratories associated with physics courses will give "hands-on" experience with the phenomena studied and with the tools used.

Finally, a firm understanding of the physical universe cannot be obtained without an ability to speak the language of physics - mathematics. While there have been a few great physicists - the genius Michael Faraday to note one - who did not have or need formal training in mathematics, few of us would be able to function without it; training in and understanding of mathematics make it possible to comprehend the workings of nature. Believe it or not, as you proceed through the curriculum, you will see that the courses in the "higher", more complex fields of mathematics actually simplify things.

THE HONOR SYSTEM

"A people that values its privileges above its principles soon loses both."
–Dwight David Eisenhower

"The oldest story in the world: if you don't stand up to evil it eats you first and kills you later, but not soon enough." –Alan Furst, Blood of Victory



The Physics Department supports all aspects of the Gettysburg College Honor Code. The general requirements of the Honor Code apply to all your work, and it is important for you to understand what constitutes "authorized aid" for problem assignments, laboratory work laboratory work, and computer exercises.

It is standard practice for physicists to discuss their work with each other, and you are encouraged to work with other students, as these interactions are usually very invigorating and productive. At the same time, it is very important for you to pursue and take responsibility for your own work and not that of others. The guidelines below are intended to promote a free and stimulating atmosphere, while insuring that the Honor Code functions effectively.

1. Problem assignments play a major role in most physics courses. The problems you submit for correction and grading should represent your own work. You will want to and should discuss problems with other students, but you should not show or ask to see any written solutions. Whenever you have obtained substantial aid in solving a problem, you must acknowledge this aid. Write out and sign the honor pledge on each assignment that counts toward a grade.

2. Laboratory work is often performed by students working together. Close cooperation between you and your partner(s) is essential. Again, the Department recognizes help from other students in laboratory work as "authorized aid". If you and your partner(s) turn in identical laboratory reports, you will not be accused of cheating. You will, however, receive a low grade because of your poor scholarship. Signing the Honor Pledge on a laboratory report means that you were present when the experiment was performed and that you actively participated in taking data, performing calculations, and answering questions. Active engagement is how one learns, and anything short of that is wasting everyone's time, talent, and resources.

3. Computer assignments follow a pattern not too different from problem assignments. Variations among courses, however, are extensive enough to require separate rules for each course. Your responsibility is to be very sure that you understand and follow the particular rules in each course. If there is anything you don't understand, don't hesitate to ask your professor, who is there to guide and assist you in every way possible.

THE CURRICULUM

"Humanity needs practical men, who get the most out of their work, and, without forgetting the general good, safeguard their own interests. But humanity also needs dreamers, for whom the disinterested development of an enterprise is so captivating that it becomes impossible for them to devote their care to their own material profit." - *Marie Curie*

The physics curriculum for majors is designed according to two principles. The first is that there is certain training required of every physicist, education that should include an introduction to a wide range of physical phenomena, experimental investigation and scientific thinking. Further, this training should be at a level that provides physics graduates with the ability to begin graduate work in physics. The second principle recognizes that people major in physics for different reasons, and a physics curriculum should have the flexibility, clarity and effectiveness necessary to accommodate a variety of interests. These principles are reflected in the Physics Department's required core of studies and in its collection of elective physics courses.

The physics courses that may be submitted for a major are:

Physics 111: Introductory Modern Physics I
Physics 112: Introductory Modern Physics II
Physics 211: Introductory Electricity and Magnetism
Physics 240: Electronics (taught in the spring, even years)
Physics 255: Mathematical Techniques for Physicists
Physics 310: Introductory Quantum Mechanics
Physics 312: Thermodynamics and Statistical Physics (spring, even years)
Physics 319: Classical Mechanics (taught in the fall, odd years)
Physics 324: Experiments in Quantum Physics
Physics 330: Electricity and Magnetism (fall, even years)
Physics 341: Quantum Mechanics (spring, odd years)
Physics 352: Optics and Laser Physics (spring, odd years)
Physics 381: Special Topics in Physics and Astronomy
Physics 420: Advanced Research Methods in Physics
Physics 452: Tutorials: Special Topics
Physics 462: Independent Study in Physics and Astronomy

The Physics Department offers both *Bachelor of Science* and *Bachelor of Arts* degrees for the major.

B.A. Requirements: A minimum of nine physics courses is required for the major. This includes the following six core courses: Physics 111, 112, 211, 255, 310, 324, and three (3) additional courses at the 200-level or higher, at least one of which must be from Physics 312, 319, 330 or 341. In addition, majors are required to complete a capstone, either Physics 420 or an individual research project, Physics 462, and mathematics courses through Mathematics 211 or its equivalent.

B.S. Requirements: In addition to the six core courses mentioned above, the B.S. degree requires Physics 462, at least three courses from Physics 312, 319, 330 and 341, and any two courses at the 200-level or above. In addition to mathematics through 211, candidates for the B.S. degree must also complete Mathematics 225.

A typical 4-year schedule for a physics major is as follows:

FIRST YEAR

FALL	SPRING
Physics 111	Physics 112
Math 111	Math 112
Foreign Language	Foreign Language
English 101/elective	Seminar 100

SOPHOMORE

FALL	SPRING
Physics 211	Physics 255
Math 211	Elective
Elective	Dist. Req./elective
Distr. Req.	Physics 240[3]/ 352[3]

JUNIOR

FALL	SPRING
Physics 310	Physics 324
Physics 319[3]/330[3]	Physics 312[3]/341[3] or Physics 240[3]/352[3]
Math 225[1]	Math[4]
Dist. Req.	Dist. Req.

SENIOR

FALL	SPRING
Physics 330[3]/319[3]	Physics 462[2]
Physics 420[2]	Physics 312[3]/341[3] or Physics 240[3]/352[3]
Dist. Req.	Electives
Electives	Electives

[1]Required for BS students only.
[2]Either of these courses will satisfy the capstone experience. Typically BA students will take 420. BS students are required to take 462.
[3]Course taught every other year.
[4]Possible courses include Math 364.

Rest assured that this curriculum is more than adequate for students who wish to continue the study of physics in graduate school.

Students who wish to combine their physics education with another discipline such as chemistry, computer science, management, or mathematics should consider the following electives:

Chemistry
Chemistry 107-108, 305, 306, 317

Computer Science
Computer Studies 103, 104, 216, 311, 341, 371, 373

Management
Economics 103,104, 241, 242, 243, 245, 351
Management 153,154, 247, 266

Mathematics
Mathematics 321-322, 351-352, 356, 362, 364, 366

A physics minor consists of Physics 111, 112, 211, and three additional courses in physics at the 200-level or above, and is an appropriate complement to a variety of majors, including mathematics and computer science.

Course titles and descriptions can be found in the College Catalog, as well as on the Internet under the applicable department web pages (see http://www.gettysburg.edu/academics/department_listing.dot).

Because physics is such a versatile major, there are many other possibilities for courses. If you are interested in securing a job immediately after graduation rather than pursuing further studies in physics, you can tailor a course to suit your particular needs.

THE DUAL-DEGREE ENGINEERING PROGRAM

"Although we modern persons tend to take our electric lights, radios, mixers, etc., for granted, hundreds of years ago people did not have any of these things, which is just as well because there was no place to plug them in....What in the world is electricity? And where does it go after it leaves the toaster?" -Dave Barry

"It is a great profession. There is the satisfaction of watching a figment of the imagination emerge through the aid of science to a plan on paper. Then it moves to realization in stone or metal or energy. Then it brings jobs and homes.... elevates the standards of living and adds to the comforts of life. That is the engineer's high privilege." -Herbert Hoover

Looking for an opportunity to pursue a specialized career in engineering on a broad and solid liberal arts foundation? The Dual-Degree Engineering Program at Gettysburg College is operated in collaboration with Washington University in St. Louis, Columbia University, and Rensselaer Polytechnic Institute (RPI). Recent Gettysburg College students participating in the dual-degree program at Washington University at St. Louis include Ross Hempel, '07 (physics and mechanical engineering), and Peter Lall, '08 (physics and civil engineering). Brook Getachew, '08 (physics and biomechanical engineering), Mike Lazur, '10 (physics and civil engineering), and Kyle Wendler, '11 (physics and electrical engineering), are among our most recent Combined Plan students with Columbia University. Brian O'Neill, Class of '92, obtained his degree in civil engineering at Penn State, in addition to his physics degree at Gettysburg, so keep in mind that other collaborations may also be possible.

Students in this program normally attend Gettysburg for three years or four and then complete the program in two more years at the applicable school of engineering. A student completing the program will receive both an engineering degree from the engineering school and a Bachelor of Arts degree from Gettysburg College. Its design encourages:

- Students who are interested both in liberal arts and in engineering to pursue *both* goals. The liberal arts have a significant role to play in the education of engineers, and many engineering firms are increasingly seeking engineers with a liberal arts background because of their communication and writing skills. Because engineers conceive and apply technology for service to mankind, it is important that engineers have an understanding of society's cultural and ethical values, and the ability to articulate those values.

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The Dual-Degree Program also introduces students to engineering more gradually than an engineering school does. While this point is important for able students who may need time to mature, one should not make the mistake of considering the cooperative program as an easy way to get an engineering degree. By the time these students leave Gettysburg, they will be expected to compete with upper-class engineers, and our curriculum is designed to prepare them for that.

The cooperative agreements Gettysburg has with these institutions give preferred status for transfer to recommended Gettysburg students. Although these agreements do not guarantee admission to the engineering institution, no student who has been recommended for transfer has ever been refused admission. Students should note, however, that in most instances a 3.25 average is required for recommendation by the Department.

Since students must satisfy Gettysburg's distribution requirements and also take the necessary science and engineering courses within three years, it is very important to plan schedules carefully with the help of their academic advisors. Any student considering transferring after junior year is strongly urged to speak with the coordinator for this program as soon as possible, to obtain assistance in determining the specific requirements of the engineering discipline in which she/he may be interested.

A *typical*[1] schedule for a Dual-Degree student goes something like this:

FIRST YEAR

FALL	SPRING
Physics 111[2]	Physics 112[2]
Math 111	Math 112
Foreign Language	Foreign Language
First Year Seminar	English 101 or English 111

SOPHOMORE YEAR

FALL

Physics 211[2]	Math 212 or Math 225[3]
Computer Science 107 or 111	Economics 103 or 104
Math 211	Dist Requirement
Major Requirement	Major Requirement

JUNIOR YEAR

FALL	SPRING
Chemistry 107	Distribution Requirement/Elective
Math 212 or Math 225[3]	Distribution Requirement/Elective
Distribution Requirement	Major Requirement
Major Requirement	Elective
Elective	

[1]This typical schedule will differ from student to student, depending on the engineering discipline pursued. Chemical engineers, for example, are required to take organic chemistry, and an additional semester of physics may be required by some schools for electrical engineering and related disciplines. *Some electives, therefore, may have to be selected to fill certain, specific requirements.*
[2]Students not majoring in physics and interested in certain disciplines may prefer to take Phy109/110 instead of Phy111/112/211.

[3]Math 212 and 225 are required by many by not all disciplines.

WASHINGTON UNIVERSITY AT ST. LOUIS

Washington University at St. Louis sees its Dual Degree Program as a valuable alternative to its traditional engineering curricula. Our emphasis on the development of strong communication skills and a broad background in the humanities and social sciences, developed in a supportive, more personalized environment, is combined with their first-class technical education. You have the opportunity to flourish in a career that more and more requires multidisciplinary teams to address multifaceted challenges with strong oral and written communication skills, dexterity, imagination, and teamwork.

Washington University offers the following engineering and science fields to Dual-Degree students:

- Biomedical Engineering
- Chemical Engineering
- Computer Engineering
- Computer Science
- Electrical Engineering
- Mechanical Engineering
- Systems Engineering

Combined Degree Programs:

Students may also elect the combined B.S.-M.S. program and earn both degrees in six semesters of work at Washington University. A combined B.S. (Engineering)-M.B.A. (Graduate School of Business Administration) is also available. Again, the program requires a minimum of three years or six semesters of work at Washington University after three years at Gettysburg.

COLUMBIA UNIVERSITY

Columbia Engineering's 3-2 Combined Plan Program for the B.A. and B.S. is designed to provide students with the opportunity to receive both a B.A. degree from Gettysburg College and a B.S. degree from Columbia Engineering in five years. Students complete the requirements for the liberal arts degree along with a pre-engineering course of study in three years here and then complete two years at Columbia. Admission to Columbia Engineering at the end of the junior year is possible for those students who have an overall grade-point average of 3.25 or better; a math and science pre-requisite grade-point average of 3.25 or better, are recommended by your liaison officer, and members of the math and science faculty; and have completed the appropriate preparation successfully, including the pre-engineering requirements and Gettysburg College requirements and major.

Another available option is the 4-2 B.A/B.S. degree program, designed to allow students to graduate from Gettysburg College with a B.A. degree, having followed a related course of study, and then transfer to Columbia Engineering to complete a B.S. degree in two years.

A student wishing to complete the Dual-Degree Program at Columbia University may select from the following fields:

- Applied Mathematics
- Applied Physics
- Biomedical Engineering
- Chemical Engineering
- Civil Engineering
- Computer Engineering
- Computer Science
- Earth and Environmental Engineering
- Electrical Engineering
- Engineering Mechanics

- IEOR*: Engineering Management Systems
- IEOR*: Financial Engineering
- IEOR*: Industrial Engineering
- IEOR*: Operations Research
- Materials Science and Engineering
- Mechanical Engineering

*Industrial Engineering and Operations Research

RENSSELAER POLYTECHNIC INSTITUTE

RENSSELAER POLYTECHNIC INSTITUTE

This program is designed for students who complete three years (through the junior year) at Gettysburg College, then transfer to Rensselaer's School of Engineering. Most students accepted into this program have achieved at least a B average, with grades of A or B in their calculus, calculus-based physics, and chemistry courses. Two years of carefully planned and successful study at Rensselaer complete the requirements for receiving degrees from both Rensselaer and Gettysburg College. RPI offers B.S. degrees in the following engineering and science fields:

- Chemical and Biological Engineering
- Civil and Environmental Engineering
- Electrical, Computer and Systems Engineering
- Industrial and Systems Engineering
- Materials Science and Engineering
- Mechanical, Aerospace and Nuclear Engineering

3-3 Program:

RPI also offers a 3-3 program. A student would complete his/her junior year at Gettysburg and then transfer to RPI for an additional three years. This program, which requires a slightly superior record than the 3-2 plan, completes the requirements for the bachelor's degree at Gettysburg and the B.S. and the Master of Engineering degrees at RPI.

4-2 Program:

Graduates of Gettysburg in the physical sciences or mathematics who have superior records may qualify for admission to RPI after graduation to work on a Master of Science degree.

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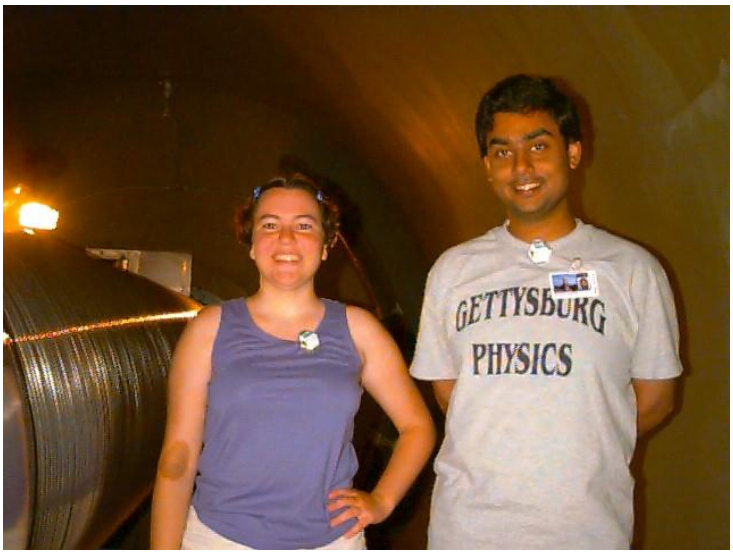
Other Options in Engineering:

While Gettysburg does not maintain cooperative engineering agreements with other institutions, it may still be possible to transfer to an engineering institution other than Columbia University, RPI, or Washington University - the Universities of Illinois, Iowa, Pittsburgh and Delaware, for example. In these cases, students had to petition the Gettysburg Academic Standing Committee, but approval was not difficult to obtain. As in the other cooperative agreements, students were able to receive degrees from both institutions.



Students may, of course, decide for one reason or another to stay at Gettysburg for four years, even though they still want to become engineers. Those who have obtained B.A. degrees at Gettysburg College with a major in physics, and with appropriate grades, will be accepted with full standing by many institutions into their engineering master's degree programs. Our web sites on curriculum and graduate study contain additional information on this possibility.

If you would like to speak with a professor regarding this program and its possibilities for *you*, please feel free to contact Dr. Bret Crawford, liaison officer for our Physics Department.

INDEPENDENT STUDY

"Don't just read it; fight it! Ask your own questions, look for your own examples, discover your own proofs." -Paul Halmos

I'll play with it first and tell you what it is later." -Miles Davis

The Gettysburg College Physics Department's curriculum of lectures and structured laboratories provides the framework for the careful study of physics. At some point, however, students are encouraged to venture forth on their own, to take advantage of the many opportunities for independent study and research available.

Independent Study and Research without Course Credit

It is not necessary to be a third or fourth year student or to be enrolled in a physics course to do independent work in physics; most of the professors in the Department have projects in which students may participate at any level. An independent study program advisor is available to help you select a project.

Physics 462: Independent Study in Physics and Astronomy

Regardless of career objectives, students should consider taking *Physics 462, Independent Study*, during the spring of senior year. In fact, this course is required for all those who select the Bachelor of Science option as their degree. Physics 462 provides invaluable training for the work encountered after graduation, whether that work is in graduate study or in employment.

Physics 462 may only be taken with the permission of the Department, and there is a standard procedure for obtaining such permission. Any physics major is eligible, but must begin developing a project and receiving Department approval in the spring term of junior year. If you need an idea or have an idea of your own, talk with the independent study program advisor, who can describe possible projects and refer you to faculty whose interests parallel your own. Probably the first thing your adviser will do, after describing these possibilities, is to send you to the library to do some background reading. After researching as much of the literature in your project field as possible, you should formulate a draft of your proposal, and take it to your adviser for his/her review. When the two of you are satisfied, it is ready to be submitted for Departmental review. Since the process of preparing your proposal will probably take about two months and is due in the Physics Department a week before the last day of classes, you should begin searching for a topic soon after the beginning of spring term of your *junior* year.

Most projects are likely to be experimental rather than theoretical in nature, as it is difficult to do substantial theoretical work on the undergraduate level. Computer projects are possible, however, and the Department has a modest budget available for equipment for such. If equipment needed for

your particular project is not available in the Department, make a list of what you need, along with its manufacturer and price, and submit it with your proposal.

All proposals must receive Department approval before students can register for Physics 462. If your proposal is submitted promptly, the Department will take action on it in time for you to make revisions before the registration session, which normally occurs around the end of April.

Unforeseen problems are the rule rather than the exception in research; if you wait until the spring term of your senior year to start thinking about and working on your project, you will most likely not get very far. Students are expected to do substantial work on their projects during the fall term, even though they are not yet formally enrolled in Physics 462. If you have an experimental project, plan to have your apparatus ready to take data before the end of the fall term. You will then be ready to concentrate on taking good data and interpreting it, instead of suffering too many last minute frustrations (there are always some!).

The culmination of your project is a presentation of your work at a physics colloquium. This may be the first time you have given such a talk and you will certainly want to make sure that your hard work receives proper recognition, so you and your adviser should plan your talk carefully. It is a good idea to have practice runs to get your timing down and to iron out any difficulties. You are also required to submit a paper on your project to your adviser before the colloquium. This paper will be added to the collection of student project papers retained by the Physics Department.

Physics 452 Tutorial: Special Topics

While it is impossible to offer a course in every field of physics, the Physics Department makes every effort to accommodate student interests in areas of physics other than those taught in its standard courses. If you would like to study a field of physics not represented in any course description, it may be possible for you to do so on a tutorial basis. Consider taking *Physics 452 Tutorials: Special Topics*, which is designed for one or more students to pursue a given subject under the guidance of a professor. Examples of possible topics include nuclear physics, particle physics, solid state physics, medical physics, and topics in astronomy. If you want to take *Physics 452*, find a professor within the Department who is able to work with you. This is normally a simple matter, though it may not always be possible for a particular professor, due to other staffing interests and responsibilities.

Physics 473: Summer Internship

A summer internship is an excellent opportunity to participate in a research program on campus or at a major research laboratory and receive course credit. Government laboratories such as the National Institute of Standards and Technology, Brookhaven National Laboratory, Stanford Linear Accelerator Center, Princeton Plasma Physics Laboratory, and Goddard Space Center, offer summer programs for student for which they are paid a modest stipend. There are also similar opportunities, normally for students between their junior and senior years, in industrial or university labs, often funded by the NSF program Research Experiences for Undergraduates (REU). In many cases, selection for these programs is nationally competitive. Since many of the application deadlines are in January and February, interested students should discuss these programs with their advisors early in their sophomore or junior years.

If these programs meet proper standards, Gettysburg College will grant one course credit for participation in these internships; students are required to keep a journal during their internship and to submit a paper and present a colloquium on their projects in the fall semester following such internships. Physics 473 will count as one of the five courses permitted as a full load in that fall term, may only be taken under the *S/U* grading system, and will count as one credit toward graduation, but it does not satisfy any requirements for the physics major.

GRADUATE STUDY

"Education is... hanging around until you've caught on." -Robert Frost

"To think is to forget differences, generalize, make abstractions." -Jorge Luis Borges

"Don't be humble ... you're not that great." -Golda Meir

Physics is a versatile major and will prepare you to enter graduate work in a variety of fields that provide attractive and satisfying job opportunities. Our students have entered graduate work in physics, astronomy, astrophysics, meteorology, mathematics, geophysics, biophysics, psychology, materials science, electrical engineering, nuclear engineering, mechanical engineering, environmental engineering, ocean engineering, business, law, music, and theology. Engineering has been a common choice and continues to remain popular. Graduate schools attended by Gettysburg College alums include Brown, Columbia, Michigan, Ohio State, Minnesota, Rutgers, Chicago, Wisconsin, Colorado, Stanford, UCLA, Texas, Delaware, Florida, Duke, MIT, RPI, Virginia, West Virginia, Pittsburgh, Penn State, Maryland, American, George Washington, Cornell, Wharton Business School and Princeton Theological Seminary, to name a few. While not all students intend to go beyond master's work, most going on for a Ph.D. have been successful.

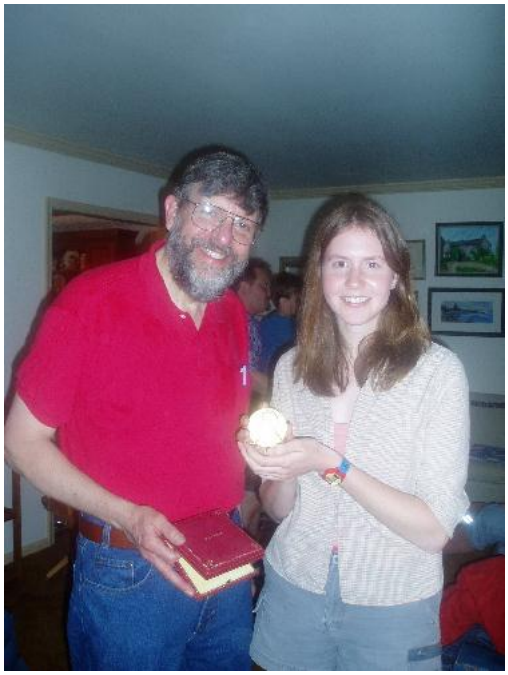
If you are considering graduate school, it is important to have a conference with your faculty adviser as soon as possible. While the final decision is obviously yours, your advisor can help you sort through the various programs available to you based on your interests and abilities. The following guidelines are offered to assist in this pursuit.

To be certain of being admitted to graduate school, one should have at least a 3.0 grade point average, with a minimum 3.5 needed for acceptance into the more prestigious graduate school programs. Both your physics average and your overall average are important, and a transcript that shows steady improvement over the past two years is beneficial. While grade point average is important, it is not the *sole* indicator of suitability for graduate work. A student who has high grades but finds his or her motivation dwindling is not a good candidate. On the other hand, some students with an overall average as low as 2.5 have gone on to graduate schools and done well, their success attributable to a high degree of interest and the willingness to work hard.

All graduate schools will require you to take the aptitude section of the Graduate Record Exam (website: http://www.gre.org/) and most of them will also require the physics section of that exam. Graduate schools will want to know your scores before their application deadlines, which are usually in February or March. The dates and locations for these tests may be obtained from the Gettysburg College Career Planning and Advising Office (please feel free to review their website at http://www.gettysburg.edu/student_life/career_development/). The exams are given three times a year, April, October, and December. Exact dates are posted on the ETS web page (http://www.ets.org/). Keep in mind, too, that any scholarship programs, and some graduate

departments, require that applicants take both parts of the GRE on or before the October testing date. Be aware that the registration deadline falls more than a month before the test date.

Many students take the general test in the April of their junior year and the physics test in the October of their senior year (it is not a good idea to take both exams on the same day!). GRE registration packets should be available at the College's Center for Career Development and/or go online to the Educational Testing Service.



Some of the more competitive graduate schools are placing increased reliance on GRE scores. It is difficult to improve aptitude scores by advanced preparation, but there are books available with sample GRE questions and you may find them useful. The GRE is a timed, multiple choice exam, similar to the SAT. Some sample questions are available in the free GRE General Test Descriptive Booklet and some will be mailed to registrants for the physics test, but you may also find it useful to study the ETS booklet *Practicing to Take the GRE Physics Test*. This booklet contains two GRE physics exams that were actually administered in previous years. It is useful to take these trial exams individually, timing yourself, and then to discuss your answers with others. Mock GRE's from other publishers are available, but may not accurately reflect the real GRE (for example, the sample tests given in J.J. Molitoris's *GRE Physics* - "the purple book" - are atypically advanced and difficult).

Preparation for the *physics* section of the GRE is *definitely* worthwhile. Your best bet is to review the material covered by the courses in the seven-course core. If time is limited, confine your study to the texts you used in Physics 111,112, 213, 310 and 312. Ninety percent of the questions on the exam can be answered at a level compatible with those texts. Most of the questions concerning classical physics (mechanics, electricity and magnetism, thermodynamics, waves, etc.) are at the level of the Halliday & Resnick text, and it makes good sense to review this book, paying special attention to the chapter summaries. Most of the questions concerning quantum physics are at the 100-level courses. There are many questions concerning the facts of atomic physics, and a thorough review of your 1st year physics text during the summer before you take the test is recommended - or some other text on modern physics, whatever you are most familiar with (Serway, Moses and Moyer's *Modern Physics* or Eisberg and Resnick's *Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles*, etc.)

The Physics Department has considered offering a review test in the early fall if enough interest develops, so let your advisor know in the spring of your junior year if this appeals to you.

How do you decide where you should apply? Take a look at the graduate school information, graduate school posters and information-request postcards in the Masters Hall Student Lounge *and* online! If you find a program that attracts you, ask a physics faculty member/advisor if more information is available and/or contact the graduate school directly. If you have a specific field in mind but cannot find a university that offers programs in this field, consult the booklet, *Graduate Programs in Physics, Astronomy and Related Fields*, published by the American Institute of

Physics; a copy is kept in the Student Lounge. Don't hesitate to ask your academic advisor, your professors, everyone in the Department, to help in your pursuit.

Representatives from various graduate schools come to the campus, usually during fall semesters, and hold brief, informal sessions that are excellent sources of information even if you are not interested in the particular schools they represent. Notices of these sessions are normally advertised on the Gettysburg College website and newspaper, and via e-mail (various "digests"), and all juniors and seniors who are contemplating graduate school should consider it their responsibility to attend them.

After obtaining as much information as you can, start narrowing your choices down to five or six universities. Some students prefer to apply to at least one institution where the competition is strong and to one where acceptance is believed to be more certain. Your advisor can give you some notion as to the relative competitiveness of an institution. The AIP guide to graduate programs also gives information about graduate requirements.

Most schools request at least three references. Ask faculty members who know your work well to write recommendations for you. It would be helpful to them if you could tell them about some of your past accomplishments and future aspirations. The Career Counseling and Advising Office will be happy to help you prepare an information sheet or résumé.

At the time you apply for admission to graduate school, you should request information on financial aid, assistantship programs and scholarships. If you are an international student, note that in your request for such information (it might also benefit you to request information on financial aid for continuing education from the appropriate consular officials representing your country here in the United States).

Notices of acceptance to graduate school usually arrive in mid to late April. If you receive more than one acceptance, your adviser can help you with your decision, but a trip to each campus might provide the best information. Once you have accepted an offer, write promptly to the schools you are declining, so that they can extend an offer to someone else.

And remember to keep us posted on your progress while you are in graduate school – and beyond!

PURSUING A CAREER

"From what we get, we can make a living; what we give, however, makes a life." –Arthur Ashe

"Work is not the curse.... drudgery is." -Henry Ward Beecher

Physics principles are basic to a large number of more specialized fields. You may not know what type of work you would like to do after graduation, but you will acquire knowledge and skills as a physics major applicable to almost any technical job. These skills include the ability to solve both experimental and mathematical problems, the ability to use a wide range of general purpose scientific instruments, and the ability to perform complicated sets of instructions that require organizational, research, reasoning and communication skills. Since physics is not a narrow or specialized field, physics majors are prepared to fit into any one of a number of technical jobs more easily than most college graduates.

Without a Ph.D. degree, work as a pure physicist is unlikely, but physics training provides skills that are useful in many and varied fields of employment. Gettysburg College's non-Ph.D. physics graduates are working in systems analysis, information technology and computer programming, nuclear, electrical and mechanical engineering, pollution control, energy and environmental research, telecommunications, metallurgy, meteorology; general and technical sales, geophysics, small businesses, insurance, the law, medical technology, and secondary education, again to name a few.

The following suggestions may help in the career decisions you make. Obviously, it is your responsibility to do everything possible to get your career off to a good start, but any help Physics Department personnel can give you is yours for the asking.

During your first year here, go to the College's Center for Career Development to obtain its very helpful booklet on job preparation. This office also offers aid in long-range career planning and in job placement.

The American Institute of Physics publishes a very useful booklet on job possibilities for the physics baccalaureate, a copy of which is on file in the Department's business office (Masters 111). Throughout your college career, be alert for every chance to talk with faculty, alumni, parents, and friends concerning the nature of whatever jobs in and about which they might be involved and aware. Department colloquia are fine ways to meet specialists informally and to discuss their particular fields of interest and employment.

Try to obtain a technically oriented summer job at the end of your junior year; with luck, you might obtain such a position even earlier – don’t wait for the last minute! Check the Department's Summer Research Opportunities website and again, don't hesitate to ask faculty and staff members for help - you are why we are here!

Check with the Physics Department faculty, your academic advisor, and/or the Center for Career Development for more detailed suggestions. Again - please remember that Physics Department faculty and staff are here to help you in every way possible.

HONORS

"The scientific method is nothing more than doing your damnedest, no holds barred."
-Percy Bridgman

"If you work hard enough, lucky things happen." -Harish Saluja

"Success is the ability to go from failure to failure without any loss of enthusiasm."
-Winston Churchill

Each year, members of the physics faculty review the records of its students for consideration for Department honors. While the Department does not have inflexible standards for awarding honors, a 3.5 grade average for courses taken in the Department is a typical guideline. Grades are not the only factor; if your average is closer to 3.0 than 3.5, but you've taken most of the advanced courses in the Department, done an exceptional job on your independent study project, or shown your interest or talent in some other way, you are a good candidate for honors. On the other hand, if your departmental average exceeds 3.5 but you took the minimum number of courses and did not otherwise distinguish yourself, you may not receive honors. There is no limit to the number of students who can receive such honors.

The Department offers three prizes to its majors. Endowment for two of these prizes was provided by alumni of Gettysburg College in tribute to George ("Bowley") R. Miller, a professor of physics at Gettysburg College until his death in 1952. He provided direction and leadership for the Department for nearly thirty years and was much appreciated by all who knew him. The junior prize was donated by Ralph Eno of Hammatsu Corporation, whose daughter Sarah (Class of 1984) is one of Gettysburg College's most outstanding physics graduates.

The prizes are:

The Miller First Year Student Prize - Awarded to a first year student whose performance in Physics 111-112 is judged by physics faculty to be most outstanding.

The Julius Eno Junior Prize - Awarded to the physics student selected to be the most outstanding major at the end of junior year.

The Miller Senior Prize - Awarded to a senior physics major whose sustained performance over four years is judged by the physics faculty to be most outstanding.

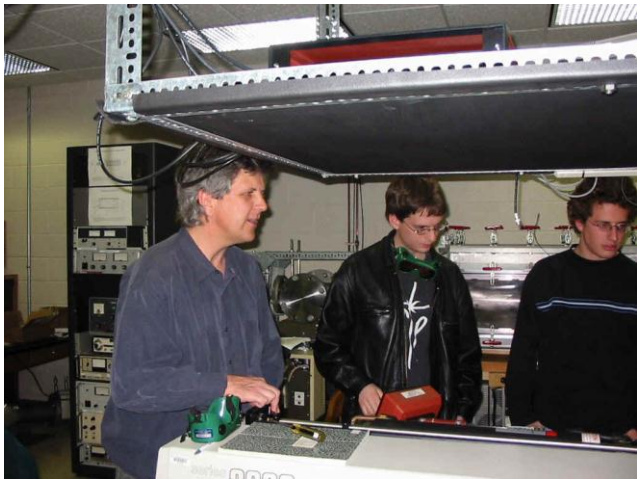
MASTERS HALL FACILITIES

"You cannot teach a man anything; you can only help him to find it within himself." -Galileo

"Science knows no country, because knowledge belongs to humanity, and is the torch which illuminates the world. Science is the highest personification of the nation because that nation will remain the first which carries the furthest the works of thought and intelligence." -Louis Pasteur

The facilities of Masters Hall are meant to be used. The policy is to maximize access by students to rooms and equipment in Masters Hall, while maintaining security and prudent use. The success of this policy requires responsible behavior by *everyone*.

When the College is in session, Masters Hall will be open from 7:00 a.m. to 11:00 p.m. Monday, Tuesday, Wednesday, Thursday and Friday nights, and from 8:00 a.m. to 11:00 p.m. on Saturdays and Sundays. The Physics Student Lounge is equipped with a blackboard, at least two computers (we're working on getting more!), work tables, chairs, a couch and some reference works, as well as a refrigerator, microwave, coffee maker and sink (which students are expected to keep clean). It's a good place to get together with friends and talk physics. When it's not being used for scheduled discussions or classes, the Seminar Room may also available for study. Keys to other rooms and labs in Masters may be borrowed with approval from faculty on an as-needed basis.



Gettysburg College has exceptional computing resources. Masters Hall, as well as every campus building and each residence hall room, is fully networked. This allows each student access to the Internet and electronic mail, as well as a number of very fine software programs. Information Technology personnel are responsible for all computing, networking, and telecommunications services and equipment for Gettysburg College, with services ranging from consultation and training of students, faculty, and staff, to the purchase, installation, programming, support and operation of College equipment and software. They are here to assist you in every way possible; do not hesitate to ask for their assistance and recommendations, so that you can obtain and use such resources to full advantage.

We want you to use Masters Hall as much as possible, but there is obviously some risk in leaving the building open after normal class and office hours. Please treat Masters Hall, everything and everyone in it with respect: keep it in good order and be mindful of persons who appear to have no purpose in the building (there are red phones, one to each floor, from which you can call Safety & Security when necessary). Our budget is modest and makes little allowance for damages or theft. Please help us to make the most out of the money you pay for your education.

LABORATORIES AND EQUIPMENT

"The hand is the cutting edge of the mind." -Jacob Bronowski

"The purpose of models is not to fit the data but to sharpen the questions." -Samuel Karlin

"Fate is the person who has the prepared mind." - Anthony Fauci

Since experience really *is* the best teacher, the laboratory is an important component to training in physics and the Department puts forth a solid and continuous effort to build and maintain an excellent laboratory program. Graduate schools and potential employers pay close attention to what can be said of a student's ability to solve experimental problems and such competence develops with practical experience. Take full advantage of this fine opportunity - don't be afraid to ask questions, to make mistakes, to repeat assignments, and to take every occasion possible to meet with faculty and with other students to discuss laboratory work.

In addition to its annual equipment budget, the Physics Department has received special grants from the National Science Foundation, the W. M. Keck Foundation, the Pew Charitable Trusts, the Commonwealth of Pennsylvania, and Gettysburg College for the purchase of laboratory equipment. Every laboratory course in our Department has benefited, so that by graduation, a physics major who takes advantage of all the laboratory courses offered will have had truly valuable and marketable experiences with quality research equipment in several different fields.

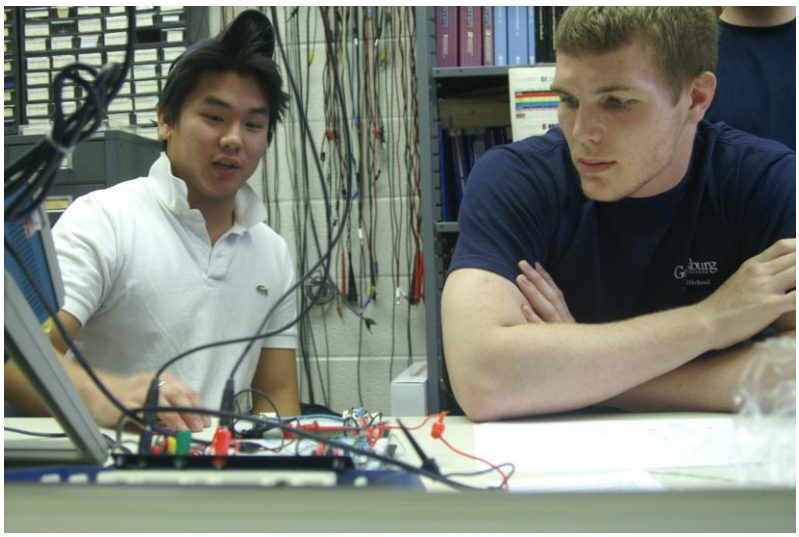
The following is only a sampling of the Department's major items of equipment, listed according to the year when students normally begin using them. Experimental equipment is upgraded regularly, and the Department also makes reserve funds available for purchase of items necessary for independent research.

First Year: oscilloscopes, function generators, digital multimeters, air tracks, scalers (for radioactivity experiments), microcomputers (for a multitude of uses, including laboratory control and measuring devices, analysis and graphical tools, access to the College's mainframe computers, as well as other computer resources), He-Ne lasers, optical benches;

Sophomore: x-ray source and spectrometer, interferometers, neutron source, grating spectrometers, multichannel analyzers, microcomputer interfacing equipment, digital electronics;

Junior/Senior: microprocessor controlled multichannel analyzers, electron spin, resonance spectrometer, 12" research electromagnet, Mössbauer drives, fast coincidence counter, x-ray diffraction apparatus, solid- state particle detectors, Fourier transform spectrometer, to name a few.

The Physics Department also has equipment available for student use, but not associated with any particular course. This includes a proton accelerator, a research quality 16" Cassegrain telescope with a computer-controlled drive, a UBV photometer, and a research-grade CCD camera; an optical isolation table, a tunable scanning narrow band ring dye laser, a 100 liter vacuum pump system, a 25 milliwatt He-Ne laser, two 5 watt argon-ion lasers, a nitrogen dye laser, fiber optics apparatus, assorted holography apparatus, a spectrum analyzer, infrared sensitive measuring television camera, and lots of assorted electronic measuring and computer equipment.



THE MACHINE SHOP

"Opportunity is missed by most people because it is dressed in overalls and looks like work."
-Thomas Alva Edison

"The creator of the universe works in mysterious ways. But he uses a base ten counting system and likes round numbers." -Scott Adams

"If we knew what it was we were doing, it would not be called research, would it?"
-Albert Einstein

While it's possible to spend four years at Gettysburg without ever stepping into the Department's workshop (Masters 104), it is very unlikely. It is more likely that you will become involved in building apparatus for a particular project and spend a fair amount of time there, getting your hands dirty and learning new aspects of Murphy's Law.

In addition to power machinery such as lathes, drill presses and milling machines, the workshop is equipped with welding equipment and a large selection of hand tools, as well as supplies of metal bar and sheet stock. Woodworking facilities are limited, but for such needs we also have access to the College's Facilities Services carpentry shop. Over the years, our capabilities have sufficiently improved to the point that it is an unusual job that cannot be handled here.

The workshop is under the direction of Gary Hummer, Department Technician, and is devoted to routine maintenance as well as to special student and faculty research. Much of the equipment used in the elementary laboratories was constructed or modified there. If you are interested, you are encouraged to develop your own projects and build your own equipment. It is run with a minimum of formality, but we do have some rules. If you need something constructed, check first with Mr. Hummer and faculty. If you wish to do your own work, he will be your guide, as well as determine your ability to use the necessary tools. It is your responsibility to cooperate in following safety regulations and in keeping the area clean. *Safety is paramount*! Mr. Hummer is in charge and will make you aware of what is expected. He can also offer some help in design and in the use of particular tools. You must, of course, be checked out on the power tools before being given permission to use them.

There is another possibility for doing shop work: the Physics Department likes to hire assistants who will spend at least part of their working time in the shop. There is a lot of flexibility and specific arrangements depend on your interests, talents and opportunity, and on the needs of the Physics Department.

THE LIBRARY

"These are not books, lumps of lifeless paper,
but minds alive on the shelves." -Gilbert Highet

"All that is gold does not glitter,
Not all those who wander are lost;
The old that is strong does not wither,
Deep roots are not reached by frost." -J.R.R. Tolkien

"Sometimes I think we're alone in the universe, and sometimes I think we're not. In either case the idea is quite staggering. –Sir Arthur Clarke

Musselman Library contains well over 4000 volumes on physics, most of which have been acquired during the past 15 years. Titles are added to the physics collection each year, and recommendations for additions are appreciated. The Library provides comprehensive coverage of most active areas of physics and astronomy, as well as dependable coverage of mathematics, technology, engineering, and the history and philosophy of science.

The Department works with its library liaison to keep physics library holdings current and comprehensive. A major goal is to maintain a collection of useful reference works to support class work and research projects, as well as to provide support for the scholarly interests of the faculty. Most journal articles and books not found in the library can be borrowed through the Interlibrary Loan Service. To use this service, check with the staff of Interlibrary Loan in the Musselman Library. Many journals are now available on the Internet; check with Musselman Library staff on how to access these, as well.

The classification system used is that of the Library of Congress. While the system is based on subject matter, some amazing classifications occur. Experienced browsers have learned to zero in on the right subject areas and then go directly to the shelves for a look at what is available. Imagination is sometimes required to locate all relevant classifications, and Musselman librarians, as well as Physics Department faculty, have the expertise and willingness to help you. Explore.

Reference Resources

All physics books and publications have been computer catalogued by Musselman librarians. These computerized files may be accessed through the network from any campus computer.

Physics Abstracts contains abstracts of most papers published in physics. The subject and author indexes, which are published every six months, are invaluable for locating articles on current research. *Astronomy and Astrophysics Abstracts* is another useful reference work. There are many general reference works, ranging from *The Handbook of Physics* by Condon and Odishaw, to the University of Chicago *Manual of Style*.

It is worthwhile to take time to browse the Library's holdings, and if you need any help in locating publications or in using the computer terminals in the library, don't hesitate to ask for assistance.

Do not keep books out for extended times; return them as soon as you are finished so that others may have access to them, as well. If a book is recalled, please bring it back immediately.

If you have any suggestion or critique concerning the Library's physics holdings, please make them known to any member of the Physics Department. Faculty and Library personnel very definitely want to maintain the finest facility possible.

THE COLLOQUIUM SERIES

"You do not really understand something unless you can explain it to your grandmother." -*Albert Einstein*

"Einstein explained his theory to me every day, and on my arrival I was fully convinced that he understood it." -*Chaim Weizmann*

"There is a theory which states that if ever anyone discovers exactly what the universe is for and why it is here, it will instantly disappear and be replaced by something even more bizarre and inexplicable. There is another that states that this has already happened." -*Douglas Adams*

Physics colloquia are held regularly throughout the academic year. These talks about physics or astronomy are given by scientists and science writers from universities, government, and industry, as well as Gettysburg faculty and senior physics majors. The following list of past colloquium topics is indicative of the varied nature of these talks: chaos, general relativity, plasma, the physics and chemistry of mesoscopic matter, high resolution imaging, holography, the top quark, solar sea power, other life forms in the universe, gender and science, Bose-Einstein condensation, supernovas, superconductivity, the super collider, magnetic monopoles, measuring ocean waves with radar, the role of plasma waves in space weather, and medieval astronomy. The level of sophistication varies: in some cases, a person with nothing more than an interest in physics can understand the entire talk, while others will be at levels that even a senior physics major may find a stretch. Each talk will have something of value to offer anyone interested in physics. Talks are advertised on our website, in College publications, as well as with on-campus flyers (http://public.gettysburg.edu/~marschal/physics/speakers.htm).

The colloquium series was established to serve as a valuable supplement to the regular physics program. The physics courses you take are as current as possible, but the majority of their content must be devoted to fundamental aspects of physics. This means that there are many new developments, interesting and novel applications, and historical anecdotes that you may not learn in class. We believe you should know some of these things, and so have gone to the trouble and expense of establishing this series of talks. While attendance at colloquia is not mandatory - as we rely on each student's growing sense of accountability and commitment - all students, from first year on, are strongly urged to attend. It

should be a rare occasion when a junior or senior physics major misses a colloquium. At this stage, students normally want to know as much as possible about physics, remembering that such presentations are also good places to find out what fields interest them and what job opportunities exist. Frequently, graduate schools and potential employers inquire about a student's interest and dedication to an academic discipline, and attendance at colloquia is a good measure of such interest.

A final note: The atmosphere at colloquia is designed to be casual, and the refreshments offered before each talk are intended to encourage that atmosphere; so please feel free to ask questions and to enter into the discussions. And eat cookies.

THE OBSERVATORY

"For every space...Is visionary...And every space...
opens...into Eternity." -William Blake

Come wander with me, she said,
Into regions yet untrod;
And read what is still unread
In the manuscripts of God." -Henry Wadsworth Longfellow

Located behind the West Building in the northwest corner of the campus is the Gettysburg College Observatory. Whether you are an astronomy buff or not, you won't want to miss a chance to view the heavens (call the "Astronomy Hotline", 337-6031, to leave a message and/or receive additional information, and speak with Dr. Larry Marschall and/or Jackie Milingo. If you take a course in astronomy at Gettysburg, you will use one of the 8-inch reflecting telescopes at the observatory several times during the semester to familiarize yourself with the stars and the planets. You will also have a chance to take pictures of the heavens using the electronic CCD cameras that are installed on these telescopes. If you take an upper class lab in physics, you might do an exercise on the larger research telescope located in the dome. And if you elect to do an upper class research project in astronomy, you will spend nights collecting data on the College telescope or at the National Undergraduate Research Observatory in Flagstaff, Arizona.

The Observatory dome houses an Ealing 16-inch Cassegrain telescope, a research quality instrument. The instrument is operated by computer from a temperature-controlled room adjacent to the dome. The telescope is equipped with a sensitive solid-state TV, called a CCD camera that makes it possible to take pictures of faint celestial objects and store them on computer disks.

The Observatory also contains six Meade Telescopes: three 8-inch LX200 - Schmidt-Cassegrain telescopes, one 10-inch GPS LX200 Telescope, one 8-inch GPS LX200 Telescope and one 7-inch Maksutov-Cassegrain Telescope, with small CCD cameras that can be "wheeled" around or mounted on concrete piers located next to the observatory. Another new addition in operation for student advanced lab work is a Haystack Radio Telescope (take a look at its website at http://public.gettysburg.edu/~marschal/clea/radio/index.htm). A classroom adjacent to the dome contains work tables and a collection of maps and charts of the skies to help in preparation for observing.

If you are at all interested in pursuing astronomy as a hobby or as a career, you may want to volunteer your time to help around the Observatory – keeping it active is an important job. You are welcome to sit in on observing when research is being done by faculty and upper-division students, and you can help serve as an assistant for public viewing nights. Assistants are also needed to help with introductory astronomy labs, to develop and maintain software and hardware at the Observatory, and to help process research data. If you are interested in helping, see Dr. Larry Marschall; he will keep you informed of activities and can arrange to help you learn what you need to know to participate in the astronomy program.

In recent years, students have designed computer hardware and software for the Observatory and have used it to measure the physical properties of binary stars that eclipse one another. They have reported on their work at national meetings of the American Astronomical Society. One previously unknown eclipsing binary was actually discovered independently at the College Observatory.

Gettysburg College is a member of the National Undergraduate Research Observatory (website: http://www.nuro.nau.edu/), a consortium of colleges that operates a 32-inch telescope in Flagstaff, Arizona. Students accompany Dr. Marschall yearly on research trips to Flagstaff, where they have conducted studies of binary stars, supernovae, and asteroids. In the past, students also observed at the Multiple Mirror Telescope and the Whipple Observatory near Tucson, Arizona.

HATTER PLANETARIUM

"...while the stars that over sprinkle all the heavens seem to twinkle with a crystalline delight..."
- Edgar Allen Poe

"The next question was - what makes planets go around the sun? At the time of Kepler some people answered this problem by saying that there were angels behind them beating their wings and pushing the planets around an orbit. As you will see, the answer is not very far from the truth. The only difference is that the angels sit in a different direction and their wings push inward."
-Richard Feynman

"Living on Earth may be expensive, but it includes an annual free trip around the Sun."-Unknown

Built in 1966 with a generous gift from Mr. and Mrs. George G. Hatter, the Hatter Planetarium was designed to provide the College community an opportunity to develop a greater appreciation of our 'place in the universe'. Located on the first floor of Masters Hall (near the Business Office and Mara Auditorium), its 32-foot square chamber is topped by a hemispherical projection dome, 30 feet in diameter, which serves as a projection screen for the Spitz A-3P planetarium projector located at its center.

The Spitz A-3P projector can simulate the sky as it appears at any time of day or night, for any time in the past or future, and from any point on the earth. The celestial motions can be accelerated so that centuries can be observed in the span of minutes. Analytical scales and diagrams can be projected to explain how man studies the heavens. A celestial coordinate system, ecliptic and meridian projectors complement the main projector to allow, among other things, accurate sky measurements. In recent years, a 4-speaker surround-sound system, VCR, laser disk player, associated color projectors, an eye-level series of slide projectors, and an overhead display have been added. The sophisticated sound system, auxiliary projection system, and other devices allow special effects such as twilight, meteor shows, comets and aurora. Rows of seats circle the room to provide comfortable seating for one hundred.

Hatter Planetarium is used to illustrate the motions of the heavens to introductory astronomy classes, as well as for public sky shows open to both the College and off-campus communities. Many pre-school, elementary and high school groups from the area visit the Planetarium during the school year for talks and demonstrations on the heavens. It has even been used as a place of meditation for Buddhist monks and for Gettysburg's Quaker community!

Any students interested in learning to use the Planetarium equipment, or who want to help produce shows or build equipment, should contact Ian Clarke (iclarke@gettysburg.edu or 337-6050).

STUDENT ASSISTANTS

"'Edwin Land once told me that those people who can stand at the intersection of the humanities and science, the liberal arts and technology, that intersection, are the people who can change the world.'" – Steve Jobs

The Physics Department needs the help of its students in order to run smoothly. While the hourly wage rate the budget allows us to pay is modest (normally minimum wage), the experience can be a very rewarding adjunct to your formal education.

Generally speaking, the categories of jobs within the Department are:

Laboratory Equipment Set-Up. Work time varies from 4 to 8 hours a week, but may be shared by two or more students.

Special Services. These jobs are awarded on the basis of skill to students who have metal shop, electronic, photographic, library, and computer skills. The number of hours per week can be arranged, and in most cases the student can work at his or her convenience.

Student Graders. Professors often employ junior and senior physics majors for grading homework in introductory physics courses. Interested students must have demonstrated knowledge of the subject and be extremely conscientious. No students, of course, grade examinations.

Laboratory Assistants. Typically awarded to seniors or outstanding juniors, this work takes place in an elementary laboratory under the supervision of a faculty member. Lab assistants are responsible for answering student questions and helping them with experimental difficulties. This position requires conscientious dedication, but provides some of the best experience a physics major can obtain.

Student Research Assistants. Faculty members sometimes have available funds for assistants to aid in research. Such jobs often allow students to master advanced work, as well as earn some money.

While we are required to advertise these jobs throughout the campus, the job requirements give physics majors an edge, so if you think you might be interested in any of these positions, come talk with a faculty member.

COMPUTING FACILITIES

"Once a new technology rolls over you, if you're not part of the steamroller, you're part of the road." - Stewart Brand

"Do, or do not. There is no 'try'." -Yoda

"If people do not believe that mathematics is simple, it is only because they do not realize how complicated life is." -John von Neumann

Computers have amplified, enhanced and transformed our environment, allowing us to calculate, speculate and communicate. Science, physics in particular, has benefited profoundly from computer development; simulating natural phenomena, automatically controlling laboratory equipment, and recording and analyzing large volumes of data from various experiments, the amount of routine labor required to obtain numerical results is considerably reduced, leaving us time for problem solving - to find meaningful patterns in numerical results, to build and study models, to unleash our imaginations, and to reinforce what education has always understood: knowledge is power.

Beginning with the Masters Hall first-year student labs equipped with computers dedicated to collecting, analyzing and graphing data directly from experiments, you will gain a comprehensive understanding of a number of computer programs. You will use them in classes and laboratories throughout your matriculation at Gettysburg College. The College is committed to maintaining state-of-the-art computer technology rivaling those of far larger institutions. Among other things, Faculty and students have assess to journals, books, library resources, databases, bulletin boards and general information systems of academic and research entities around the world.

The Computer Science Department offers formal courses in computer programming, and the College's Information Technology provides free, continuous training sessions. You will most likely discover, however, if you have not already done so, that it is not difficult to become skilled at navigating and writing programs on your own, and will find it both pleasant and profitable to use your programming proficiency to perform calculations and solve homework problems. Many programs that have already been prepared by faculty and other students for various physics courses will also be available to you.

All students pursuing a major in physics are strongly advised to purchase a personal calculator with scientific functions; any model containing at least log and trig functions and some statistical functions should be sufficient.

Physics majors are ideally trained to make the best use of computers: they have the mathematical skills to master programming techniques, and the knowledge of physics required to understand computer circuitry. We urge you to take the many opportunities available to learn how to use them to your best advantage; such experience will enrich your years at Gettysburg and will obviously provide you with an invaluable tool for the years that follow.

THE PHYSICS FACULTY

"$F = Gm_1m_2 / r^2$." - *Isaac Newton*

"$E = Mc^2$." -*Albert Einstein*

"$\dot{\theta} = \omega^2 - \sigma^2 - \frac{\theta^2}{3} - E[X]_{;a}^{a} +$" – *Amal Kumar Raychaudhuri*

Kurt Andresen received his B.A. in physics from Boston University and his Ph.D. in applied physics from Cornell University. He researches electrostatic interactions in biological systems, using spectroscopic and x-ray scattering techniques; in particular, he investigates the physical processes involved with the compaction of DNA. Students in his research lab learn aspects of many disciplines, including biochemistry and molecular biology, as well as physics.

Bret Crawford received his B.S. in electrical engineering at the University of South Carolina, an M.S. in physics from the University of Vermont, and an M.A. and Ph.D. in physics from Duke University. His research area is experimental nuclear physics, and he is currently involved in a measurement of the neutron-neutron scattering length with colleagues at the Yaguar reactor in Snezhinsk, Russia and a measurement at the National Institute of Science and Technology of the parity-violating spin rotation of transversely polarized neutrons in superfluid helium. He, along with fellow Gettysburg physics professors Sharon Stephenson and Peter Pella, and many of our physics majors, has worked over the past few years to bring a 250-keV proton accelerator online here at the College; the 1960's era accelerator was generously donated by TUNL (Triangle Universities Nuclear Laboratory). Dr. Crawford teaches courses throughout the major as well as a course on the physics of music for non-science majors and a course on energy and the environment for the Environmental Studies department.

Timothy N. Good earned his B.S. in physics at nearby Dickinson College, and his M.S. and Ph.D. in physics at the University of California, Irvine. As a staff research physicist in the Center for Research in Plasma Physics at the École Polytechnique Fédérale de Lausanne in Switzerland, he concentrated on fundamental aspects of plasma physics, applying laser spectroscopic diagnostics to the study of plasma wave-particle interactions, an important topic in the pursuit of thermonuclear fusion research and in the modeling of astrophysical plasmas. His current work also includes experiments designed to simulate plasma processes that have been observed in space during auroral magnetic storms. Such work, combined with sabbaticals to such neighboring institutions as West Virginia University, has allowed Dr. Good to achieve and maintain his dual goal of teaching physics and involving students in exciting, rewarding research experiences.

Laurence A. Marschall received his B.S. in engineering physics from Cornell University and his Ph.D. in astronomy and astrophysics from the University of Chicago. He has been a visiting scientist at Yale University and the Harvard-Smithsonian Center for Astrophysics, and a visiting professor at Boston University. He presently teaches courses and labs in astronomy and physics, encouraging student participation in his research at the College Observatory and the National Undergraduate Research Observatory in Flagstaff, Arizona. His research includes the study of

young stars in clusters and binary systems, and the study of exploding stars called supernova. He is also Director of *Project CLEA* (Contemporary Laboratory Experiences in Astronomy), a series of innovative computer exercises in astronomy distributed from Gettysburg College to students in all 50 states and 50 foreign countries. Contributing editor to the magazine, *The Sciences*, writing a regular column on current popular science books, a contributing editor for *Smithsonian Air and Space*, and to annual astronomy updates for *The World Book Encyclopedia*, Dr. Marschall has been named to receive the American Astronomical Society's 2005 Education Prize, recognizing his worldwide contribution to the field and his outreach to the public. He has also served as deputy press officer of the American Astronomical Society, and is the author of The *Supernova Story*, and co-author of *Galileo's New Universe* and *Pluto Confidential*.

Jacquelynne Milingo received her B.S. in physics and astrophysics from the University of Kansas and her Ph.D. in physics from the University of Oklahoma. Her research utilizes spectroscopy, the study of the distribution of energy emitted by an object as a function of wavelength. In the visible portion of the electromagnetic spectrum this translates to studying the energy emitted by an object as a function of color. Using this standard tool, Dr. Milingo studies optical spectra of astrophysical gas in the form of planetary nebulae to determine chemical composition. Planetary nebulae are the shed atmospheres of dying intermediate mass stars. She is particularly interested in the role they play in the chemical evolution of galaxies. She has been working for the past six years with her students and collaborators from the University of Oklahoma and Williams College; their data comes from moderate-sized telescopes at Kitt Peak in Tucson, Arizona, and Cerro Tololo in the Northern Chilean Andes, among others.

Peter J. Pella, W. K. T. Sahm Professor in Physics, received his B.S. from West Point, his M.S. from Rensselaer Polytechnic Institute, and his Ph.D. from Kent State University. Between degrees, he served in the U.S. Army and as a physicist at West Point. Participating in research at the Indiana University Cyclotron Facility, the Bates Linear Accelerator Facility, and the Thomas Jefferson Continuous Electron Beam Accelerator Facility in medium-energy nuclear physics, his work includes the study of the spin response of the nuclear force and fundamental properties of the neutron. He is also involved in issues related to nuclear weapons. As a William Foster Fellow, he spent a year and a half at the United States Arms Control and Disarmament Agency, from which he received a meritorious honor award for his service in achieving the indefinite extension of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), an award which states "…Largely due to Dr. Pella's efforts, United States officials had the best and most current information available to them when they met with their foreign counterparts." His most recent Washington sabbatical, during the 2000-2001 academic year, was with the Department of State, also contributing to work on arms control and nuclear non-proliferation.

Sharon L. Stephenson, Department Chair, received her B.S. in physics from Millsaps College and her Ph.D. in nuclear physics from North Carolina State University. Her research is in the specific structure of nuclei and in the nuclear weak force, which takes her to the Triangle Universities Nuclear Lab on the campus of Duke University, as well as to the Los Alamos National Laboratory near Santa Fe, New Mexico. Besides teaching courses and labs in introductory physics, modern physics, and classical mechanics, as well as a first year seminar on gender in science and technology, Dr. Stephenson serves as advisor to the Gettysburg chapter of the Society of Physics Students and as coordinator for the Department's Dual-Degree Engineering Program.

Michael Strickland is our theoretical physicist specializing in high-energy particle physics. He received his bachelor's degree in physics from the University of North Carolina, Chapel Hill, his

Ph.D. from Duke University, and has held multiple research positions and fellowships: Ohio State University, University of Washington (Seattle), Duke University, Vienna University of Technology (Austria), Helsinki Institute for Theoretical Physics (Finland), Frankfurt Institute for Advanced Studies (Germany), and the Johann-Wolfgang Goethe University - Institute for Theoretical Physics (Frankfurt am Main, Germany). He continues to work with the Frankfurt Institute for Advanced Studies as an adjunct fellow, assisting in guiding their theoretical program. His primary research interest is the physics of the quark-gluon plasma (QGP), and he has published 54 research papers and received over 1460 citations of his work. In addition, he is the co-author of *Neural Networks: An Introduction*. Dr. Strickland serves as advisor to the Gettysburg chapter of the Society of Physics Students.

If after reading this handbook, you have any questions, suggestions, interest in learning more about faculty research and the curriculum, please do not hesitate to speak directly with a Physics Department faculty member; each is excited about teaching and research, and would be pleased to take the time to clarify and encourage.