Five Four-Year Colleges

Carleton College

A three-term year, with three courses per term instead of the usual four or five per semester, has helped to provide a logical layout for a program that is meant as an introduction to graduate studies.

by Robert A. Reitz

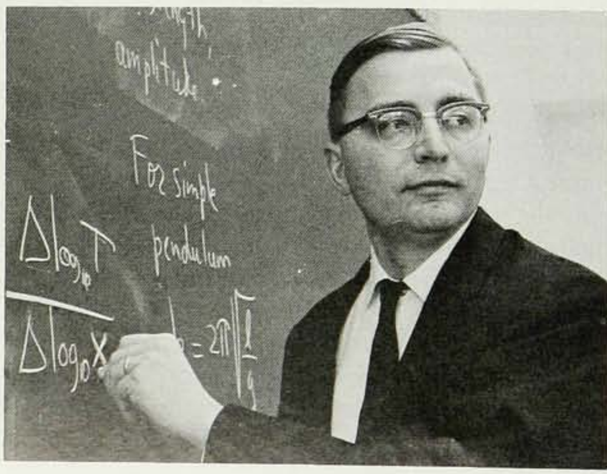
A STRONG BASIS FOR GRADUATE STUDY underlies the physics curriculum at Carleton College. The staff of the physics department at our small liberal-arts college in Northfield, Minn. consists of five physicists and two technicians, and with this limited personnel we have not been able to set up an alternate track for those students intending to go into high-school teaching or to seek employment with only the bachelor's degree.

3–3 course program

A feature that has significantly affected our curriculum is the three-term–three-course program (3–3) that we have had in effect at Carleton since 1961. During each term of eleven weeks (including one week of examinations), a student normally takes only three courses. This provides nine courses a year, comparable to the 8–10 courses usually taken under a semester system (4 or 5 courses per semester). Thus a term course and a standard semester course are actually quite equivalent.

Because physics is a strongly sequential subject and is critically tied to the student's concomitant mathematical development, a three-term year yields particular blessings that no semester system can provide. Not many years ago our beginning physics course for majors was a noncalculus one. Under a semester system the only alternatives would be either to offer a beginning course concurrent with the first calculus course and as a consequence to teach much calculus in the physics course itself, or to start physics in the second semester. By delaying our beginning course until the second term we can present one thoroughly grounded in calculus and still complete a two-term sequence in the freshman year. Most colleges offer a four-course introduction to calculus. It usually contains many other topics such as vectors and matrices, logic, and the foundation of mathematics that most mathematicians understandably want in a beginning sequence. This arrangement means that subsequent courses in advanced calculus and differential equations under a semester system must wait until the junior year, provided that a student studies mathematics every term. Under a 3–3 program this basic sequence of six terms (including advanced calculus, the special functions, Fourier analysis and differential equations) is usually completed by the end of the physics major's sophomore year. In fact it is possible for a major who begins late to get a substantial grounding in both physics and mathematics in three years.

A primary concern in the development of our curriculum is to do as much as possible with our students and still to maintain a modest number of course offerings. We offer the major only 12 courses (one of these is the advanced laboratory) and a number of students take 11. This limitation is essential if one wishes to preserve a good balance between physics and mathematics on one hand and the humanities and the social sciences on the other. We have largely avoided the luxury of developing a subject in detail at the elementary level first, then at the intermediate level and finally at an advanced level. Increased sequencing within physics has changed dramatically what we teach and when. A major rarely takes more than one physics course at a time.



ROBERT A. REITZ came to Carleton in 1954 as assistant professor and became professor in 1965. In 1955 he earned his PhD from the University of Illinois, and for 12 years he has conducted research on color centers in alkali halides.

Background: math and physics

To describe our curriculum in some detail one might start with the first course. For more than eight years, majors have begun with a combined course, more recently a two-term sequence, in physics and chemistry. All physics majors, chemistry majors and many mathematics majors take a calculus-based physics course during the second term of their freshman year followed in the third term by a chemistry course. Texts used in physics have been Resnick and Halliday, Hazen and Pidd, Sears and Zemansky (see textbook table on page 60). The physics course has the first and second courses in calculus as prerequisite and corequisite respectively; at the beginning of the physics course the student has studied differentiation and is being introduced to integration. Naturally such a one-term course in physics must be severely abbreviated. The basic idea in the course is to develop a consistent, analytical theory of the Bohr atom, and that is followed in the chemistry course by the development of the periodic table, chemical bonding, electrochemistry, and chemical kinetics and equilibrium. The combined approach offers a host of advantages. First an undecided student can make a decision between physics and chemistry by the end of his freshman year after a college course in each. Second a strong basis in physics makes possible a rather different and more sophisticated chemistry course. Third it is possible to give an early basis in both areas for physics, for chemistry and for all the other sciences. It is surely difficult to provide such a basis with conventional one-year elementary courses in a liberal-arts institution. We have thus strengthened our entire science program, and many more chemists and biologists take advanced courses in physics than ever before. This is assuredly a trend to be encouraged. A shortened beginning-physics course has also meant a ruthless pruning and culling of experiments in the elementary laboratory. Forced to supply less than ten laboratory experiments, we have only retained the more imaginative and exciting ones. A second primary course in physics (largely for biology, geology, and premedical students) is similar but uses a noncalculus approach (Atkins, Holton and Roller, Rogers).

The noncalculus physics course is still a survey course and is not satisfactory for many students in the social sciences or the humanities. In an attempt to give a viable alternative, we are introducing a third elementary course in physics this year. Its mathematical basis will be modest and its scope limited. It will essentially contrast Newtonian and Einsteinian mechanics, giving attention not only to the physics involved, but to its broader implications in history and philosophy.

A potential physics major would follow in his sophomore year with a good grounding in mechanics (Fowles, Symon), concurrent with the fourth term of calculus (some introduction to differential equations and calculus of several variables). Next, in parallel with the formal differential equations course, he would take a one-term unit in electricity and magnetism (Purcell, Corson and Lorrain). The third term sophomore usually takes our course in electronics (Korneff, Malmstadt, Ryder, Seeley and Fitchen). This course develops dc- and ac-circuit theory and provides a solid introduction to electron-tube and transistor-circuit theory. It is the only advanced course in physics with an associated laboratory, and provides a fine basis for our later advanced laboratory program both in experience and in giving the student a variety of electronic techniques that may be helpful in experimental problems. The 3-3 course program in physics and related subjects is summarized in the table on this page.

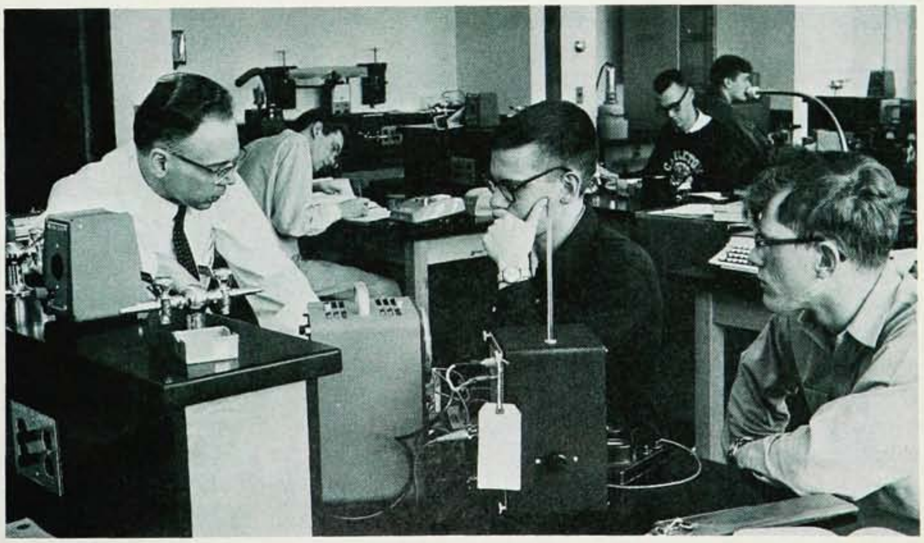
Curriculum at Carleton College

	First term	*Second term*	*Third term*
First year	Mathematics 1	Mathematics 2 Physics 1	Mathematics 3 Chemistry
Second year	Mathematics 4 Mechanics	Differential equations Electricity and magnetism	Advanced calculus Electronics
Third year	Introduction to quantum mechanics Advanced lab. 1	Atomic and nuclear physics 1 Advanced lab. 2	Atomic and nuclear physics 2 Optics *or* Thermodynamics Advanced lab. 3
Fourth year	Theoretical physics 1	Theoretical physics 2	Optics *or* Thermodynamics

Advanced topics

By the beginning of his junior year, a physics major has his required mathematical preparation behind him (although he often elects such further courses as complex variables, linear algebra, numerical analysis or probability and statistics), and he now takes a three-term sequence in quantum mechanics and atomic and nuclear physics. The first two terms are a thorough introduction to quantum mechanics drawing strongly on atomic physics as a model (White, Park, Saxon, Eisberg). They also discuss a modest amount of the experimental evidence for the development of quantum theory. The third term develops the special theory of relativity in more detail and topics in nuclear physics.

The capstone is a two-term sequence



in theoretical physics in the senior year, the first being advanced mechanics (Goldstein, Marion) and the second electromagnetic theory (Marion, Jackson). In addition we offer one-term courses in optics and thermodynamics and statistical mechanics in alternate years during the third term. Most seniors and a lesser number of our juniors elect the third-term offering.

Our advanced laboratory program is wholly independent of any of our courses, and is spread over three terms (usually in the junior year) with a one-third course credit per term. The student may choose to work in a wide variety of areas—mechanics, electricity and magnetism, optics, thermodynamics, atomic and nuclear physics and solid-state physics. Not being tied to any specific formal course, projects in the laboratory may freely cross boundaries. The student is expected to elect a broad cross section. Working with modest direction, he must read extensively for background and frequently devise his own procedures. Often during the later phases of his laboratory experience he will initiate a larger project. A number of these projects have subsequently become regular advanced laboratory experiments. As part of this laboratory, the physics major must utilize Fortran programming of our IBM 1620 computer in the analysis of data in at least one of his experiments.

Research and comprehensives

Beyond these formal course arrangements, independent study and research projects are possible both during the academic year and during the summer. For our theoretically oriented majors, independent study has been undertaken in such fields as group theory, advanced topics in quantum mechanics, the special and general theory of relativity, etc. Experimental independent study has taken a wide variety of forms, and is often, but not exclusively, centered on faculty research interests. Summer research, often beginning or following an academic-year study, is always centered on staff research and usually involves one quarter to one third of our upperclassmen. With departmental recommendation and the approval of a special faculty committee, a student undertaking independent study may be awarded "honors" at graduation.

Finally every physics major late in his senior year must take an intensive comprehensive examination in physics. This examination embraces his entire undergraduate program in physics and consists of a six-hour written examination and a one-hour oral examination. A satisfactory performance is a requirement for graduation that parallels the usual grade-point and course requirements. Graduation "with distinction in physics" is given in recognition of an outstanding achievement.

Evaluation

The foregoing curriculum represents the distillation of the efforts of many people, some no longer at Carleton, over the past decade. It continues to be in a state of flux, and probably the next decade will bring as substantial a change as the past one. How successful is our present curriculum? One means of evaluation, the comprehensive examination, is at best a rather subjective one. Probably the best measure of our program is the subsequent performance of our majors in graduate study, that is, with what courses they begin their graduate study and how well they do. We have 8 to 12 seniors each year, 90% of whom do graduate work in physics, and most of the remainder study related fields such as biophysics or engineering. Feedback of their strengths and weaknesses in undergraduate preparation has been most helpful. With the wide distribution of our majors at "good-to-excellent" graduate institutions in physics, we thus have a more objective means of measuring our accomplishments. The most important factor is not the nature of the curriculum but the nature of the student body. □

Pomona College

Strong faculty involvement in research has led to undergraduate interest and participation that provides some of the excitement of graduate school often missing at a liberal-arts college.

by Charles A. Fowler Jr

THERE IS A DECLINE in the productivity of small-college physics departments as a group. The necessary, if not sufficient, ingredients for a successful undergraduate-physics program are interested physicist-teachers and capable students, and the desire of many in each of these groups to "be where the science action is" has resulted in their gravitating toward the large universities. The physics department at Pomona College (Claremont, Calif.) offers no studies beyond the baccalaureate and would seem to typify that kind of department marked for oblivion by George Pake and others.[1,2]

But physics has flourished at Pomona to the point where the department's performance ranks creditably. The department has managed to attract and hold competent professors and good students. It has accomplished this by devising an undergraduate program that has much of the atmosphere and excitement of a graduate curriculum. The key factor contributing to this atmosphere is the existence of serious research projects by the faculty with active student participation.

Course design

The formal courses offered for the physics major have evolved over a period of several years and reflect the educational philosophies of the staff and the needs of the students, most of whom are professionally oriented. The essential subject matter is de-