

Biography of a Physicist

Joseph Henry, His Life and Work. By Thomas Coulson. 352 pp. Princeton University Press, Princeton, New Jersey, 1950. \$5.00.

Because of the demands in time and effort made by the complexities of modern physics, too few students of that subject pay adequate attention to its history or to the biographies of the outstanding contributors to its advance. Beyond the fact that Coulomb's name is associated with a law appearing in the text, or Hamilton's name with a fundamental principle of dynamics, the elementary student has little if any acquaintance with the lives of these individuals. If his studies fail to take him as far as the formulation of the electromagnetic equations, it is unlikely that he realizes that Maxwell is the originator of radio, radar, and all the marvelous applications of electromagnetic radiation which enrich our present science and technology. Still less likely is he to associate with the name of Joseph Henry the pioneering discoveries in electromagnetism which constitute one of the brightest jewels in the diadem of American science. Therefore this excellent full-length biography of Henry by Major Thomas Coulson, director of museum research at the Franklin Institute, is a very welcome addition to the all too meagre collection of biographies of famous physicists. The wealth of well documented material which the author has assembled is all the more remarkable in view of the fact that Henry's correspondence, notes and manuscripts were burned in the fire which destroyed the upper story of the main portion of the Smithsonian building in 1865.

Henry's two grandfathers arrived in New York harbor from Scotland on the same ship in 1775. Soon after arriving his paternal grandfather changed his name from the distinctive Scotch "Hendrie" to the more easily grasped "Henry". Henry's father appears to have been little more than a day laborer but his mother was a woman of strong character. Although the baptismal register of the First Presbyterian Church in Albany gives the date of Henry's birth as December 9, 1797, it seems almost certain that he was born two years later. His first ambition as a boy was to go on the stage, and for a time he engaged extensively in amateur theatricals. His interest in science was awakened by a chance perusal of Gregory's *Lectures on Experimental Philosophy, Astronomy, and Chemistry* at the age of sixteen. This led him to prepare himself for the medical profession, but soon his studies at the Albany Academy diverted him to the fundamental sciences of chemistry and physics, with particular attention to the phenomena of electricity.

Turning aside from other more lucrative offers, Henry accepted a position on the staff of the Albany Academy, and it was here, beginning in the summer of 1827, that he carried out the researches in electricity which were his greatest claim to fame. His first interest was in electromagnets, where, in his construction of "intensity" and "quantity" magnets, he showed experimentally the importance of properly matching the resistances of the different parts of an electric circuit. These experiments led to his greatest dis-

covery, electromagnetic induction, both in the form of mutual and self-induction. It was a discovery for which he was not to get the credit which he deserved, however, for Faraday anticipated him in publication, at least so far as the phenomenon of mutual induction is concerned. This may have been due to a certain indecisiveness in Henry's character which led him in a number of instances to put off too long the formulation of a conclusion.

At the age of 36 Henry was appointed to the chair of natural philosophy at the College of New Jersey (Princeton) where he continued his researches in electromagnetism, developing the electromagnetic relay, discovering the essential characteristics of the transformer, and showing the oscillatory nature of the discharge of a Leyden jar. Undoubtedly other discoveries would have followed had he not been persuaded at the age of 49 to leave Princeton to become the first Secretary of the Smithsonian Institution. Here he showed equal ability in work of a very different character, which brought him into contact with many of the foremost men of the time, including President Lincoln. Although he was not one of the promoters of the National Academy of Sciences, he was one of the original fifty members and gave important scientific advice to the armed services during the Civil War. High as was the esteem in which he was held by his countrymen, his later years were saddened by Morse's failure to give him the credit he deserved for his discoveries underlying the invention of the telegraph. When he died in 1878 Congress paid him the unusual honor of a memorial service in the House of Representatives.

Major Coulson has written a biography which is as entertaining as it is informative. He has resisted the tendency to show a bias in favor of Henry's claims to priority and has appraised with even-handed fairness such controversies as arose. The book should be on the shelves of the library of every physics laboratory, and should be read by everyone interested in the place of the United States in the progress of scientific research.

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Some Unexpected Paradoxes

Hydrodynamics. By Garrett Birkhoff. 186 pp. Princeton University Press, Princeton, N. J., 1950. \$3.50.

Theoretical physics has a habit of losing interest in a subject, once it has been "understood in principle". The working out of practical details is left to people whom the pure of heart refer to as "engineers", "applied physicists", and the like. This is less a matter of snobbishness than a very necessary division of labor. People who work on important problems in stellar dynamics or the propagation of microwaves (understood in principle by Newton and Maxwell, respectively) are called astronomers and radio engineers, while physicists are those who are busy hauling in new problems and opening up new fields. In some circles, frequented by the very purest of hearts, one is not considered a theoretical physicist today unless he is working on meson field theory or quantum electrodynamics.

This being the case, one might suppose that a book entitled *Hydrodynamics*, written by a talented mathematician, would be simply the sort of thing that every hydraulic engineer or airplane manufacturer should have on his shelf, because it would be essentially a compendium of computational recipes for the solution of practical problems; for surely hydrodynamics was understood in principle by men like Stokes in the last century, although it must be ad-

mitted that subjects like boundary layers, turbulence, and compressible flow still require a great deal of working out.

That something must be wrong with this picture is shown by a glance at the book. It is much too thin to be the looked-for compendium, and the subtitle is *A Study in Logic, Fact, and Similitude*. Furthermore, on opening the cover, we find that the first chapter is devoted to the discussion of about two dozen hydrodynamical paradoxes! "Aha", we say, "a semi-popular account of the subject" (although we might be slightly uneasy about this conclusion because of later section headings such as "General Local Existence Theorems" and "Curvature of One-Parameter Subgroups"), and we settle down to read, because we all love paradoxes, especially when we know that they will be painlessly explained away on the next page. Some of the paradoxes are indeed of the expected kind, like the familiar Earnshaw paradox: "Plane sound waves of finite amplitude and stationary form are mathematically impossible in a gas which vibrates adiabatically". We even know how to resolve this one, having had occasion to explain to students that soundwaves must either be dissipated or eventually break down into shocks: the usual equations of acoustics are known to be merely approximations to the nonlinear equations of hydrodynamics. Later on, our smugness is distinctly upset by the statement that as yet no satisfactory explanation has been advanced for Von Neumann's triple-shock paradox: regular reflection (as opposed to Mach reflection) of weak shocks occurs for angles of incidence somewhat greater than those permitted by theory, and "the predicted limits for triple shocks seem to differ grossly from those observed". This might conceivably be due to inadequate analysis of the problem (which is a difficult one) or to unsuspected imperfections of the experimental arrangements; but still later we read, "The phenomenon of turbulence raises interesting questions regarding the differentiability of the functions (describing the velocity field). . . . One recent guess, based on the statistical theory of turbulence, is that these functions have fifth but not sixth derivatives", whereas another guess is that one "must go back to discontinuous molecular considerations in dealing with turbulence". This is disturbing because we had supposed that the problem of turbulence was the purely mathematical problem of inventing statistical methods powerful enough to deal with families of solutions of the Navier-Stokes equation in much the same way that classical statistical mechanics deals with solutions of the equations of motions of a system with finitely many degrees of freedom (but with differences because of dissipation of energy).

In the second chapter, on free boundary theory (a field to which Birkhoff has contributed extensively), there are further paradoxes, mostly connected with the fact that the basic equations used are inadequate to determine the flow uniquely under what one feels intuitively are adequate boundary and initial conditions. Apparently what is needed is some *new physical principle* to fix the points of separation of a fluid from a solid wall past which it is flowing, under conditions leading to cavitation.

We seem at last forced to admit that hydrodynamics is not even understood in principle. Although these things are presumably well known to experts in the field, it is thought-provoking to have them presented in the clear, concise form in which they appear in this book. To be sure, it is doubtful that any basically new concepts are needed; certainly all properties of a fluid must be eventually traceable to known macroscopic aspects of the behavior of its atoms and molecules, provided we can only work out the details.

But perhaps it would be best not to regard any subjects as understood in principle until we are reasonably sure that we can really write down equations that will give unique answers, in agreement with experiment, by known mathematical methods!

The book is by no means devoted exclusively to paradoxes and limitations of our knowledge. The subject of the third chapter, modeling and dimensional analysis, has obvious important applications of interest to the aforementioned hydraulic engineer and airplane designer. There are many kinds of modeling in hydrodynamics, depending on which of the basic phenomena, like gravity, surface tension, compressibility, viscosity, or cavitation, can be neglected and which cannot. The problem is the prediction of the behavior of a full-scale system from that of a small model under suitably altered conditions of fluid velocity, density, pressure, etc., and the prediction is based on how the basic equations transform under certain groups of transformations of variables. This is straightforward sometimes, but not always. For example, cavitation effects in liquids appear to be influenced by such things as vapor pressure (and therefore by temperature) and dissolved gases, and these must be taken into account in translating model results to full scale. The mathematical and physical bases of dimensional analysis, and of what Birkhoff calls "inspectional analysis", both of which are of value in modeling, are discussed in detail. This is very welcome, because both the limitations of these methods, on the one hand, and their full power, on the other, are likely to be unsuspected.

Several parts of the book, especially the part on dimensional analysis, make difficult reading (surprisingly enough, there appears to be some lack of mathematical clarity; for example, in failing to make clear, at least to the casual reader, what the variables are when partial differentiation is involved, and failure to define terms and symbols!) but this is of course largely due to the inherent complexity of the ideas that are essential to a real understanding of the subject.

The theory of modeling leads naturally into the next chapter, on group theory and fluid mechanics. Particular solutions of the partial differential equations of a problem can often be obtained by searching for similarity solutions. These are flows whose patterns look exactly alike at two different instants, except for possible changes of scale of distance and velocity and for possible Euclidean transformations. This search is often very fruitful in hydrodynamic problems, as are also a number of other closely related methods, such as the method of separation of variables, the hodograph method, and numerous "tricks" that people seem to stumble onto. These methods can be largely understood and systematized by consideration of groups of transformations of the independent and dependent variables under which the original system of equations is invariant. For example, given such a group, one writes down the most general possible flow which is also invariant under this group (a "self-symmetric" flow in Birkhoff's terminology) and substitutes it into the original equations; he finds that such a flow indeed satisfies the equations, provided the functions defining it satisfy certain other equations which have fewer independent variables than the original equations and are therefore more easily solved. Furthermore, one can find other, more general solutions by postulating only part of the properties possessed by the self-symmetric solution. Generally, the a priori postulation of special properties leads to interesting particular solutions if, and only if, the properties postulated have some intimate connection with

the group theoretical properties of the system under consideration. Although workers have usually proceeded quite successfully by intuitive methods, it adds much to one's understanding to see these connections. As Birkhoff is careful to point out, very little is known theoretically, except in special cases, about the stability of solutions obtained in this way, and for this reason, it is not always true that the solution observed in experiment has the same symmetry properties as the problem itself.

The last chapter, on virtual mass and groups, deals with a subject that has some practical application but is of much more interest because of the conceptual relations involved. These relations are of such generality that they are likely to have application to wider fields than the subject dealt with, and the author quite properly stresses their generality and abstractness by appeal to the Lie theory of continuous groups, the Lagrangean formulation of the equations of motion involved, etc. If a rigid body is moved in accelerated motion, of translation or rotation or both, through an ideal, incompressible, nonviscous fluid, forces must be exerted on the body, in addition to those necessary to accelerate the body itself, to set the fluid in motion. The simplest case is the familiar one of the induced mass of a sphere moving through water, but, in general, translational acceleration may result in sideways forces or a torque, and conversely. Paradoxically enough, a ship's propeller is *not* a case in point, because if the fluid really moved as an ideal one (irrotationally), rotation of the propeller would not produce either thrust or torque! The induced mass and other coefficients in the expression of the total kinetic energy as a quadratic form in the generalized velocities, constitute, in general, a tensor or matrix of thirty-six elements, and the general properties of the resulting equations of motion are studied in detail. In spite of the abstractness (at one point the author finds himself discussing the motion of fluids in non-Euclidean spaces!), there are applications to such problems as the initial upward acceleration of a gas filled balloon, the small-bubble method of photographing velocity fields in liquids, and wing-flutter.

In summary, this book, though it would not serve as a text or reference book in the ordinary sense, gives the study of hydrodynamics a stimulating and vital quality that the reviewer has not seen elsewhere, and it would seem likely that studies of this sort might have much more bearing on the ultimate progress of the science than the conventional treatise.

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Briefly Noted

Proceedings of the First National Pollution Symposium. 149 pp. Stanford Research Institute, 1950. \$2.50.

Proceedings of the Second Annual Northern California Research Conference. 66 pp. Stanford Research Institute, 1950. \$2.00.

The National Pollution Symposium, held in November, 1949 at Pasadena, California, was sponsored by Stanford Research Institute in cooperation with the California Institute of Technology, the University of California, and the University of Southern California. The second North California Research Conference was held in San Francisco January 1950 and was sponsored by SRI in cooperation with San Francisco Chamber of Commerce, the University of California, and Stanford University. A limited supply of both sets of proceedings is available upon request to the

Public Relations Office, Stanford Research Institute, Stanford, California.

American FIAT Review of German Science. 88 Volumes. 22,000 pp. Office of Technical Services, U. S. Department of Commerce, Washington, D. C., 1950.

A compendium of German achievements in physics, biology, chemistry, mathematics, medicine, and the earth sciences started at the war's end has now been completely translated into English for the American researcher. Supplementing the information contained in the FIAT volumes is a collection of some 50,000 "PB" reports in the German technological collection of the Office of Technical Services. A free catalog describing the titles covered is available from the Office of Technical Services and interested persons may place their names on the waiting list for loan copies of individual titles.

A Survey Report on Basic Problems of Underwater Acoustics Research. 137 pp. National Research Council, Washington 25, D. C. 1950.

The Panel on Underwater Acoustics of the NRC Committee on Undersea Warfare prepared this report surveying the present status of research and suggesting further work still required in the field. The six chapters of the report consider the generation and reception of underwater sound, including transducer types; standards and calibration methods for measurements; ambient noise, soniferous marine life, and noise from ships; transmission and scattering of underwater sound; fluctuations in underwater sound; and the recognition of underwater sounds. The report is available without charge from the NRC Publications Office.

Books Received

SURVEY OF MODERN ELECTRONICS. By Paul G. Andres. 522 pp. John Wiley & Sons, Inc., New York, 1950. \$5.75.

DIRICHLET'S PRINCIPLE, CONFORMAL MAPPING, AND MINIMAL SURFACES. Pure and Applied Mathematics Series, Vol. III. By R. Courant. 330 pp. Interscience Publishers, Inc., New York, 1950. \$4.50.

ELECTRICITY FOR STUDENTS OF SCIENCE AND ENGINEERING. By T. Townsend Smith. 410 pp. International Textbook Co., Scranton, Pa., 1949.

WAVE MOTION AND SOUND. By R. W. B. Stephens and A. E. Bate. 448 pp. Edward Arnold & Co., London, 1950. \$9.00.

TV INSTALLATION TECHNIQUES. By Samuel L. Marshall. 330 pp. John F. Rider, Inc., New York, 1950. \$3.60.

SECURITY, LOYALTY, AND SCIENCE. By Walter Gellhorn. 300 pp. Cornell University Press, Ithaca, N. Y., 1950. \$3.00.

RESPONSE OF PHYSICAL SYSTEMS. By John D. Trimmer. 268 pp. John Wiley & Sons, Inc., New York, 1950. \$5.00.

CHEMICAL THERMODYNAMICS. By Frederick D. Rossini. 514 pp. John Wiley & Sons, Inc., New York, 1950. \$6.00.

HEAT INSULATION. By Gordon B. Wilkes. 224 pp. John Wiley & Sons, Inc., New York, 1950. \$4.00.

Correction: The publishers of *PHYSICS*, by G. Shortley and D. Williams, Prentice-Hall, Inc., New York, 1950 (noted in the Books Received section of *Physics Today* for December, 1950), have informed us that they erroneously quoted the trade prices of \$6.00 and \$7.35 for volumes I and II respectively of this work. The cost for college people is \$4.50 and \$5.00 instead of the higher book store prices.