

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-

quence called the "general-physics lecture." A four-semester course of calculus and differential equations must be taken concurrently. This means that a student who is not prepared to begin calculus in his first semester cannot be a physics major and still graduate in four years. A mathematics placement test is given at the beginning of the summer before entry into college, and students who need remedial work in algebra and trigonometry can accomplish it in a noncredit course during the summer. The requirement that calculus be started in the first semester of college probably reduces the number who attempt a physics major; however, this corequisite advances the mathematics level in the general-physics course. Traditionally this course has been effective in determining those who are likely to succeed as physics majors.

The junior-year major takes two semesters of mechanics, a rather demanding problem-solving course. At the same time he takes one semester of thermodynamics followed by a semester of physical optics. This year the concept of the physical-optics course has been altered slightly to treat waves and oscillations in a general manner with applications especially to optics and acoustics. This plan represents an attempt to make a less popular course more interesting and profitable.

The senior-year physics major takes two full-year courses: electricity and magnetism, atomic and nuclear physics. Both are high-powered courses with considerable emphasis on problem solving.

Two electives are offered regularly. Electronics is offered in the summer following the sophomore year, and all are strongly urged to take it. The other elective, available to the student in his last semester, is introduction to solid-state physics, a two-credit course that considers selected topics from Kittel's book (see table on page 60). The department's opinion is that this course should be required and expanded; however, at present this is not possible because of a college-wide limitation on the number of credits a department can require. We generally expect graduate-school-bound students to take this course.

Laboratory courses

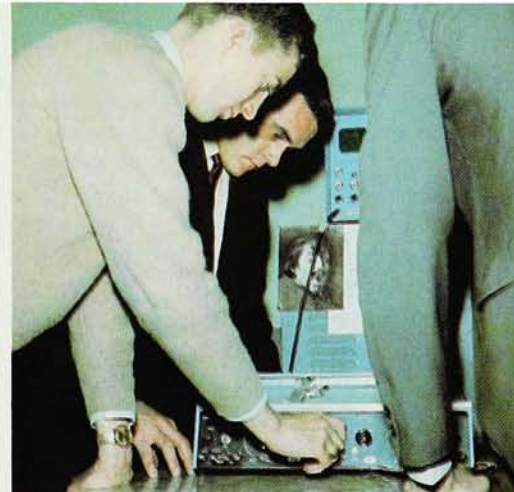
The present laboratory curriculum includes a 1-credit (3 clock hours)



course each semester. This new plan represents a considerable reduction from the program of three to five years ago. A college-wide curriculum revision that increased the number of general requirements forced this change.

In his freshman year the student takes introduction to measurement, in which, during the first semester, he learns significant figures, graphing, error analysis and report writing in addition to performing some of the standard and more interesting general-physics experiments. (The one in which probability is studied by rolling dice has been received most enthusiastically.) In addition to the text (Baird), a guidebook for investigations that was composed by a senior member of the staff is used for the general-physics experiments. Although the experiments use standard equipment, they are open-ended with respect to the basic problem, procedure and analysis.

The sophomore major continues along the lines of his freshman course with a lab called "experimental physics." Now he uses the techniques of



measurement and analysis that he has learned. Toward the end of the year he does more sophisticated experiments formerly performed in the advanced labs.

The junior physics major takes his last formal laboratory course—advanced experimental physics. This lab has no text, and the student is referred to the laboratory literature and to standard works on measurements. This course is designed for wide coverage of classical and modern physics without sterile repetition.

The final-year student takes the independent study lab, "projects in physics," in which he takes up one or two experimental projects in depth under the close guidance of a faculty member. The students in the honors research program—to be discussed below—are not required to take this course.

The success of a physics program is strongly dependent on the available mathematics training. Following the four-semester sequence of calculus and differential equations, the physics major takes, in his junior year, a two-semester course in advanced calculus



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for scientists. Formerly the major took a regular advanced-calculus course offered by the mathematics department. Experience indicated that this type of course was not well suited to the needs of the physics major because only a few topics were treated. The physics major needs a large number of topics and needs them fast. As a result, two years ago the course mentioned above was initiated and is being taught by members of the physics department. Topics include calculus of vectors, tensors, complex variables, transforms, orthogonal functions and solutions to partial differential equations.

Honors research program

An important development for the better physics students has been the honors research program. It began in 1962 and has been supported continuously by the National Science Foundation undergraduate research-participation program. Students with a total cumulative average of B or better may

apply for participation at the end of their sophomore year. The number of juniors has varied from three to eight. During the junior year a student works a minimum of four hours a week on a project along with a senior and a faculty members. The three or four best performers are then selected for a 40-hour, 10–12 week summer session headed by a full-time faculty member. When the number of deserving students exceeds the number of openings in the department, appointments in undergraduate research-participation programs elsewhere or other training programs related to their project interest are sought for them. Three such appointments were found in the last two summers. In the senior year the student again works a minimum of four hours per week on his project.

In the spring of 1967 I attended an Undergraduate Research Participation directors' meeting in St. Louis. The consensus appeared to be that the program during the academic year is generally unsuccessful. Contrary to this opinion, at Villa Madonna we feel that this program has been quite successful during the academic year as well as during the summer. Not only does it provide valuable research experience, but it also serves as a motivating force: The lower classmen attempt to maintain excellent academic records to be eligible; the program stimulates a greater enthusiasm among the participating upper classmen that spreads to those not directly involved; it provides students with better criteria for evaluating the graduate schools to which they will apply.

Another factor that must not be overlooked is the effect on the faculty, especially in a small institution where there is no graduate research. Here faculty members have been stimulated by the opportunity to continue some research with their better students and have good experimental apparatus in operation. Since research is part of the structured curriculum, it is one fifth of the teaching load. These are important faculty-recruiting devices.

Other activities

For a fuller training the formal course work should be supplemented by extracurricular activities of a professional nature. The vehicle for such activities at Villa Madonna is a rather active Student Section of the American Institute of Physics. Each year this

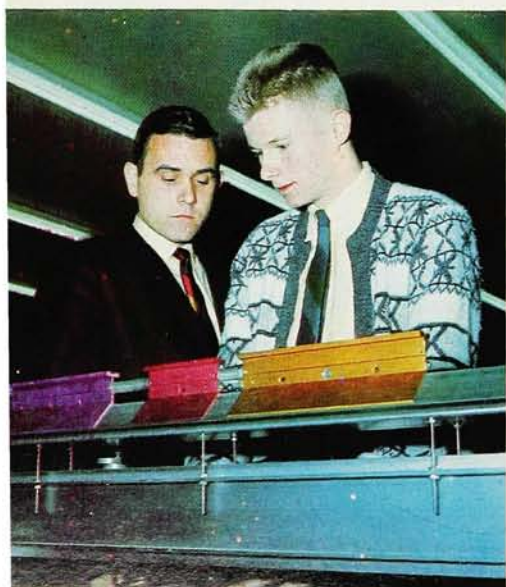
group sponsors three or four outside speakers, a visiting professor, films, an open house and perhaps a field trip. For the past two years the freshmen and sophomores in the section have been successful in the Bendix Award competition. Last year the group began a practice of making a three-day trip to Argonne National Laboratory to perform experiments. The total program broadens the students' scope by acquainting them with scientists outside the college.

Villa Madonna also offers a 3–2 double-degree engineering program in collaboration with three engineering schools. The student takes the first three years at Villa Madonna and the last two at the engineering school. He receives a liberal-arts degree in physics from Villa Madonna and an engineering degree from the other institution. The preengineering program is identical to the physics program through the junior year except that physical optics is not required. This setup allows for an easy change of major until the end of the third year.

Evaluation

Since Villa Madonna's curriculum is intended to prepare the student for immediate entrance into graduate school, it is reasonable to measure its success by admissions to graduate school, fellowships and assistantships. In the past five years the department has graduated 50 majors. 40 have worked full time toward an additional degree, 29 in physics and 11 (the total number of preengineering graduates) in engineering. At least three of the remainder have pursued graduate work on a part-time basis. Of those who entered full-time graduate study in physics, 15 held some type of national fellowship or traineeship; the remainder received assistantships. At least 16 graduates have been awarded the PhD, and four to six others will be awarded the doctorate this spring.

Another test of success is the Graduate Record Examination. The GRE results of the last five years, considering only those in the full Curriculum R (that is, excluding those in secondary education, a terminal degree program or the preengineers who do not take GRE), show that of 32 students exactly half scored above the 600–650 range. Of the remainder most are also in graduate school doing satisfactory work—in fact in some cases work of



unusual excellence. Thus a lower score does not necessarily indicate that the student is not capable of graduate work.

Through contact with graduate schools who are recruiting students, the department has acquired some indication of the desirability of its products. Also professors from the visiting scientists program have been asked for evaluation and suggestions for improvement. The department has been greatly encouraged by the feedback from these sources.

Alumni feedback

A most important, although perhaps not as objective, source of information for evaluating and improving a program is feedback from alumni. Statements of the type, "I wish that I had studied more . . .," are quite meaningful when heard from several students. Such statements must be evaluated promptly and the necessary changes made. Recently I circulated a questionnaire among the alumni and asked them to list the two or three strongest points in the program. From a total of 63 replies, 49 mentioned the quality of the lecture courses. The faculty's strong points, including personal interest, personal contact and conscientious academic advising, were mentioned by 39. On the negative side, the most often noted weakness

(24 times) was mathematical training. As mentioned earlier, this program has been changed recently because of similar observations from alumni in the past. The second most mentioned weakness (19 times) was the labs. Eight graduates of at least ten years ago, commenting on the program as they experienced it, complained that the equipment was inadequate. This situation has changed drastically to the point where visiting physicists are usually amazed at the instrumentation available in an undergraduate institution. The format of the labs was criticized by the others. Interestingly enough, the laboratory is one area in which the faculty is constantly innovating ideas in an effort to improve effectiveness. An encouraging aspect of the survey is that earlier graduates suggested many changes or additions that have been made since their departure.

Present and future

Even though the department has enjoyed a certain amount of success, the faculty member at Villa Madonna still labors under handicaps. Heavy teaching loads, small financial resources and a lack of technical and secretarial help make it difficult for a scientist to maintain an active research interest and respond rapidly to changes in the needs of his students. In agreement with the 1965 COFFIC report published by AIP,

we know of no better way for a teacher to study the latest developments in his field than through active research. This situation takes a significant portion of his time and therefore appears to require teaching loads lower than now in existence.

One can say that the department is achieving the goal of adequately preparing students for graduate school. However, one must not think that we believe that a student is a success only if he continues his education in that manner. He is considered successful if, when he graduates, he has the option or is qualified to enter graduate school. We feel that this type of training is also good for those who do not plan graduate study. Ideally a department should also offer Curriculum S for those in secondary education and others. However, in a small college it is not practical to offer two high-quality curricula. At Villa Madonna, where there is no Curriculum S, the only secondary-education students who can major in physics are those who can take an abbreviated Curriculum R.

Respectable physicists can be produced in a small private college this year. Will this be the case next year? It will be so only if a department can respond to next year's needs and only if the funding agencies and college administrations continue to demonstrate their concern. □

Four Universities

University of California at Berkeley

Upper-division physics courses are currently being reassessed after further experience with the Berkeley Physics Course. A wide variety of alternative elementary courses is offered.

by Burton J. Moyer

THE DEPARTMENT OF PHYSICS at Berkeley is a member of the College of Letters and Science. As such it shares actively in the efforts of the college to evolve and provide the components of a liberal education. Furthermore such efforts are intended to be consistent with the increasing demand that the

physical sciences should make themselves more generally understood in spirit and significance by the nonscientist in the educated populace.

There has been considerable exposure in the past few years of the "Berkeley Physics Course" for physical-science majors and engineers (see PHYSICS TODAY, March 1967, page 50). First, therefore, I will briefly comment

on current developments in the BPC and then I will discuss the elementary physics courses serving students in other major programs and contributing to the concerns mentioned in the first paragraph.

Trends in the BPC

Beginning in the last academic year the BPC, with its complement of five