The increased application of atomic physics in other scientific fields calls for informative courses on the subject for non-physicists.

ATOMIC PHYSICS

By Wolfgang Finkelnburg

ATOMIC PHYSICS in its wider sense, including nuclear, molecular, and solid-state physics, as well as quantum mechanics, seems to be taught at most schools either as separate fields of knowledge, or under the unwritten but nevertheless unmistakable label "For Physicists Only". That means that it is taught with all the details and in particular with all the mathematics required for a thorough mastery of this difficult field. This custom was justified at a time when atomic physics was merely a small and restricted region of physics striving to establish its right of existence beside the older fields of mechanics, heat, acoustics, electricity, magnetism, and optics. This custom may have advantages for the graduate physicist who looks toward a career in atomic physics, though even here the predominance of mathematics makes many a student overlook the fact that the basic difficulties of a true understanding of atomic physics lie in its new concepts and ideas rather than in its mathematical formalism.

The question which we want to pose here is whether the label "For Physicists Only" and the methods of teaching resulting from this attitude are still justified. Such treatment of atomic physics necessarily excludes the vast majority of the nonphysicists, chemists, biologists, philosophers, and particularly engineers, from any systematic knowledge and understanding of atomic physics.

It is well known how fundamentally the position of atomic physics has changed during the past two decades. It is no longer an isolated field of knowledge supplementing the older subjects of physics, though it is still treated in that way in numerous college physics texts; rather it has become the very basis of all natural sciences and nearly all branches of engineering, and it has changed our ways of thinking about nature in a very fundamental way. Let us look at some examples before drawing conclusions from this new situation.

More than half of present-day astronomy, under the name of astrophysics, is actually applied atomic physics. Atomic and molecular spectra with all the details of their theory, including the concept of line broadening, serve to determine composition, temperatures, and pressures in the atmospheres of the sun and fixed stars. Stellar magnetic fields are measured by means of the Zeeman effect, and nuclear physics has provided the key for an understanding not only of energy production in the stars and in our sun, but indeed of all cosmology.

Chemistry received not only the explanation of the Periodic Table of the Elements from atomic physics, but also its very basis, in modern terms, by the quantum mechanical theory of chemical valence which accounts for the existence of some, and the nonexistence of other molecules. To an ever increasing extent, furthermore, atomic physics with all its branches helps the chemist in obtaining a deeper insight into all the interactions between atoms and molecules which form the coherent states of matter.

Electrical engineering, long accustomed to regard the electric current as its God-given basis, had to learn from atomic physics how this current comes about as a consequence of the drift of the conduction electrons through the metal-ion lattice; from atomic physics it received the explanation of the resistivity of metals and alloys and its dependence on temperature and lattice structure. The different aspects of magnetism, of such immense practical importance, were understood by going back to the elementary particles, their properties and interactions, just as was the amazing variety of gas discharge phenomena of which so much practical use is being made. New discoveries by the atomic physicist pose new problems for the engineer, be it superconductivity, ferroelectricity, antiferromagnetism, or the new field of solid-state electronics with its latest wonder-child, the transistor.

Metallurgists have to make constant use of solid-state atomic physics in interpreting the properties of alloys, or in their attempts at understanding and controlling the different modifications of solid matter in different temperature ranges, the meaning of elasticity and plasticity, or the processes going on in the atomic structure of a metal during cold-working and annealing.

The properties of all materials, investigated and improved by taking advantage of atomic experiments and theories, form the basis of every machine design by the mechanical engineer who, in thinking about nuclear power plants, must even understand and take into account the changes in the properties of his materials under strong neutron irradiation. Surface problems,

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lubrication theory, or the high-temperature plasmas in combustion engines, jets, or rockets seem to be minor problems compared with the more sensational ones associated with nuclear power, but they are important and require a surprising amount of knowledge from different fields of atomic physics for their best possible solution.

Let us mention only in passing that modern mineralogy is based on solid-state atomic physics and the atomic theory of interatomic forces, that geologists and archaeologists are determining the age of their objects of study by nuclear-physics methods, that biologists are looking towards atomic and molecular physics in their attempts to understand the basic processes of mutations, of cell multiplication, and of all the radiation effects which medicine is using to an ever increasing extent in research, diagnosis, and therapy.

In many a popular book or article the philosophical implications of quantum mechanics have been expounded, though sometimes with more emphasis than success in making them understandable. But there can be no doubt that atomic physics has led, with quantum mechanics, to a revision of our basic concepts of thinking and of the basic prerequisites of obtaining knowledge—a revision which is by no means complete, partly because few physicists have sufficient knowledge of philosophy and few philosophers a true understanding of quantum mechanics.

The extent to which atomic physics has contributed to an understanding of the natural and engineering sciences and of other fields of knowledge may be seen from this brief and necessarily incomplete review. Decisive progress in each of these fields of human endeavor is being achieved, and will be achieved to an even larger extent in the future, by a systematic "atomistic" approach in thinking, experimenting, and theorizing. No modern natural scientist or engineer, consequently, can be really up-to-date without an understanding of the basic facts and ideas of atomic physics.

What follows from this situation, in particular for the schools bearing the responsibility for training future scientists and engineers? In the first place it would seem that a true understanding of atomic physics cannot be reserved exclusively for physicists any more than an understanding of mathematics is reserved for pure mathematicians. But just as mathematics courses are being taught for physicists and engineers in a different way from those for pure mathematicians, atomic physics must be taught in a different way for the nonphysicists than for the graduate physicist who might be considering a career in atomic physics or theory.

This statement is not meant to imply any cheap popularization of which there is too much already. On the contrary! What is called for are informative courses in which atomic physics is presented in its entirety and in its beautiful harmony, in as concise and correct a manner as possible, but stripped of all the detail which is of interest mainly for the future active worker in the field. All possible emphasis, however, should be placed on the basic ideas which, contrary to wide-spread belief, *can* be explained without a prohibitive amount of mathematics. No doubt, this requires a much more thorough understanding of the subject on the part of the instructor than does a more formal mathematical course.

On the other hand, such an informative course, acquainting the student with the basic material, the new concepts, the theoretical ideas, and the close interrelations between the seemingly so divergent fields of atomic physics, should prove an excellent basis for more detailed and mathematical courses, even for the physics major. It would prepare the few top-level students of chemistry, biology, and engineering who want to proceed with a deeper study of atomic physics for the more advanced courses whose instructors will profit from the more uniform level of initial knowledge and from the elimination of all those who are looking for no more than a qualitative, but accurate general background and understanding. The informative course would furnish a clear and concise idea of the whole of atomic physics to those who need this information and understanding for their future careers as progressive scientists and engineers, but who lack the time or knowledge of higher mathematics for getting this information from conventional books or courses.

Wolfgang Finkelnburg, German-born physicist who for several years has been on the research staff of the Fort Belvoir laboratories, in Virginia, is the author of *Atomic Physics* (McGraw-Hill, 1950).