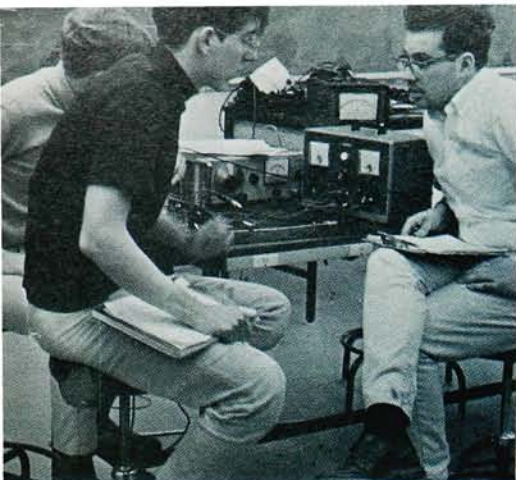




they are the bulk of the curriculum.

Perspective

It is safe to say that, with the exception of the advanced laboratories, we

now cover in the first two years most of the material that ten years ago was covered in three years. The last two years deal with the "backbone" of physics—classical mechanics, electromagnetic theory, relativity and quantum mechanics—at a level and with a mathematical sophistication that the older ones of us associate with graduate school. It seems to work! The best students can often save valuable time in graduate school and proceed to independent work that much faster. The average students may have to repeat some of the material in graduate school, but they are more than adequately prepared for it. The poor students did not try it in the first place or dropped by the wayside.

Life can never be a complete bed of roses and our program is no exception. There are definite losses; a student taking the minimum program can graduate knowing little about optics, thermodynamics and statistical mechanics, and practically nothing about the latest developments in solid-state physics, nuclear physics or particle theory. We hope they will browse in the library and learn some of these things, and many of them do so.

We end as we began with a system in dynamic equilibrium. Five years from now it will almost certainly be different; we hope it will still be producing broadly educated graduates who are well prepared for industry, education courses and graduate work. □

Swarthmore College

Highly motivated upper-class students can take part in an honors program wherein independent study leads to the presentation of seminars and eventual grading by invited outside examiners.

by William C. Elmore

THE SWARTHMORE HONORS PROGRAM, initiated in 1922 by President Frank Ayedelotte, has come to distinguish Swarthmore's educational processes and results from those of most other colleges and universities. In recent years about 90% of those majoring in physics have either obtained doctoral degrees or are currently pursuing graduate work in physics at schools such as Cornell, Yale, Harvard and

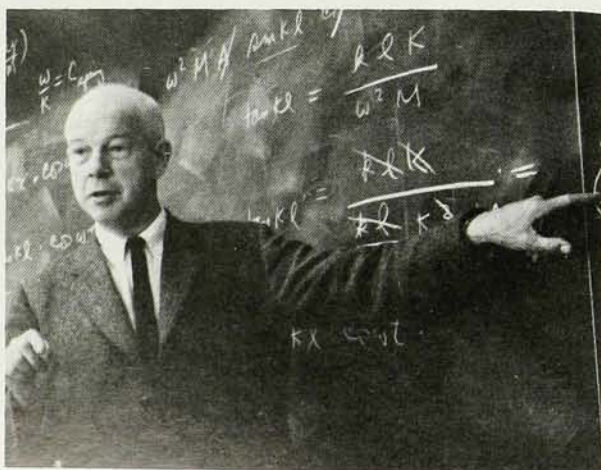
Princeton; the complete list includes at least 20 different universities. Swarthmore graduates are on the physics faculties of more than 25 colleges and universities, as well as on the staffs of most of the national laboratories.

Beginning at the beginning

The department currently offers a single one-year introductory general physics course that is fairly conventional. It serves the needs of prospec-

tive majors in physics as well as majors in the other sciences and engineering. The course is based on three weekly lectures, one weekly conference section and an afternoon laboratory session. To accommodate the current enrollment of 83 students, there are five conference sections and five laboratory sections. In the laboratory, students work in teams of two; all teams do the same experiment in a given week. Much of the laboratory equipment has been constructed in the physics shop, which is staffed by a full-time mechanic. Considerable thought and effort have gone into making the experiments interesting and instructive and into writing an effective set of laboratory notes. Each student keeps a "research" notebook that is initialed by the instructor for completeness and correctness before the student departs from the laboratory. Each week students are given problems that are evaluated by upper-class student assistants. A group of the most capable students is assigned to a "hotshot" conference section in which topics too advanced for the average student are discussed.

We have not been able to justify a



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separate introductory course for prospective physics majors for two reasons: Students normally do not decide, and should not be required to decide, on a major until their fourth term at college; the limited teaching time of the faculty is better spent on advanced courses rather than dissipated in teaching multiple courses in introductory physics. Nonscience students at Swarthmore can elect a terminal physical-science course to fulfill a college science requirement. This latter course occupies a unique position at the college in that it is not the direct responsibility of any one department; rather, each department shares in the responsibility.

The serious study of physics starts with a second-year course in mechanics and wave motion. The course is unusual in that it is accompanied by a fairly sophisticated laboratory, one long afternoon each week, that introduces students to important laboratory techniques and methods of working with experimental data. Many experiments are original at Swarthmore and for the most part are well received by the future physicist. No separate grade attaches to any laboratory work at Swarthmore, a situation that may account for its acceptance as something that is fun to do—an opportunity to learn, not just another hurdle to be cleared. This course is often elected by chemistry and mathematics majors, and it gives a second-year student a good chance to discover how well he can do physics before committing himself to a major in the subject.

During his fourth semester at Swarthmore each student makes a formal application for a major either in the regular course program or in the honors program. Applications are carefully considered in divisional faculty meetings, with close attention given to each honors applicant and to his proposed program. A student and his program of honors papers are accepted only if the program is reasonably well integrated and it is felt that the student can profit by being in honors. The requirements to become a course major are much less demanding. At present 32% of the juniors and seniors throughout the college are in the honors program. The format and requirements of the course program differ but little from those at comparable colleges. The Swarth-

more honors program, however, is probably unfamiliar to many readers of *PHYSICS TODAY*, and a description of its essential features should prove of interest.

Honors: free from lock steps

The honors program is basically one that encourages independent study with a minimum amount of formal lecturing by the faculty. It is best suited to capable students who are highly motivated and therefore can be freed from the usual academic lock step. Typically a student in honors takes only two subjects at a time during each of the four semesters of his upper-class years. These intensive double-credit courses are known locally as honors seminars. He thus devotes full time to two subjects each semester rather than the four that characterize the usual course program. The number of students in a seminar section rarely exceeds eight. Students meet one afternoon each week for 14 weeks with the faculty member in charge of the seminar. The students take turns presenting the subject matter of the seminar; the faculty member serves sometimes as a lecturer but more often as a moderator and consultant on obscure and difficult points. If a science-seminar subject requires laboratory experience, as do all seminars in physics, a student devotes one full day each week to this important aspect of the science. It is evident that a single faculty member assists the students in integrating a large body of material, a practice that is contrary to the typical fragmentation in a university.

At the end of his senior year a student in honors has thus prepared himself to write eight examination

papers on the work of his last two years. (He writes four trial papers at the end of his junior year for practice and to show the faculty whether he is profiting by being in honors.) For seniors all examinations are set and evaluated by outside examiners invited by the college. The examiners come to the campus in late May to give brief oral examinations to each senior and to vote on his degree of honors.

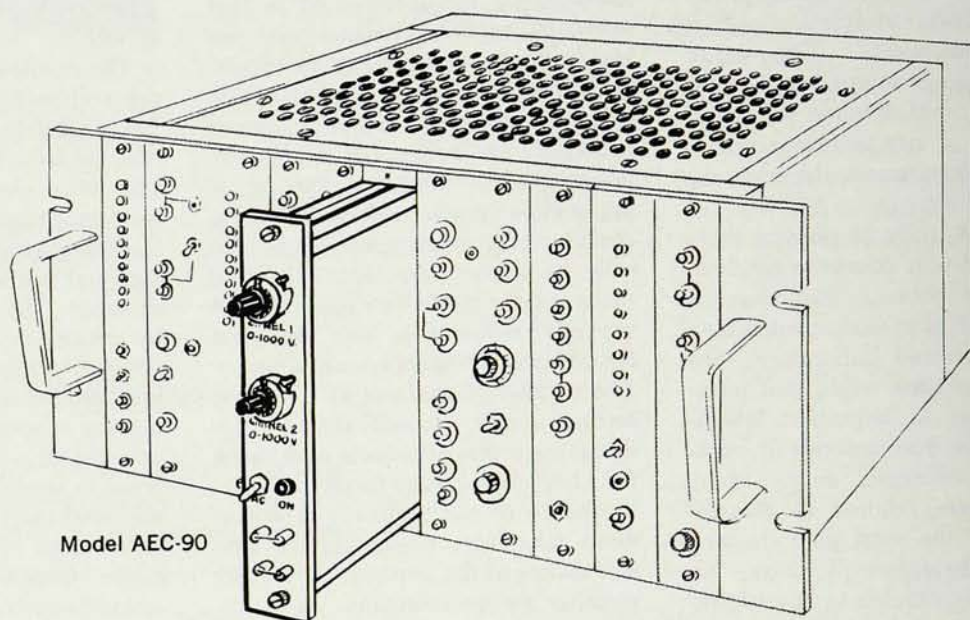
The examination aspect of the honors program has many advantages both for the student and for the faculty. The students tend to regard the faculty more as coaches than as taskmasters. Furthermore they endeavor to master a subject for the distant future and not for an impending examination. The faculty profits greatly by advice from the examiners, and it is constantly kept on its toes since its best students will be examined by outside experts in the field. An incidental advantage of the system accrues to students applying for graduate work in university departments from which outside examiners have come. Over the years the outside examiners in physics have included many well known physicists such as Leigh Page, Lee A. DuBridge, R. Bruce Lindsay, Gaylord P. Harnwell, Franzo H. Crawford, Walter C. Michels, William E. Stephens, Robert L. Sproull and Ernest D. Courant. We are convinced that the honors program helps a student develop an independent, mature attitude toward learning and thinking about a subject. It is evident that the program is an expensive method of teaching, perhaps suited only to a smaller institution that is not obliged to engage in the standard mass-education techniques that

Curriculum at Swarthmore College

	Course	Text
<i>First year</i>	General physics	Sears and Zemansky
<i>Second year</i>	Mechanics and wave motion	Symon; Elmore and Heald
	<i>Honors Seminars (double courses)</i>	
<i>Third year</i>	Electricity and magnetism	Reitz and Milford
	Atomic and nuclear physics	Eisberg
<i>Fourth year</i>	Radiation and statistical physics	Elmore and Heald; Leighton; Reif
	Quantum mechanics	White; Messiah



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are often necessary at most large universities.

Papers, courses, labs

At the present time students who major in physics in honors normally prepare for four papers in physics, two or three in mathematics, with the balance of their eight papers chosen from astronomy, chemistry, engineering, philosophy or possibly some subject fairly remote from physics. Their program, in general, is heavily weighted toward minor subjects that support the major subject. The four physics seminar subjects are electricity and magnetism, atomic and nuclear physics, radiation and statistical physics, and quantum mechanics. These are taken in sequence, one each semester, with each seminar building on knowledge acquired in previous seminars and in the fairly high-level sophomore course in mechanics and wave motion. Each seminar is accompanied by one full day of laboratory work each week with approximately one fourth of the total time devoted to independent projects, which can include the 1620 computer.

The subject matter of the four seminars (double courses) should be clear to the reader from their titles, with the

possible exception of radiation and statistical physics. About 40% of this seminar is spent on various aspects of electromagnetic waves and the special theory of relativity. The rest is spent on thermodynamics and statistical mechanics. A seminar represents such a large block of time that in some cases two or more unrelated subjects must be grouped together. The level of the four physics honors seminars may be judged by the textbooks in current use. These include all or parts of the well-known textbooks by Reitz and Milford, Eisberg, Leighton, Reif and Messiah (see table on page 60), supplemented by a reserve shelf in the library for accounts of particular topics of interest.

In choosing laboratory work to accompany the four honors seminars and the advanced regular courses in physics (see table on page 33), a number of objectives have been kept in mind. We feel that it is a valuable experience for an undergraduate physics major to have measured most of the important fundamental constants of nature. This objective familiarizes him with a great variety of techniques and equipment as well as the theoretical analysis underlying experiments. We feel that he should do a

basic experiment in as many of the different areas of physics as possible. At Swarthmore these include spectroscopy, x rays, crystal structure, electron diffraction, the diffraction of light, nuclear-physics measurements with a variety of detectors, solid-state physics, paramagnetic and nuclear magnetic resonance, mass spectroscopy and microwaves. He should gain experience with the kind of apparatus and electronic gear that is currently used in research, have a good understanding of vacuum systems and at least an introduction to circuit electronics. He should acquire considerable experience in analyzing experimental data and should also learn how to program a computer.

It is clearly obvious from the description of Swarthmore's program that we have a student-oriented philosophy. We feel that the student should be treated as a serious and mature scholar, a person who must be given every opportunity to develop in an atmosphere of free enquiry and constructive independence. With this outlook, the student can regard his professor as an informed colleague who will work with him in the acquisition of knowledge and profound understanding. □

Villa Madonna College

Feedback from alumni has been important in illuminating faults in the physics program of the past and lighting the way to improvements now and in the future.

by George K. Miner

WE MUST CONTEND with a variety of problems that are common to many small colleges. For example, in past years there has been a steady flow of comments about the inadequate laboratory equipment and the weak format of laboratory training. Furthermore there had been noticeable shortcomings in mathematics instruction in addition to difficulties with the physics curriculum. A final example is that the faculty must labor under severe handicaps such as heavy teaching loads, small financial resources and a lack of technical and secretarial assis-

tance. On the other hand, of course, there are a number of advantages to a small college such as Villa Madonna. However, before I discuss more extensively the strengths and weaknesses of our college, including methods for evaluation, I will deal with the curriculum itself.

Villa Madonna is a Catholic, liberal arts college in Covington, Kentucky that grants only a bachelor's degree and has a full-time day enrollment of about 1000 students, two thirds of whom are men. The college operates on a plan of two 15-week semesters and a six-week summer session. The physics department, with a staff of

five, has averaged ten majors per year, most of whom earn an additional degree in either engineering or physics.

The structure of the lecture curriculum represents an attempt to put into operation Curriculum R as suggested by the Second Ann Arbor Conference. These recommendations are periodically reviewed and discussed by the upper-division course instructors. The course requirement for physics majors is a minimum of 34 lecture credits along with eight lab credits.

Lecture courses

In the freshman and sophomore years the student takes a four-semester se-