tial loss of coherence when the drops become larger.

Instances of such unusual insight and expository care are to be found throughout the book and give the "Lectures" their unique excellence.

The laboratory

The Feynman volume 1 base for the introductory course places little restriction on selection of laboratory experiments. I believe, however, there are several general requirements if the course is to have unity of purpose. The work should give satisfaction and pleasure to the student; it should challenge his ability to make correct and careful use of good instruments; it should involve theoretical interpretations and evaluation of precision for numerical results. As the laboratory is presently conducted, each student performs six experiments a semester. The directions consist very largely of oral briefing, and a concise but complete written report is required on each experiment. There is no specified pedagogical format. Typical experiments involve measurement of many fundamental constants (c, G, e, e/m, the Rydberg constant), Bragg diffraction of microwaves and electron diffraction, and such open-ended experiments as determination of air friction on a falling styrofoam ball as a function of velocity by means of stroboscopic photography.

". . . All Feynman chapters are fun chapters. . . ."

Student reactions

Do students like the "Lectures"? I asked for written comment at the end of the first year. There were very few who did not express pleasure in the reading; many thought there should be more help with problems; one third of the class would have preferred a different text. I hope that there will be fewer than this doubtful third next time. From classroom discussion I am convinced that for a significant fraction of the class Feynman was highly successful in conveying a sense of the excitement in contemporary physics.

In assigning the chapter on "Mechanisms of Seeing," which describes the physiology of the eye, I referred to it as a "fun" chapter. A student rejoined, "All Feynman chapters are fun chapters." An overriding consideration in the choice of text is that a teacher must be able to make assignments from it not merely without reservations but with enthusiasm and enjoyment. I find "The Feynman Lectures" meets this criterion. □

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The Berkeley Course

by A. Carl Helmholz

THE BERKELEY PHYSICS COURSE is intended to present introductory physics to students in engineering and the physical sciences in a new and fresh way, to give them the flavor of the way in which practicing physicists use the subject. It consists of five volumes ("Mechanics," "Electricity and Magnetism," "Waves and Oscillations," "Quantum Physics" and "Statistical Physics") and a new laboratory manual. Since the course is designed to acquaint the student with the basic principles and ideas of the physics of today, it does not survey all of physics; rather it selects topics that characteristically illustrate the basic elements of physical reasoning. Consideration of the subjects common in present-day physics has influenced the choice of many of these topics.

The combination of texts and laboratory provides a rounded course that should be useful in many schools. It best fits into a two-year introductory course.

How the course developed

The course was conceived in a conversation between Philip Morrison and Charles Kittel late in 1961. With encouragement from NSF and the Commission on College Physics a committee was formed; it met in May 1962 to draw up a provisional outline for a course. (Original members were Kittel, Luis Alvarez, William Fretter, Walter Knight, Morrison, Edward Purcell, Malvin Ruderman and Jerrold Zacharias.) By the time volume 1 appeared several of the group had dropped out because of the press of other activities. (At that time the committee consisted of Eugene Commins, Frank Crawford Jr, Kittel, Knight, Morrison, Alan Portis, Purcell, Frederick Reif, Ruderman and Eyvind Wichmann.) Kittel served as chairman until January 1966, when he resigned. Purcell and I were then appointed cochairman. (Present members are Crawford, A. Carl Helmholz, Kittel, Knight, Portis, Purcell, Reif, Ruderman and Wichmann.)

Financial support for development of the course came from Educational Services Inc. and NSF. Headquarters

What is in the Berkeley Physics Course?

Volume 1, Mechanics

1. Orders of magnitude and geometry of familiar systems.
2. Vectors—addition and subtraction, scalar and vector products, differentiation. Some classes omit vector products and consider them later.
3. Newton's laws, absolute and relative velocity and acceleration, Galilean invariance. Conservation of momentum is derived both from Newton's third law and from Galilean invariance and conservation of energy and mass.
4. Problems in nonrelativistic dynamics, the electron in static electric and magnetic fields and in alternating fields.
5. Conservation of energy—work, kinetic energy, power and potential energy.
6. Conservation of linear and angular momentum.
7. Harmonic oscillator.
8. Dynamics of rigid body. This chapter will be drastically revised since the general equations of rigid-body motion are too difficult at this point.
9. Inverse-square-law forces—forces and potential energies are discussed, then orbits.
10. Measurements of the speed of light, Doppler effect, Michelson-Morley experiment.
11. Lorentz transformations.
12. Relativistic energy and momentum and their transformations.
13. Simple problems in relativistic dynamics.
14. Principle of equivalence. Not usually covered in the standard course.
15. Particles of modern physics. Not usually covered in the standard course.

Volume 2, Electricity and Magnetism

1. Electrostatics.
2. Potential—includes an extensive mathematical section. Although chapter discusses the curl, many instructors postpone discussion until much later.
3. Electric fields around conductors, capacitors and electrostatic energy.
4. Direct currents.

5 & 6. Electric and magnetic fields of moving charges as manifestations of relativity and the invariance of electric charge.

7. Electromagnetic induction.
8. Alternating-current circuits.

9 & 10. Electric fields in matter and magnetic fields in matter. Microscopic point of view; treatment is concise and very illuminating.

Volume 3, Waves

1. Modes.
2. Waves.
3. Emission and absorption of waves.
4. Polarization.
5. Interference and diffraction, geometric optics.

Volume 4, Quantum Physics

1. Introduction — emphasizes that quantum physics is relevant for all of physics, not just for microscopic phenomena.
2. Magnitudes of physical quantities, "natural" combinations of physical constants, how to make estimates on simple models.
3. Energy levels. Simple examples given. What conclusions can be drawn from observation that level systems occur in nature? Connection between level width and lifetime.
4. Wave and particle properties of photons —important experimental facts and how to think quantum mechanically about them.
5. Wave nature of material particles. Chapters 4 and 5 emphasize the implications of experimental fact that all particles found in nature have wave properties and why the wave nature of particles does not contradict the results of macroscopic physics.
6. Some general rules of quantum-mechanical thinking.

7 & 8. Introduction to Schrödinger theory—some of the problems such as barrier penetration and the particle in the box that beginning students seem perfectly capable of understanding.

9. Qualitative discussion of how to describe interactions between elementary particles.

Volume 5, Statistical Physics

1 & 2. Introduction. Qualitative discussion of concepts of equilibrium and irreversibility. Elementary notions of probability theory.

3. Description of a system of many particles in statistical terms.
4. Thermal interaction between two systems, fundamental concepts of temperature, heat, absolute temperature, entropy and the Boltzmann factor.
5. Microscopic theory and macroscopic measurements—stresses the experimental macroscopic content of fundamental concepts discussed in previous chapter. The understanding of these concepts, hopefully achieved at the end of this chapter, fulfills the main purpose of the volume.

6, 7 & 8. These three chapters are independent of each other and elaborate previously developed theory. The instructor may use these chapters to suit his available time and the interest of his students. Chapter 6 —statistical theory in terms of classical mechanics, Maxwell velocity distribution and the equipartition theorem. Chapter 7, which is likely to be of greatest importance to chemistry or biology students, exploits the macroscopic content of the theory by summarizing explicitly some of the most fundamental results of thermodynamics. Chapter 8—transport phenomena in dilute gases by the simplest mean-free-path arguments.

has been the Department of Physics, University of California at Berkeley.

Because the authors intended to write something different, which presented the subject of introductory physics in a new manner, it was early apparent that student reaction and feedback would be desirable before a volume was published. Therefore extensive testing of all of the volumes has been accomplished, mainly at Berkeley, but also in other schools. The first version of volume 1, *Mechanics*, written by Ruderman, was taught by Knight in an experimental class in Berkeley in spring 1963. In each semester from 1963 through the spring of 1966, one section of the Berkeley three-semester course for engineers, chemists and physicists used these texts; at the same time another section used a conventional introductory text. The former, called Physics 4A*, 4B*, 4C*, unfortunately did get the reputation among students of an honors course, but it has been popular, retaining, for example, 25% of the total enrollment of both sections by the end of the third semester after starting with 40%. The Berkeley Laboratory, developed by Portis, was introduced in February 1964 for the whole course, regardless of the lecture section.

Using comments of faculty and students, Kittel and Knight revised volume 1, and it appeared in January 1965. Volume 2, "Electricity and Magnetism" by Purcell, was published in fall 1965. Volume 3, "Waves and Oscillations" by Crawford, appeared in a preliminary edition in October 1966. The final hardbound edition will probably be published late in 1967, as "Waves." Volume 4, "Quantum Physics" by Wichmann, will appear in preliminary form in spring 1967; and volume 5, "Statistical Physics" by Reif, will appear in final form this month. During the experimental periods, instructors both in Berkeley and elsewhere were able to get offset notes from the Berkeley office, but now that the volumes are published, such notes are no longer available. The Laboratory Manuals A, B and C-D have also been published. The publisher for all is McGraw-Hill.

. . . an appreciation of invariance and a respect for symmetry arguments . . .

General characteristics

Although some may feel that the course is an attempt to move material from the junior-senior courses to the freshman-sophmore course, the purpose is to introduce the important concepts and principles so that the student can use them in his subsequent learning. Correspondingly, junior and senior courses may well need some revising.

The reaction of students has been good. Highly motivated students are never a problem, but it is apparent that many of them are very enthusiastic about the material in the course and that they retain this enthusiasm in the succeeding years. Poorer students have found the course too hard in its three-semester version, and certainly a two-year sequence is much to be preferred. When given with care without attempting to rush, the course seems to accomplish what the authors intended.

The volumes were written for a student with good preparation in high-school physics. Students with no high-school course or a weak one should certainly study some book such as the PSSC one before beginning volume 1. It is also assumed that the student is familiar with introductory calculus and will be taking calculus concurrently. As is perhaps natural, the first attempts included more topics and some topics more difficult than could be handled by the average introductory student. Because the books can be used in various types of courses, for example, two-year introductory courses, three-semester courses, sophomore courses after a one-year noncalculus course and even in junior courses, no serious attempt has yet been made to remove these advanced topics. Instructors who consider using the texts should bear this point carefully in mind: An entire volume is *not* meant to be covered in any single introductory course. A list of the more important sections is given in the introduction, but much of the choice has been left to the instructor. The problems are stimulating and challenging but hard, and instructors may find it necessary to supplement with problems suited to their own students.

One of the unusual features of the course is the early coverage of special relativity, given at the end of volume 1. The ideas and knowledge of special relativity are used in volume 2 when the magnetic field is introduced. Students do find special relativity particularly interesting, and so, whether it is used in electricity and magnetism or not, the inclusion at this early stage seems a good idea. A second feature is that quantum physics is given before statistical physics (which covers the type of material called "Heat and Kinetic Theory" in the usual texts). The ideas of quantum states, discrete energies, etc., are then used in the treatment of statistical physics, and it, as a consequence, has a much more modern flavor.

The Berkeley Physics Laboratory [1,2] is not closely tied to the texts; in fact over the last four years it has been used by many students who did not use the Berkeley Physics texts in their lectures. This lack of correlation is not desirable, and the introduction of subjects in the laboratory that have not been mentioned in the lectures has caused trouble. Now that the University of California has moved to the quarter system, the introductory course at Berkeley has been converted from three semesters to five quarters. The first quarter (taken by students in their second quarter at the university) will be purely a lecture course; laboratory will start in the second quarter and continue through the fifth. This delay should materially aid those with weak backgrounds since the electron, the laboratory test particle, is the most often used example in volume 1. After mechanics in the first quarter, special relativity will start the second quarter. Electricity and magnetism, except for electric and magnetic fields in matter, waves and optics, will be covered in the rest

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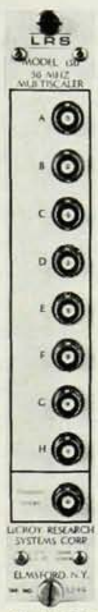

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of the second and in the third quarters, quantum physics in the fourth, statistical physics and electric and magnetic fields in matter (such as in Purcell, chapters 9 and 10) in the fifth.

The question of units is always an awkward one for elementary texts. Since the intent of the Berkeley Physics Course was to introduce the student to physics as practiced by modern physicists, the authors decided to use those units most commonly employed in the contemporary physics literature. Thus cgs units are used throughout as the basis for all discussion of theory, whereas practical electrical units are introduced for electrical circuits or electronic apparatus in the laboratory. As the authors of the first volume remark, "Every scientist and engineer who wishes to have easy access to the literature of physics will need to be familiar with all three systems (cgs, mks and practical)."

Course content

Brief comments about each volume follow; an attempt is made to give the particular flavor of each. The box on page 51 contains the approximate contents of each book.

Volume 1 treats many of the usual topics in elementary mechanics, with special emphasis on vector analysis, electron dynamics, frames of reference, symmetry, invariance and conservation laws from a more general point of view. Special relativity is covered in more than usual detail for this level. Advanced topics in certain chapters are of interest to the brighter students.

A statement from the preface to volume 2 expresses well the philosophy and the differences from the conventional text. "The sequence of topics, in rough outline, is not unusual: electrostatics; steady currents; magnetic field; electromagnetic induction; electric and magnetic polarization in matter. However, our approach is different from the traditional one. The difference is most conspicuous in chapters 5 and 6 where, building on the work of volume 1, we treat the electric and magnetic fields of moving charges as manifestations of relativity and the invariance of electric charge. This approach focuses attention on some fundamental questions, such as: charge conservation, charge invariance, the meaning of field. The only formal apparatus of special relativity that is really necessary is the Lorentz transformation of coördinates and the velocity-addition formula. It is essential, though, that the student bring to this part of the course some of the ideas and attitudes volume 1 sought to develop—among them a readiness to look at things from different frames of reference, an appreciation of invariance and a respect for symmetry arguments. We make much use also, in volume 2, of arguments based on superposition." At the end of the book there is a series of further problems and questions. The back cover includes tables and conversion factors for the cgs and the practical system of units.

Volume 3, "Waves," has gone through a number of rather substantial changes. These have been the result of teaching experience. The preliminary edition will probably also undergo some substantial changes in its final form. The most consistent example used after the first two chapters is electromagnetic waves; the last two chapters treat the usual subject of "optics." Geometric optics is covered less extensively than in the conventional text. The book attempts to give the student a real feeling for waves by numerous examples, by the suggestion of a large number of home experiments, and by inclusion of an optics kit including polarizers, quarter- and half-wave plates, a circular polarizer and filters. Numerous suggestions for ingenious experiments with sound are also included. The problems are unusual in the number that are related to "home experiments." Finally there is a set of advanced topics at the end that make the book usable for a more advanced class. Some of the topics not emphasized in usual introductory books are: superposition, characteristic impedance, dispersion, bandwidth and coherence time, interference and coherence.

Volume 4, "Quantum Physics," aims to introduce beginning students to quantum-mechanical thinking, to acquaint them with some of the characteristic phenomena and the sizes of quantities in microphysics. After a thorough discussion of energy levels, lifetimes and the wave-particle problems, Wichmann gives an introduction to the general rules of quantum-mechanical thinking and to Schrödinger at an elementary level.

Volume 5, "Statistical Physics," builds on the most basic notions of atomic physics to develop a coherent conceptual framework capable of describing and predicting the properties of macroscopic systems consisting of many particles. The book attempts to present the fundamental ideas of statistical mechanics, thermodynamics and heat from a simple, unified and general point of view that stresses physical insight based on the microscopic significance of the basic concepts. (This volume owes a debt to Reif's more advanced book, "Fundamentals of Statistical and Thermal Physics," published by McGraw-Hill in 1965.)

Berkeley Laboratory

There are three parts to the published Berkeley Physics Laboratory, A, B and C-D. Part A attempts a synthesis between laboratory practice in electronics and analytical mechanics. The first group of four experiments are concerned with electron dynamics, using a cathode-ray tube. The second four experiments use a cathode-ray-tube device, the oscilloscope, to study the circuit analog of transient and periodic particle phenomena. The final four experiments of Part A examine a range of nonlinear phenomena including negative resistance with the introduction of phase plane analysis.

Part B begins with an examination of the transistor and its use in both negative and positive feedback circuits. The next four experiments examine signal propagation in discrete and continuous media. The final four experiments are concerned with microwave generation and propagation, polarization and interference.

Part C is concerned with statistical phenomena. It begins with electron statistics, using first a beta-ray source and then a vacuum diode as a dense source of electrons. The next group of experiments introduce the photon by means of the photoelectric effect, going on to the photomultiplier, suggesting the presence of discrete processes through an examination of the fluctuations in anode current. Polarization and interference phenomena, studied with the photomultiplier, complete this part of the laboratory.

Part D is a project-type laboratory in atomic physics. Particular attention is given to electron diffraction, optical and microwave spectroscopy, and quantum optical and electrical phenomena. It is expected that the Part D laboratory can be kept quite flexible and open and will serve as a bridge to more advanced undergraduate and graduate laboratories.

° ° °

I am greatly indebted to the other members of the committee for their assistance. □

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The New MIT Course

by Robert I. Hulsizer

DESCRIBING THE NEW introductory course at Massachusetts Institute of Technology is like trying to describe an evolving nation. It exists and therefore can be characterized at its present state. Yet one's view of the course is a mixture of past tradition, past and present hopes and partial realization of these hopes. Furthermore, any introductory course perforce selects its topics, viewpoints and themes from a set far too rich to be encompassed in any one course. The course described therefore represents a compromise of many choices and many points of view. It also represents the present state of experimentation, from which any particular lecturer will depart and from which the future structure will certainly depart.

Who takes it?

The present "introductory" course, which has just been adopted, runs for five semesters. A large fraction of students who need fairly advanced work in physics will take the whole five semesters. The course includes work in special relativity, quantum physics and topics in atomic, molecular, nuclear and solid-state physics. Physics majors will continue with a three-semester sequence in theoretical physics, two elective courses in specialized topics, a junior laboratory course and a senior thesis.

Students in fields closely allied to physics will probably stay with the introductory course for the whole five semesters. Students in less closely related fields will take the first three semesters. The department is still wrestling with the problem of what to offer students who elect to take only two semesters of physics.

Production of the new course

Text material for the first, second and fourth semesters of the new introductory course has been written at the Science Teaching Center at MIT with financial support from the National Science Foundation. Although many people at MIT and elsewhere have participated in the planning and preparation of the material, the final writing for the first two semesters has been done by Anthony P. French and that for the fourth by Arthur K. Kerman, Leo Sartori and Edwin F. Taylor. It will be published by the W. W. Norton Co. of New York. The text most recently used for the third semester treatment of electricity and magnetism has been Edward M. Purcell's volume[1] in the Berkeley Physics Course. The text most recently used for the fifth semester was Robert M. Eisberg's.[2]

The text material actually used in the courses is left, of course, to the discretion of the lecturer, but during the experimental period of the last three years, all the new text material has been used either for the whole class of 900 students or for smaller trial groups.

Describing the new introductory course at MIT is like trying to describe an evolving nation.

Course content

Throughout the five semesters the course is conducted with three lectures and two one-hour recitation sessions. In the first semester students are introduced to the particulate nature of matter along with some discussion of quantum properties of light and wave properties of particles. Then Newtonian mechanics of one- and two-particle systems is developed and described for electrical, magnetic, gravitational, elastic and contact forces.

The second semester is used to develop the theory of special relativity in the context of introductory electricity and magnetism.

Electromagnetic waves are presented in the third semester in conjunction with a discussion of other forms of wave motion (mechanical vibrations, sound). The ideas are then extended to a discussion of the optical properties of material media.

In the fourth semester a review of electromagnetic wave propagation, the Huyghens principle and wave optics precedes introduction to the basic