

# Physics Handbook

Bryn Mawr College  
2021-2022

<http://www.brynmawr.edu/physics>



Welcome to the Bryn Mawr Physics Department! Over the last 10 years Bryn Mawr has had between 6 and 16 physics majors a year. The 10-year average is ~9. This gives us the best of all worlds. We stay small compared with the mathematics, biology and chemistry departments at Bryn Mawr and, as such, physics faculty members, graduate students, and undergraduate students form a close-knit community of friends and scholars. But we have a huge effect on the national scene, something you won't realize until you begin "life after Bryn Mawr." Nationwide, women represent only about 21% of students earning bachelor's degrees in physics and closer to 18% of those earning Ph.D.'s. So, even though we are small, the Bryn Mawr physics department is home to one of the largest groups of women physics majors and pre-majors in the country. In the physics department you will experience great diversity and encounter many peers as friends, coursework collaborators, mentors, tutors, and role models for career discussions.

Physics majors from liberal arts colleges such as Bryn Mawr have many career options: teaching, finance, engineering, business, industry, computer science, law, patent law, medicine, and graduate work in the physical sciences ranging from astrophysics and physics to materials science, earth science, oceanography, and physical chemistry.

## Department Staff, Faculty and Graduate Students

Faculty and Staff	Room	Phone	Email
Nina Fichera (Admin. Assistant)	348	5358	nfichera
May Cheng	343	5357	xcheng
Kate Daniel	347	5634	kjdaniel
Mark Matlin (Majors Advisor)	352	5355	mmatlin
Chandani Nandadasa	351	7561	cnandadasa
Mike Noel (Chair)	344	5363	mnoel
David Schaffner (on leave AY '21-'22)	345	7846	dschaffner
Michael Schulz (on leave Spring 2022)	340	5367	mbschulz

Graduate Students	Room	Phone	Email
Joshua Carlson	143	5362	jmcarlson
Carlos Cartagena-Sanchez	143	5362	ccartagena
Andy Clark	134	7559	atclark
Tyler DeMan	341		tdeman
Olivia McAuley	240		omcauley
Amy Smock	240		asmock

## Programs of Study that include Physics at Bryn Mawr

- Physics major (14 courses in physics and math, minimum; 14-16 courses, typical)
- Physics minor (10 courses in physics and math, including 2 physics at the 300-level)
- Astronomy or Astrophysics (at Haverford)/Physics double major
- Mathematics/Physics double major
- Mathematical Physics independent major
- Chemistry/Physics double major
- Chemical Physics independent major
- Physics major with a minor in Computational Methods
- Physics / Computer Science double major
- Physics major with secondary school teacher certification

- Combined A.B./M.A. in Physics
- 3+2 Physics and Engineering dual degree programs with the California Institute of Technology and Columbia University
- 4+1 A.B./M.A. Engineering Program at the University of Pennsylvania

## Basic Offerings for the Major

PHYSICS AND ASSOCIATED MATHEMATICS COURSES	
<i>Fall</i>	<i>Spring</i>
P121 <sup>1</sup> Modern Physics M101 Calculus I P201 <sup>2</sup> Electromagnetism M201 Multivariable Calculus P306 Mathematical Physics (required for the major; offered every year at BMC) P398 Senior Seminar (half-credit)	P122 <sup>1</sup> Classical Mechanics M102 Calculus II P214 <sup>2</sup> Intro. to Quantum Mechanics M203 Linear Algebra P331 Advanced Experimental Physics P305 Advanced Electronics Lab (P305 or P331 is required for the major; one is offered every year at BMC)
<i>Choose at least three courses listed below to complete the major.</i>	
P303 <sup>3</sup> Statistical and Thermal Physics P308 <sup>4</sup> Advanced Classical Mechanics P322 <sup>3</sup> Solid State Physics	P302 <sup>4</sup> Advanced Quantum Mechanics P309 <sup>3</sup> Advanced Electromagnetic Theory P324 Optics P325 <sup>5</sup> Advanced Theoretical Physics
Or any one course from among ASTR 342-344, or any 300-level math course.	

<sup>1</sup> Students may also begin with P101 and P102. P121 has M101 as a co-requisite. P122 has M102 as a co-requisite.

<sup>2</sup> P201 has M201 as a co-requisite. P214 has M203 as a co-requisite.

<sup>3</sup> Alternates with Haverford; offered at BMC every even-numbered year.

<sup>4</sup> Alternates with Haverford; offered at BMC every odd-numbered year.

<sup>5</sup> Alternates with Haverford P335 (which is the same course); offered at BMC every odd-numbered year.

## Majors' Advising

The Majors' Advisor helps each student plan a full program that matches their career goals and interests. Students meet with their Advisor as often as they like or as often as necessary. In addition to advising junior and senior majors, the department also advises students in the 100- and 200-level courses, regardless of their intended major. Mark Matlin is the Majors' Advisor for 2021-22: [mmatlin@brynmawr.edu](mailto:mmatlin@brynmawr.edu).

## Required Courses for the Major

Ten physics courses and four mathematics courses are required for the major. The Physics courses are P121, P122, P201, P214, P306, P305 or P331, P398, and three additional courses at the 300-level in physics. The mathematics courses are M101, M102, M201, and M203. Equivalent physics and mathematics courses at Haverford may be substituted. Any one course from among

Astronomy 342, 343, 344, *or* (but not *and*) any one 300-level Math course may be substituted for one of the three additional 300-level physics courses.

## **Required Courses for the Minor**

Seven physics courses (P121, P122, P201, P214, P306, P305 *or* P331, and one additional 300-level physics course) and four mathematics courses (M101, M102, M201, and M203) are required for the minor.

## **A Typical Four-Year Program for the Minimum Major**

**Freshman year:** Introductory physics (P121 and P122) and Calculus (M101 and M102).

**Sophomore year:** Intermediate physics (P201 and P214), Multivariable Calculus (M201), and Linear Algebra (M203).

**Junior year:** Math Methods (P306), Advanced Electronics (P305) *or* Advanced Experimental Physics (P331), zero or one additional 300-level physics courses.

**Senior year:** Three or two 300-level physics courses and Senior Seminar P398. Additional electives can be added, depending on career goals.

## **A Four-Year Plan Providing a Minimum Preparation for Graduate School**

**Freshman Year:** Introductory physics (P121 and P122) and Calculus (M101 and M102).

**Sophomore Year:** Intermediate physics (P201 and P214), Multivariable Calculus (M201), and Linear Algebra (M203).

**Junior Year:** Math Methods (P306), Advanced Experimental Physics (P331), and either P303 and P309 *or* P308 and P302

**Senior Year:** P308 and P302 *or* P303 and P309, Senior Seminar P398, plus P403 (both semesters)

## **Majoring in Three Years**

Students sometimes take introductory physics in their sophomore year with no intention of majoring in physics and, for a variety of reasons, decide they want to major. This happens a lot because students find out that physics is a lot more fascinating than they thought and not as intimidating as their great uncle implied. As such, the department makes this doable without the load being outrageous. However, careful planning is required, and you should speak with the Majors' Advisor as soon as you are even remotely thinking

about this change of direction. There is no harm in asking. A typical three-year major program after taking introductory calculus in the freshman year (or placing out of it) might be:

**Sophomore year:** Introductory physics (P121 and P122 or P101 and P102), Multivariable Calculus (M201), and Linear Algebra (M203).

**Junior year:** Intermediate physics (P201 and P214), Math Methods (P306), and Advanced Electronics Lab (P305) *or* Advanced Experimental Physics (P331).

**Senior year:** Three 300-level physics courses, Senior Seminar P398, and research (P403).

## Double Majoring

Students often double major in Physics and a Humanities or Social Science. A satisfactory completely independent program must be developed to meet the requirements of both majors and your Physics Majors Advisor won't be much help designing your other major. Students can also double major in Physics and Computer Science, Physics and Mathematics, Physics and Geology, and Physics and Chemistry. Your Physics Majors Advisor can help you with both majors and can work closely with the Majors Advisor of the other department. It is important not to create a constant overload and end up doing a "minimum major" in each subject instead of going a little more deeply into one or the other. It is wise to complete advanced courses (and some research, if possible) in the field you wish to pursue as a career. Typically only one or two courses may be counted toward both major programs and the details need to be approved.

## Designing an Independent Major

You should start by reviewing the college catalog for the requirements and the procedures for the Independent Major. The faculty members of the physics department have developed guidelines for some common independent majors, which it is willing to consider on a routine basis (mathematical physics, chemical physics, computational physics). We are always open to proposals for uncommon majors. The most important features of a special major program are that the courses make a consistent concentration for study in depth and that the program satisfactorily meets your career goals and what you want to do immediately after college

graduation. Independent majors that are combinations of two fields are suitable for many careers but are rarely adequate preparation for graduate school in either field. Consult any faculty member for details.

## **Minor in Educational Studies or Secondary-School Teacher Certification**

Students majoring in physics may pursue a minor in educational studies or state certification to teach at the secondary-school level. Students seeking the minor need to complete six education courses including a two-semester senior seminar, which requires five to eight hours per week of fieldwork. To earn secondary-school certification (grades 7-12) in physics students must: complete the physics major plus two semesters of chemistry and one semester as a teaching assistant in a laboratory for introductory or intermediate physics courses; complete six education courses; and student-teach full-time (for two course credits) second semester of their senior year.

## **Teaching Assistantships**

Physics students have opportunities to both assist the department and develop their physics understanding by serving as teaching assistants (TAs) of various types. Sophomores through seniors may act as homework graders for courses they have taken, using solutions provided by the course instructor. Others serve in the introductory physics lab helping PHYS 101/102 students with the experiments. Teaching in the lab is a lot of fun, both for teachers and students. The lab is unconventional in that there are about 16 experiments set up and they stay out for a whole semester. As a TA, you would be assigned a few experiments and you would come in to help students who are doing these experiments. The schedule is flexible.

## **Academic Year Research for Undergraduate Majors**

Physics 403, two semesters of senior research, is one of the cornerstones of the department's mission. All tenure-line members of the faculty are engaged in state-of-the-art frontier research. These programs are funded by the National Science Foundation and NASA, and most student research is published in internationally refereed journals. In this sense, the Bryn Mawr Physics Department is very much like that at a large research university. The presence of the graduate program contributes to this atmosphere. Ironically, Physics 403 is not required for the major and doesn't even "count" towards

the major. Indeed, research is not for everybody. But students in Physics 403 certainly get a sense of what it's like to be a graduate student. For experimental work it helps to have had P331 (Advanced Experimental Physics) before your senior year.

Some physics majors have done research at Swarthmore, Haverford or Penn, but it often requires an investment in commuting and depends on the willingness and availability of faculty members at those schools. Students majoring in Astronomy or Astrophysics at Haverford have the opportunity to do research with associated faculty members there. Consult with the particular faculty member you wish to work with and check with your Majors' Advisor.

## **Summer Research for Undergraduate Majors**

Summer work opportunities on campus are often available after the second or third year courses have been completed. Funding might be available directly from the faculty member, but most students doing summer science research at Bryn Mawr are funded through the Summer Science Research Program, <https://www.brynmawr.edu/summer-science-research>.

Many opportunities are available off campus, most under the rubric of NSF-funded REU (Research Experience for Undergraduates) programs. See the NSF web site for listing of positions. There are hundreds of positions available every year and our majors are very successful at getting these summer REU positions. Check out our summer research page: [http://www.brynmawr.edu/physics/majors/summer\\_opportunities.html](http://www.brynmawr.edu/physics/majors/summer_opportunities.html).

Research and summer job opportunities provide exposure to what practicing physicists do in many fields. Off-campus experiences are particularly valuable as they provide students with a different perspective on the practice of physics. This can be invaluable in choosing between different career options, and evaluations of your research are often the most effective part of your dossier when you apply for jobs or graduate school.

## **The Effect of the Graduate Program on the Undergraduate Major**

The Physics Department has a strong and successful graduate program and all Bryn Mawr PhD's find excellent jobs as professors in universities and



liberal arts colleges or as researchers in industry. This means that Bryn Mawr physics undergraduates work not only with faculty but also with graduate students, both in research and in courses since the graduate students are "in training" to be college professors. Graduate students do not teach any courses since that is the domain of the faculty, but they do help out. This interaction has a huge positive effect on the undergraduate major and the pre-major courses and laboratories. In the department, faculty, post-doctoral fellows, graduate students, undergraduate majors, and undergraduate students in first and second year pre-major courses, form a small, close-knit social and scholarly community.

## **The Bryn Mawr - Haverford Relationship**

The two departments have coordinated their course offerings for many decades. At both Bryn Mawr and Haverford the courses for the first two years of the curriculum (100 and 200 level) are offered every year. In addition, Bryn Mawr and Haverford both offer their Advanced Experimental Physics Laboratory course (P331 at Bryn Mawr) each year. Bryn Mawr also offers Mathematical Methods (P306) every year. This course has no counterpart at Haverford.

Several 300-level theory courses usually taken by juniors and seniors alternate between the two campuses and the two faculties stay in touch to make sure the courses are the same as they go back and forth. They are Advanced Quantum Mechanics (P302), Statistical and Thermal Physics (P303), Advanced Electromagnetism (P309), Advanced Classical Mechanics (P308), and Solid State Physics (P322). This offers students the best of all worlds. Some students want to take all their courses at Bryn Mawr and since these 300-level courses are offered every second year at Bryn Mawr, this is easily done. Other students want to sample courses at Haverford and can do so. Others, who do Junior Year or Semester Abroad may have missed a course at Bryn Mawr and can do it at Haverford. It allows for considerable flexibility.

## **Junior Year or Semester Abroad**

Undergraduate physics courses are surprisingly standardized throughout the world. Many programs can be arranged at American and foreign universities. Semester-long research/study programs at national laboratories also are available. The Bryn Mawr College Physics Department encourages students, especially Americans with limited international cultural

experiences, to take advantage of this program. The Majors' Advisor will work with you to design an appropriate set of courses to take wherever you go.

Recently, students have spent a semester or a year at Los Alamos National Laboratory, Lawrence Livermore Laboratory, University of Edinburgh, St. Andrew's University, Université de Paris, Université de Lille, University of Costa Rica, Trinity College in Dublin, Argonne National Laboratory, and U.C. Berkeley.

## **Getting Help in the Physics Department**

We try to be a very open and accessible community of faculty and students. Faculty members encourage students to ask questions at any time, both in and out of class. Remember, if something is unclear to you, it is probably unclear to others in the class. Questions that indicate what is clear and what is not are the best feedback to faculty members, so that they can modify the style and pace of their courses. Faculty members post office hours to guarantee times when they will be accessible, but come anytime with questions. If the faculty member in your course is not available, most physics majors, or other faculty members and graduate students, are willing to help students in intermediate and advanced courses. By all means, ask! Often courses have Learning Assistant who are other students in the Physics department. They will be offering in person and online help through Piazza for students to ask questions and get help with problem sets. There are also college-wide tutoring services available to students through the Quantitative (Q)-Project Center, <http://www.brynmawr.edu/qproject/> and the Writing Center, <http://www.brynmawr.edu/writingcenter/>.

## **Physics Colloquia**

The department usually has two special colloquia each semester. We invite outstanding scientists to tell us about their research. Many of these visitors are carefully chosen to present a research frontier that complements but does not reproduce the research done at Bryn Mawr. These presentations are a valuable broadening of the undergraduate experience. They are a lot of fun and an important coming together for the department. We all meet in the Dorothy Vernon Room of Haffner Hall at 5:30 on a Monday to dine together. The speaker sits at a table with students. Then, at 6:30, we clear away the dishes and have the presentation. Speakers are instructed to make sure that

first-year physics students can understand the first one-third of the presentation and that second-year physics students can follow at least three-quarters of the presentation.

## Major Representatives

The President and Vice President of the SPS chapter at Bryn Mawr also serve as the Major Representatives for the department. These representatives are generally invited to attend select departmental faculty meetings during the term. Major representatives help to administer teaching evaluation programs, organize and solicit student opinions at the time of promotion and tenure evaluations of faculty members, hold information sessions for prospective majors, design and order the department T-shirt, and advise the faculty members of issues in the department that need attention. One or two seniors also serve on all search committees during the academic year that are appointed to evaluate candidates to fill faculty vacancies. Whenever possible candidates are invited to meet with students and to give public presentations of their research, all students are invited. The major representatives also sit on the Majors Council and are candidates to serve on the Student Curriculum Committee.

<b>Major Representatives / SPS Officers</b>	
Senior Rep / SPS President	Sam Berry
Junior Reps / SPS Vice-Presidents	Lily Goltz & Emmy Wisz
SPS Secretary	Fatima Irfan
SPS Treasurer	Ellie Hughes
SPS Communications Chair	Julia Moylan
SPS Outreach Chair	Hannah James
SPS Twitter Spokesperson	Catie Robinson

## Keys and Access

On request, physics majors are issued keys to the intro labs upon their major declaration. Additional keys can be given out if the student is performing research with a professor and needs access to their lab. Majors are also encouraged to use the Seminar Room 339 for group study efforts when this room is not in use for meetings. In Park 437, majors have their own study and work area with computers, tables, lockers and bookshelves. Physics majors are also given mailboxes in Park 346.

## **Preparation for Graduate Work in Physics**

For graduate school it is best to have completed, in addition to those courses required for the major, at a minimum: Advanced Quantum Mechanics (302), Statistical and Thermal Physics (303), Advanced Classical Mechanics (308), and Advanced Electromagnetism (309). These four courses alternate with Haverford so they are offered every year on one campus or the other. Graduate programs in physics and astronomy typically require students to take courses that have these undergraduate courses as prerequisites. Solid State Physics (322) and Advanced Theoretical Physics (325) add breadth and depth for those interested in experimental and theoretical physics respectively but are not absolutely required. In addition, some advanced mathematics courses such as Complex Variables and Partial Differential Equations are strongly encouraged for those with theoretical physics interests. Students are also strongly advised to consider taking an introductory computing course, introductory chemistry, and/or numerical analysis courses.

Research experience and the letters of recommendation that result from strong performance in research can be big factors in being accepted for graduate work. Strong laboratory preparation provided by the laboratory courses (P201, P214, and P331) are useful for summer jobs and experimental research opportunities, which together form a package for strong applications to graduate school.

## **The AB/MA Program in Physics**

The Physics Department has a strong Graduate Program and offers both the MA and the PhD in Physics. Students who are advanced placed (i.e., those who place out of introductory physics and get "a year ahead") could do both a BA and an MA in five years. This can give you a real advantage when you go to a PhD program elsewhere. To earn an M.A. degree in physics in the College's A.B./M.A. program, a student must complete the requirements for an undergraduate physics major and also six units of graduate level work in physics. Of these six units, two units may be undergraduate courses at the 300 level taken for graduate credit (these same two courses may be used to fulfill the major requirements for the A.B. degree, so they double count), at least two units must be graduate seminars at the 500 level, and two units must be graduate research at the 700 level leading to the submission and oral defense of an acceptable M.A. thesis. Students must also demonstrate skill in computing or in a foreign language. The usual 500-level courses are quantum mechanics (P501 and P502), which has P302 and P306 as prerequisites and

P308 as a corequisite, and electromagnetism (P503 and P504), which has P309 and P306 as prerequisites.

## **Engineering, Applied Physics, and Industrial Physics**

While Bryn Mawr College does not offer engineering courses and degrees, there are several time-tested routes to degrees and jobs in engineering and applied physics starting with the physics major at Bryn Mawr College. Students can do an AB at Bryn Mawr, taking the appropriate electives en route, and a course or two in engineering at Swarthmore College or the University of Pennsylvania.

For engineering, applied research, or industrial positions, it is important to have an introductory computing course and other computing experience, to have electronics experience, to have two semesters of chemistry, and to have completed a summer research program. Some non-physics courses, especially in advanced chemistry and geology, may count for some of the required physics courses but this requires permission from the department. Advanced engineering courses at the University of Pennsylvania and Swarthmore also may count. However, counting courses other than physics courses and the automatically accepted astronomy and mathematics courses toward the required five 300-level courses requires specific approval from the department. Students satisfying all these boundary conditions have been very successful at being admitted to engineering master's degree programs, both professional and academic.

Alternatively, in conjunction with the California Institute of Technology (Caltech) and Columbia University, Bryn Mawr offers combined programs in the liberal arts and engineering. Students in these programs spend three years at Bryn Mawr and then apply as a transfer student to Caltech or Columbia where, if accepted, they do two additional years of course work. Our experience is that Caltech accepts all students the Bryn Mawr Physics Department recommends, but they do not guarantee acceptance. Although there is no fixed grade point average for this program, the standards are high. Our affiliation with Columbia is newer, but prepared students have been successful in being admitted there too. While that program is less competitive regarding acceptance, they do have many more required prerequisite courses. See this webpage for more information on both programs: <https://www.brynmawr.edu/academics/abbs-dual-degrees> .

At the end of the five years, students are awarded the A.B. by Bryn Mawr and the B.S. by Caltech or Columbia. Students interested in this option should consult the Engineering Advisor in the Physics Department (Mark Matlin, [mmatlin@brynmawr.edu](mailto:mmatlin@brynmawr.edu)). Because these programs require very careful planning, early advising is essential.

In addition, in collaboration with the School of Engineering and Applied Science at the University of Pennsylvania, Bryn Mawr offers a 4 + 1 Master's dual degree option. In this program, students complete a Bryn Mawr degree in the typical 4-year time frame with a major in a field of science or mathematics. While still Bryn Mawr undergraduates, they can take up to three graduate courses that count toward their Penn Engineering master's degree. These courses also count as credits for the Bryn Mawr degree and, at the discretion of the student's major department, toward their undergraduate major. Upon graduation from Bryn Mawr, students matriculate into the Penn Engineering Master's program to complete the master's degree. Students interested in this program should reach out to the appropriate Bryn Mawr faculty contact here:

<https://www.brynmawr.edu/academics/41-master-engineering-penn> .

## **The Graduate Record Examination**

For those who want to go to graduate school in physics, preparation for the Graduate Record Examination (GRE) in Physics is very important and should begin in the junior year. The exam is taken in early November of the senior year. Depending on interest, the department may offer a GRE course for juniors that could begin immediately after the exam in November and that goes through to the end of the academic year. It then would pick up for the same group (now seniors) in September the following year and end just before the same students take the exam. Typically, students will be taking one of the core 300-level theory classes second semester of their senior year, well after taking the GRE exam, so this material must be covered in a "cram" course as part of the GRE course. You should inquire about this during your sophomore year. *Very bright students are routinely rejected from many good graduate programs because they do poorly on the GRE.* Finally, it is important to take the "General" part of the GRE seriously as well and students should practice this exam in the summers between their junior and senior year.

## **When to Apply to Graduate School**

Graduate school applications for admissions and support are due in late December or early January of your senior year. In the summer between your junior and senior years you should get on the internet and start looking at schools. Faculty members are always willing to discuss the various graduate programs with you and some have their own list.

## **Picking a Graduate School**

Different schools have different specialties and different course requirements, exams, and teaching styles. Some have large research groups with many faculty members, postdocs, and graduate students in each group. It is important to pick a school with several research areas that interest you and several faculty members with whom you might want to work. As you receive acceptances you will want to visit the schools (many grad schools will pay to have you visit) and to check closely with current graduate students on their progress, their forms of support, style and level of exams and course work, and their interactions with their research supervisors. Faculty members at Bryn Mawr are eager to advise you and to write letters of recommendation, but please given them at least several weeks to prepare their letters before the deadlines. Important: Many applications have deadlines in January before you return to the College, so plan accordingly.

## **Financial Support for Graduate School**

Almost every student admitted to graduate school in the sciences these days receives a full tuition scholarship and a fellowship or assistantship (teaching or research). This means that graduate school is "revenue neutral." It won't cost you anything but neither will you get rich. Stipends are also offered to students for summer research. Teaching assistantships usually require 15-20 hours of teaching in labs or recitation sections per week during 9 months of the year. Other fellowships to support graduate study include the AT&T Bell Labs Graduate Research Program for Women Scholarship (which includes a mentor/Advisor assignment from the research staff at Bell Labs); the NSF Graduate Fellowships; The National Physical Sciences Consortium Graduate Fellowships, and others. Applications to the programs are often due midway through the fall semester and qualifications for them vary, so be sure to consult your Advisor and faculty early to write for application forms.

## **What's After Graduate School?**

Graduate degrees in physics lead to an unbelievably diverse set of professions. Physicists are taught to solve problems and PhD physicists get jobs in a surprising number of disciplines. You can get all the facts at <http://www.aip.org/statistics>. About half of master's degree recipients continue their studies and the other half take jobs, typically high school teaching or in business or in industry. Of doctoral degree recipients, many take a postdoctoral research position for 1-3 years and doctoral degree recipients end up with jobs in industry, government, federally funded research centers, universities and colleges.

## **Careers and Summers at National Laboratories and in Industry**

Many students are potentially interested in careers in national laboratories and private-sector industrial laboratories. What are some of the differences between national labs and industry? In general, the national laboratories are research facilities, which focus on issues of national policy (such as sources and uses of energy, measurement standards, nuclear technology, space exploration, defense weapons and guidance systems, communications). Bachelor's level employees enter as part of research teams. Ph.D. level employees usually enter as major scientists to lead particular research projects. The industrial research laboratories are generally more product oriented, though some do have basic research programs. The bachelor's and Ph.D. level work is similar to that in a national lab but there is more motivation and evaluation based on product performance in the marketplace. There are also policy and business positions in both environments, though the industrial environments include such matters as product safety, environmental impact, patents, and marketing. Summer research opportunities at these places are similar as both view the programs as much more than jobs, students are being encouraged to pursue scientific careers and are often being recruited. Summer programs include seminar programs of outside speakers, close coordination between supervisors and students, and careful preparation of final reports that summarize and synthesize the work that has been done.



## **What Graduates Have Done with Their Physics Major**

BMC physics majors have gone on to graduate programs at: U. Texas, U. Washington, Harvard, UCLA, U. Delaware, SUNY Stony Brook, Stanford, Columbia, Yale, West Virginia, North Carolina, Dartmouth, Duke, Courant Institute, U. Pennsylvania, Bryn Mawr, Georgia Tech, U.C. Berkeley, South Carolina, U. Colorado, U. Tennessee, MIT, U. Illinois, Indiana U., U.C. Davis, Drexel, Michigan, Cornell, CalTech and have attended business, law, medical, veterinary, and architecture schools.

Others have pursued careers in engineering, industrial research labs, architecture/city planning, law, national research labs, college and university teaching, finance, software development, optics firms, environmental consulting, high school teaching, medicine, investment banking, patent assessment, and veterinary science.

