HISTORY OF PHYSICS

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Introduction

HISTORY CAN BE WRITTEN from quite divergent viewpoints but still with complete adherence to the truth. There is justification for every viewpoint from which the historian can extract something of historical interest. The history of a science can likewise be treated from a variety of viewpoints. The basis of the present text is the genesis and the changes experienced by certain ideas and information that are of importance to the physics of today. Just as any political history must close before it can include the political events of the present moment, the history of a science likewise cannot deal finally with those problems which cannot be considered as definitely solved.

The extreme past can contribute very little to this report, and its accomplishments in physics can be adequately summed up in a few sentences. The Sumerians, Babylonians, and Egyptians admittedly had considerable acquaintance with single physical topics which, of course, gave the impression of being accidental, unsystematic, and not really thought through. The Greco-Roman period gave rise, among the fields of knowledge that are dealt with in this book, only to statistics, which is a branch of mechanics. Certain statements of Plato (427-347 B.C.) that have come down to us, reveal a thorough contempt for all empirical research, joined to a vigorous disparagement of efforts to remove the exalted science of mathematics from the realm of pure thinking and to desecrate it by applications to matters of actual experience. It is fully in accord with such thinking that his pupil Aristotle (384-322 B.C.) saw fit to include, in his otherwise grandiose system of natural science, only a few concepts, taken rather noncritically from superficial observations, and their logical or oftentimes merely sophistical analysis. Thus even a genius like Archimedes (287-212 B.C.) remained without enduring influence. Nothing in either antiquity nor the medieval period points to any systematic scientific investigation.

The first signs of a new spirit of inquiry were given by the great voyages of discovery at the close of the fifteenth century, especially that of Christopher Columbus (1446?-1506), which culminated in his discovery of America in 1492. This brave adventurer not only knew that the earth is a sphere, a fact known even to Eratosthenes (276-195 B.C.), but he was the first to have so much faith in this idea that he made it the entire basis of his undertaking, a venture which many of his contemporaries considered foolhardy. But even in the sixteenth century which, through translations and commentaries, had successfully adopted the scientific notions of the ancients, the superior feat of Copernicus (1473-1543) received the attention of only a few, some agreeing with, others denying his heliocentric theory. It was not until the early years of the seventeenth century, when the circle of those interested in natural science became large enough, that any discussion of a continuously advancing research is really warranted. The interest in science was greatly vitalized by the then generally current effort to abandon speculative methods and tradition and to base science instead on observation, or even more, to institute carefully planned experiments. This completely new approach was regarded by many at the time as an abrupt break with the past, an idea that still persists. Was this really the case? If, in antique culture, the dominant principle was the subordination of the individual in the general scheme of things, as was proclaimed by the Greek dramatists and as was carried out by the mathematicians in their science, the new disposition toward the natural sciences was merely the logical extension of this philosophy to a field which the ancients had barely entered. Suddenly, about 1600, two new fundamental means of observation were available: the microscope and telescope. Their actual inventors are not known. Galileo Galilei, who, unlike Copernicus, did not write solely for the scholars ("mathematicians" as he called them) but for everyone, attracted numerous pupils and followers. It was not until this time that the Copernican system came to be generally known, and the smoldering controversy about accepting it was fanned into a fierce flame. It was at least in the background when Giordano Bruno was sent to the stake in 1600, because the doctrine of the infinite extension of space and the multiplicity of worlds, which was among his alleged heresies, was a pertinent extension of the Copernican system. However, neither this execution nor the ecclesiastical interdict, which the Inquisition laid on Galileo and the Copernicans as a class, proved to have any lasting effect. The ban was finally and completely lifted at the beginning of the nineteenth century.

The eighteenth and nineteenth centuries witnessed no further attempts by the ecclesiastical and governmental authorities to interfere with the scientists; the guillotining of Lavoisier in 1794 had no connection with his scientific beliefs. This attitude of noninterference was maintained until the Hitler regime came to power; the relativity theory, in particular, was proscribed by the Nazis but this ban was lifted eventually. In general, physics was permitted to develop peacefully according to its own laws.[1] As a result, the science grew into a movement not divorced from daily life, but instead, through its technical applications, exerted a direct influence on both individuals and nations. In fact, its concepts, in a quiet but nonetheless effective manner, had such potent repercussions that even political history cannot be understood without taking these influences into account. One of the aims of this book will be to demonstrate the marked extent to which the mental structure of the man of today reflects the mental labors of the physicists of the past three or three and a half centuries.

Though the churches, in general, abstained from interfering officially, the scientific activities of the physicists have always been influenced by their private religious views. The latter, of

[1] Obviously, the personal lives of the physicists were intertwined with the events of their times, but this phase of the history of physics must be treated elsewhere.

course, were not necessarily identical with the ecclesiastical doctrines, but the philosophical attitudes of the scientists were affected, at least to some extent, by the prevailing religious thought. Kepler, Descartes, Leibniz, and Newton freely acknowledged this influence; it played a part in the principle of least action in the eighteenth century. After this period, in which Kant's philosophy proclaimed the complete independence of scientific understanding and religious belief, not much more about it is found in physical writings. However, this by no means signifies that the investigational urge of later scientists was not intimately connected with their religiosity. The tenet that the scientific experience of truth in any sense is "theoria," i.e., a view of God, might be said sincerely about the best of them. The search for knowledge without regard to its applicability for use has been "an essential trait of man through the centuries, a sign of his higher origin."[2]

Physics has always been in close touch with its fellow sciences: astronomy, chemistry, and mineralogy. The boundaries separating it from them are marked only by rather superficial differences, characterized especially by the dissimilarity in apparatus; consequently the fields have frequently overlapped. In the seventeenth century, and even later, it was not rare to find an astronomer, physicist, and chemist united in a single person. Robert Boyle (1627-1691) and Edme Mariotte (1620-1684), who will be mentioned later, were primarily chemists, and this was also true of Henry Cavendish (1731-1810), Antoine Laurent Lavoisier (1743-1794) and Humphry Davy (1778-1829). Physics and chemistry have participated equally in the creation of the atomic concept. As a result of the work of Svante Arrhenius (1859-1927), Jacobus Henricus van't Hoff (1852-1911), Wilhelm Ostwald (1853-1932), and Walter Nernst (1864-1941), physical chemistry emerged as a separate science at the end of the nineteenth century. After a long interval, the physicists, in the twentieth century, began to concern themselves once again with the theory of crystals, which had otherwise been left to the mineralogists.

[2] R. Jaspers, *Die Idee der Universität*, Berlin, 1946.

The connection between physics and mathematics is almost more intimate. The latter is the mental tool of the physicist. It alone enables him to express the natural laws in a final, precise, and teachable form; it alone makes possible their application to more complicated processes. For instance, logarithms, which were invented soon after 1610 by Jost Bürgi (1552-1632) and independently of him by John Napier (1550-1617) and Henry Briggs (1556?-1630), received one of their first applications in Kepler's astronomical computations. Likewise, the progress of physics in later years, especially in mechanics, was most intimately allied with the concurrent advances in mathematics (see Chapter II). More than once, problems posed by physics have directly initiated mathematical advances.

The relation of physics to philosophy is quite special. At the opening of the period being considered here, physics also occupied the attention of some men who are known to us primarily as philosophers. Examples are Leibniz and Descartes, who, it is true, fundamentally rejected the Galilean method of investigation. Even Kant was active in science; the best known of his physical achievements are his cosmological ideas regarding the origin of the planetary system. d'Alembert is better known as one of the leaders in the French "enlightenment" than for his accomplishments in mechanics. Later, the relations were reversed; physicists and chemists wrote on philosophy. Pertinent examples are Helmholtz, Mach, and Poincaré. They treated questions mostly related to the theory of perception, which, of all the philosophic disciplines, appealed most strongly to them. The author begs his reader's indulgence if he doubts that all these scientists-philosophers possessed the philosophical training essential to a successful handling of their subsidiary field. However, there is no doubt that the advances of the natural sciences furnished a powerful impetus on all philosophers of eminence. The best known example is the influence of Newton on Kant. In the nineteenth century there appeared an all too justified opposition by the scientists to the "identity philosophy" of Hegel, which denied the right of existence to all empirical science. Unfortunately, this opposition was often extended to the entire field of philosophy, and in fact to all theory whatsoever in natural science. For example, J. R. Mayer, the champion of the energy principle, suffered from such attacks because of the highly speculative complexion of his writings. In fact, such objections were raised even against Helmholtz, when he first issued his famous treatise on the conservation of energy.

The relations between physics and technology are quite clear. The latter for the most part is applied physics, and its advances usually have followed closely on the heels of the progress in physics itself. However, technology has developed some ideas of its own which have proved to be of value for physics. Instances of such contributions are the steam engine by James Watt in 1770, and the setting up of the dynamo-electrical principle for the generator by Werner von Siemens in 1867. Above all, technology, in ever-increasing measure, has enlarged the experimental possibilities of physics. It would be utterly impossible to fit up a modern physics research institute without the extensive aid of technology.

Priority polemics constitute an unfortunate chapter in the history of every science. Even today it is difficult to decide such questions because every tolerably noteworthy advance is published in a periodical and the scientific press is only passably well organized. How much worse were the conditions when the news of the results of investigations could be spread only by books or in letters! There were no scientific journals prior to the middle of the seventeenth century. The Royal Society, founded in 1662, began to issue its Transactions in 1664. This example was followed, at considerable intervals, by the other scientific organizations and by the many academies founded around 1700. Thus, a system of sorts came gradually into the business of publishing results. Priority matters will not be given much attention in this book. From our standpoint it is much less important that the gas law named after Robert Boyle and Edme Mariotte actually was read out of Boyle's measurements by his otherwise unknown pupil Richard Townley, than that the existence of this law was recognized about 1662—but of course not by everybody; it had to be discovered again by Mariotte, independently of Boyle.

However, it is invariably true, no matter what the period, that if an investigator publishes a fundamentally new fact, sooner or later voices will be heard claiming priority either for themselves or for a third party, because it is alleged that they "really" had made the discovery earlier. Sometimes such claims possess a measure of justice. Cases can be cited in which a certain discovery was "in the air" and actually was made by several entirely independent workers because events had reached the point where the discovery was the natural next step (see Boyle and Mariotte). Rutherford[8] states that it is a far rarer case for a scientific discovery to be made without the apposite mental preparation of the world of science. In addition, such claims should be received with skepticism. Quite often vaguely expressed notions are subsequently embellished with a clear interpretation derived entirely from the work of some one else. Sometimes a man has had an idea or has made an observation the significance and importance of which are not appreciated until they are pointed out at a later time by another. A discovery should be dated only from that time at which it was so clearly and definitely stated that it had a distinct effect on further progress. If it is really announced in this form, then petty criticism should not be leveled against the text of the announcement, because it does not contain every incidental point in perfect order. Perfection has never been conferred on any mortal.

The history of nations and peoples records only such events and persons as have some kind of significance. Likewise, the history of a science can include only certain memorable points of investigations and those who participated in them. Thousands must remain unmentioned who, since the seventeenth century, set physics on the move and have devoted themselves to this

[8] Lord Rutherford, *Background of Modern Science,* Cambridge, 1938, p. 55.

science, many because of pure idealism and sometimes at the cost of self-sacrifice. However, their labors were neither superfluous nor in vain. The silent collaboration of these many unsung workers was required to produce the necessary profusion of observations and computations and they insured the continuity of progress. It was only the variety of interests and talents that prevented the researches from being confined within a few restricted directions. The activities of these many now forgotten workers constituted and still provide the indispensable preliminary setting in which outstanding accomplishments can be produced, including even the strokes of genius. Since the end of the seventeenth century, physics has been a highly cooperative effort. This, too, is an historical fact.

The question is often raised as to the objectivity, the truth of scientific knowledge. It is by no means accepted without doubt. There have been and still are perception-theoretical movements—and these recently were widely disseminated through political propaganda—which, basing their case on the human fortuity in the origin of all knowledge and the frequent change in physical views and theories, draw the conclusion that the whole is dependent on all possible environmental factors, mental or even biological, and therefore completely determined by time and convention. As a matter of fact, physics never has had a completely rounded-off form that lasted through all periods of its history; furthermore, it never can have, because the finiteness of its content will always be opposed by the infinite abundance of possible observations. Yet, it itself furnishes proof of its objective truth, proof that has overwhelming power of conviction. A study of the history of this science reveals repeatedly that two trains of physical thought, e.g., optics and thermodynamics (Chapter XIII) or the wave theory of X rays and the atomic theory of crystals (Chapter XII), pursued up to then by different sets of workers, who were quite independent of each other, unexpectedly meet and fit together with no compulsion. Whoever has been privileged to live through such an extremely surprising event, even at a considerable distance, or, at least, to survey it after it has occurred, can no longer retain any doubt that the confluent theories certainly contain, if not complete truth, a substantial core of objective truth that is devoid of human embellishment. The ideal of a history of physics must be to set forth as clearly as it can such momentous events.