

grounds that this is a reasonable maximum that may be expected from presently understood rocket systems, he stops there. A further reason for stopping at this point is the fact that a speed of five percent of that of light is sufficient to enable a star ship to reach the nearest stars in a time of the order of a century. Strong considers this to be reasonable for such a journey, but also feels that it is the maximum time that could be considered reasonable.

The only place where one might read of such journeys in ships outfitted to maintain a closed ecological system for a century or more is, so far as I know, in various science fiction stories, whose authors generally come to the conclusion that on a trip of over a century or so, the voyagers would lose sight of their purpose and degenerate into savagery. They also treat (in fiction) the possibility that voyagers on a journey that lasts too long would be met on arrival by others who started later, with ships developed in the meantime back on earth, capable of much higher speeds. These possibilities are said to limit a reasonable journey to a century or so. As Strong puts it, "Space writers take a gloomy view of the hazards within sealed star ships . . . (for very long trips)." He uses this as an argument that a century is a maximum for such a trip. I find this argument weak, since space writers are compelled to invent hazards. Else where is the story worth writing about?

Strong's ship then, is somewhat arbitrarily taken to be about three-quarters of a mile in length, with a mass of about 100 megatons of which 95% is fuel, and is to support 100 to 150 people for 100 years. Accessible space is thus a sphere of radius 20 light years. (This ship may be compared to one written about by Heinlein, some 20 or 30 years ago, which was five miles long and supported several hundred people for a century.)

Required power, thrust, etc. are analyzed and described. Strong then discusses the 55 stars to be found within 16 light years of the solar system, of which three are known to have, and four more suspected of having, unseen companions of planetary size.

Following this is a discussion of the possibilities of finding life on some of these stars, and a short discussion on the basics of attempting communication with alien life forms, both before and after a possible face-to-whatever meeting. Several books have appeared recently on the subject, some of which have gone into more detail than the present book. The discussion here is speculative, as it must be, but not unreasonable.

He concludes with speculation on the subject of why star travellers from elsewhere have not visited us recently.

I noted only two misstatements in reading the book. First, Pauli, and not Dirac, discovered/invented the neutrino. Second, although Strong was correct when he wrote that "not a single atom of antihydrogen has been created in the laboratory," he is no longer correct. Antideuterium was reported to have been created at Brookhaven [Phys. Rev. Letters, 14, 1003 (1965)].

This book is an attempt to interest someone in the author's personal dream, that of stellar flight. If that "someone" should read it, Strong may succeed.

Results of instruction

SCIENCE TEACHING AND TESTING. By Leo Nedelsky. 368 pp. Harcourt, Brace and World, New York, 1965. \$6.95.

by Robert L. Weber

Teachers and students of science are much indebted to Professor Nedelsky for his continuing crusade to persuade teachers to improve their own teaching and for his offering of tools effective in this task. He urges teachers to be more analytic about the goals of instruction and of conditions conducive to learning. A course may be analyzed in either of two ways: by observing teaching materials and processes and gauging them against an accepted standard or by measuring the stu-

* * *

The reviewer, who is a professor of physics at The Pennsylvania State University, is the author of a number of textbooks and has long been interested in methods of teaching science.

dents' achievement. The observation technique requires familiarity with theories of learning with respect to which "most college science teachers are ignorant, suspicious, belligerently defensive, and, when opportune, jubilantly offensive." For most of his exposition in this book, Nedelsky turns to the other technique, the measurement of how much students learn. "This technique, in principle . . . , is congenial to scientists, for it is largely empirical and can be readily mastered."

Essential to the measuring and judging of the results of instruction is a statement of desired results or objectives. Mere description of course content is inadequate. One needs to know what students are expected to be able to do with the content. In chapter 2, Nedelsky gives a list of possible objectives of a course in physical science. Three general types of competency (1) knowledge, (2) understanding (both analytical and intuitive) and (3) the ability to learn are subdivided using a simple decimal classification scheme employed throughout the book in relating sample questions, published tests, and bibliographies to specific course objectives. "This book, however, tries to avoid all—and especially semantic—coercion; its rhetoric is intended to make things clear and leave decisions to the reader."

Three chapters on teaching methods discuss (1) reading and analytical understanding, (2) disciplined and imaginative thinking and intuitive understanding, (3) the laboratory. There follow extensive chapters on tests: theory of testing, measuring understanding of science, forms of tests, preparing tests, uses of tests in diagnosis and research and annotated bibliographies. Part II, comprising 35% of the book, presents with comments sample tests for knowledge, tests for understanding, tests for ability to learn and laboratory performance tests.

The annotations in the bibliographies are not only helpful literature guides but often interesting comments. Under a listing of Jacques Barzun's *The House of Intellect* appears "Professor Barzun writes: 'Taking an objective test is simply pointing. It calls for the least effort of mind above that of keeping awake: recognition.'" Ne-

Attention on individuals

THE QUESTIONERS: Physicists and the Quantum Theory. By Barabara Lovett Cline. 274 pp. Thomas Y. Crowell, New York, 1965. \$5.00.

by Eugen Merzbacher

The history of physics from 1900 until the thirties is a subject of such obvious interest that it is surprising that so little has been written about it. Mrs. Cline has now demonstrated that the task is not impossible. In *The Questioners* she has not intended to produce a comprehensive history of quantum physics and relativity; rather, with remarkable skill, she has written a compact and coherent story of the development of physics in this century, starting with radioactivity, black-body radiation, and special relativity, and ending with quantum mechanics and general relativity.

Apparently, Mrs. Cline is not a physicist, and a few mistakes, such as the incorrect spelling of Sommerfeld's name, confirm this conclusion. But one suspects that she must have observed the species at close hand for a long time. She writes "as if from within," much as Laura Fermi and Jeremy Bernstein have done with more limited objectives, and she exhibits a clear understanding of what is important and what is not.

Written for the educated layman, this is a fairly sophisticated attempt to describe the new concepts of quantum physics and relativity, with almost no equations, by focusing attention on the individuals who did the work. Yet, historical anecdotes are included only to support the basic story which deals with physics and ideas—explained by Mrs. Cline with humor, intelligence, and fine prose.

The use of the controversy between Einstein and Niels Bohr over the interpretation of quantum mechanics as a dramatic climax is a somewhat unconvincing and artificial literary device. Nevertheless, we know that Niels Bohr attached great importance to this debate, and future generations will find it instructive to know about it, even when the issues are no longer alive. Mrs. Cline places the epistemological problems raised by quantum

mechanics before her reader in the traditional form of a dialogue. Anyone who feels that it might be possible to write an even more lucid exposition of this difficult subject will find that this book has set a high standard against which other efforts will be measured. There are only a few factual errors in the book.

This reviewer has subjected *The Questioners* to an acid test of popular science writing by reading it aloud to his wife. With her enthusiastic approval, the book is recommended as a suitable gift to those whose well-being depends on an appreciation of what makes a physicist tick.

* * *

Eugen Merzbacher is a theoretical physicist who has written on quantum mechanics. He is acting chairman of the physics department at the University of North Carolina.

Dynamic programming

QUASILINEARIZATION AND NONLINEAR BOUNDARY-VALUE PROBLEMS. By Richard E. Bellman and Robert E. Kalaba. 206 pp. American Elsevier, New York, 1965. \$8.50.

by T. Teichmann

The advent of large high-speed digital computers has not only enabled the solution of large linear systems but has also begun to make possible quantitative, if not qualitative solutions to certain nonlinear problems. Because of the added complexity introduced by the nonlinearities, even more care must be taken than in the linear case to ensure rapid convergence. The authors, who have both spent many years at the RAND Corporation working on a variety of problems largely clustering round the notion of "dynamic programming," have now essayed to apply similar methods to nonlinear boundary-value problems.

The main pillars of the method are first the application of Newton's method to functional operators (thus replacing simple iteration by a scheme involving first-order derivatives lin-

* * *

A theoretician, Dr. Teichmann is associated with the General Atomics Division of the General Dynamics Corporation in San Diego.



PHOTO BY S. A. GOUDSMIT

ENRICO FERMI AND NIELS BOHR walking on the Appian Way in 1931. From: *The Questioners*.

del'sky counters, "If Professor Barzun used a typewriter in writing the sentences above, he also had only to recognize the right key and point or push. But surely he thought before or during typing: pointing may require thought. He is right, however, in saying that objective tests make it easier for the students to get by without learning to write."

While this book deals in general with science teaching, physics is emphasized. Nedelsky shows that his recommendations differ only in priorities from those of the Carleton College conference on physics teaching, the Commission on College Physics and the University of Connecticut Conference. Nedelsky's book, superbly organized and written, is both a guide and a persuasive invitation to implement some of the good ideas in physics teaching. The publisher has contributed attractive styling and typography to this very useful book.