

The Historical Development of Science

II.—THE EARLY DEVELOPMENT OF MECHANICS AND THE PROPERTIES OF MATTER.

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IN observing the historical developments of science, we are hampered by the fact that the earliest observations either were not recorded or that the records are lost to us. When people specialise in one activity, their experiments are more likely to be noted and attempts made to correlate them.

In the first article we dealt with the subject of early work in heat. In this we deal with the properties of matter and mechanics. They are not intended to comprise a history of science, but to deal with those developments of certain sections of scientific work, and may on occasion in the future deal with the work even of one man or group of contemporaries.

The foundations of science lie in measurements of the size of things, their masses, and in measurements of time. We have records in Egyptian manuscripts of the use of a beam balance for comparing masses, or "weighing" things, to the nearest one-fortieth of an ounce—and some early Egyptian medical prescriptions actually call for weights as small. We have now no difficulty in making direct measurements of mass to one-millionth part of that, and by indirect methods can calculate the mass of minute particles of matter far too small to be seen by the most powerful microscope, and which consequently have an extremely small mass.

Measurements of length were required and were made with the rise of the earliest landowners, before the times of the records we possess; even in our earliest records the application of this measurement is noted in the use of elementary surveying methods.

Time was first measured, as fractions of the day, by rather inaccurate sundials and water clocks; the Babylonians gave us the week of seven days and, about 5,000 years ago, used the "hour" which we employ today. The Babylonians were also responsible for the use of the minute, the sixtieth part of an hour, and the second, the sixtieth part of a minute. I do not know, certainly,¹ why the number 60 appealed to them, but it was they also who divided the circle into 360 degrees, and each degree into 60 minutes, and each angle of one minute into 60 seconds. This "60" complication still persists, even in the metric system, so far as time is concerned, though we may dodge it to a certain extent by using decimal fractions of a second.

The first big application of a fixed unit of length and of time was to astronomy; the Babylonians made quite precise measurements in this field, and to Ciderias (343 B.C.) must be given credit for the discovery of the precession of the equinoxes, with which you are all familiar.

¹ See this Journal, Vol. I, No. 1, p. 32.

Physicists took their part in the Greek schools, which we may start with Thales of Miletus, about 600 B.C. Unfortunately the early Greeks were more interested in the philosophical and speculative side of physics, and though capable mathematicians appear generally to have considered actual experiment as being undignified. The two most famous physicists of these schools were Aristotle (born in Macedonia in 385 B.C.) and Archimedes (born in Syracuse, probably in 287 B.C.). Aristotle, one fears, was not a sound physicist, and would not pass the elementary science examination for the Intermediate Certificate; many of his statements are as vague and rambling as those of the small boy or girl who receives 5% for the paper, and many of his statements are wrong. One of his worst misstatements in mechanics persisted until the time of Galileo, nearly 2,000 years later. Aristotle held that falling bodies fall to the ground quicker in exact proportion to their weight. That is, if you took a lump of iron weighing an ounce, and another weighing a pound, the ounce would take sixteen times as long to reach the ground as would the pound, falling from the same height. It is really remarkable that such a ridiculous statement could have persisted and been accepted for 2,000 years! If you have any doubts on the matter, just drop a threepenny piece and a two shilling piece at the same instant and see if you notice any difference in the time they take to reach the floor.

Archimedes is best known for his work on floating bodies, though you probably also associate him with levers; did he not say, "Give me a fulcrum on which to rest, and I will move the earth"? That the earth happens to be hurtling through space at a great speed is beside the point; another little movement wouldn't do it any harm, and at any rate his statement was rather rhetorical. A possible movement, or even complete removal of the earth, is quite a scientific possibility, and would be exceedingly interesting for us all, but it will probably not be done by any simple lever system.

Archimedes was really the founder of the science of mechanics. His two books, "The Equiponderance of Planes" and "Floating Bodies", deal with statics and hydrostatics respectively. I will *not* tell you here the story of Archimedes in his bath, because it is as well known, and probably as apocryphal, as that of Alfred and the cakes. We will pass on to the times of the Romans.

The Romans were not originators in physics; not one of them appears ever to have dropped a two shilling piece and a threepenny piece simultaneously, or else in the rush no one observed which, if either, reached the ground first. They were largely echoes of the Greek schools. The most famous as far as this article is concerned is Lucretius, who lived about 90 B.C., and wrote one of the earliest text books of physics in his "De rerum natura". You have, of course, vastly superior text books of physics today, but his book summed up the information, correct or incorrect, to his time.

The Alexandrian Ptolemy, who lived between A.D. 100 and 178, was a great mathematician and astronomer, and so is claimed as a physicist. He was the originator of the Ptolemaic conception of our solar system, which held the earth as the centre of the universe, and required the planets to revolve round it. A system very comforting to our sense of importance, but involving many mathematical difficulties. A series of articles at some later date on early and present ideas of the world and the universe would be interesting, but we will have to reserve pure astronomers for such a later article.

The next big advance in mechanics was the development of the study of bodies in motion ; it is usually referred to as " dynamics ". The famous artist, anatomist, engineer and pure physicist Leonardo da Vinci contributed much original matter to this section, investigating the laws of motion. da Vinci, an Italian, lived between 1452 and 1519, and can hardly be said to be a specialist ; moreover, as a physicist he was a speculative physicist rather than an experimentalist. He, amongst others, arrived at the well-known law of falling bodies, $h = \frac{1}{2}gt^2$. The actual experimental determination of the laws of falling bodies is due to the native of Pisa, Galileo Galilei (1564-1642).

The 16th century ushered in the Renaissance, and the beginning of serious and systematised scientific research. Galileo was the originator of experimental physics. Working generally under great difficulties, his views met with a very hostile reception. Having originally studied medicine at the University of Pisa, he shortly after abandoned it for more scientific studies. He was, in 1589, appointed to the Chair of Mathematics at Pisa, during which time he is supposed to have carried out his famous experiments with bodies falling from the tower at Pisa. Whether he carried out the experiments or not, he made himself very unpopular by criticising hostilely the accepted statements of Aristotle, to which we referred earlier ; these statements had persisted for 2,000 years then, and it was therefore, not unnaturally, considered quite wrong for a professor to doubt them—or at any rate to criticise them publicly. He was compelled to resign in 1591, but was appointed next year to a chair at Padua, which he occupied till 1610. We will have occasion to refer to the work of those years in a later article. He later became physicist at the court of Tuscany. The record of the later life of Galileo is not pleasant. It is the story of a man working in a period when any statement not in accordance with the accepted ideas and conceptions of the preceding thousands of years was necessarily wrong and dangerous ; and when any statements which, however earnestly and conscientiously made, offended those in power, led to disastrous results for the utterer. Fortunately those periods lie 400 years behind us.

Isaac Newton (1642-1727) was interested in many sections of physics. In this section of the work we note him as the announcer of the three laws of motion that now bear his name, and also of the law of universal gravitation. The story of Newton and the falling apple is as familiar as that of Adam and the same fruit ; the researches of Newton have had as far-reaching effects as those of Adam, although he does not appear to have been assisted by a wife.

I should like to spend a page discussing the arguments taking place at this period between the followers of Descartes and Leibnitz as to what measures the " efficacy " or " effectiveness " of a moving body. Newton supported the Cartesian school, so called after Descartes, and thought in terms of the momentum of a moving body—the product of its mass and velocity—and of the time rate of change of momentum, or effective force on the body. Leibnitz thought in terms of the product of the mass of the body and the square of its velocity—which is a measure of what we now call its kinetic energy. The argument between the two schools was only due to a lack of definitions, and has been useful, in that it has resulted in a clearer conception of the principles involved. We can tackle the same problems by many different ways,

provided we know what we are talking about. If we do not know what we are talking about, it does not really matter what we call it. We are frequently rung up by newspapers and asked, "If a body weighing 10 stone fall 170 feet on to the water (or concrete, once), with what force will it strike?" They do not *really* want to know anything about the *force* of striking, which depends on lots of conditions on which they have no information; actually they do not know what they mean by force, and are content to be told the possible velocity and kinetic energy at the instant of striking. None the less, they often put in a sub-heading: "He would strike the water with terrific force".

Early in this period we got our pendulum clock. Galileo, Newton and Huyghens shared in the development. Huyghens wrote the first book on the subject, in 1673, in Paris.

An interesting physicist of the 17th century was Blaise Pascal, born in Auvergne in 1623. He experimented with fluids, primarily with liquids at rest, and the well known "Pascal's Law" was included in his book, "A Treatise on the Equilibrium of Liquids", published in 1663, the year after his death.

The two great physicists Torricelli and Boyle also lived in this rich period, Torricelli having been a friend of Galileo, and taking over his position as Professor of Mathematics at the Academia at Florence after Galileo's death. Torricelli was actually the inventor of the barometer, though his contemporary Pascal was the first actually to show the variation of atmospheric pressure with altitude, and to record variations in atmospheric pressure. Glass tubing apparently became available about this time (1646), rendering the experiments practicable. Robert Boyle, the announcer of Boyle's law—that the volume of a given mass of gas was inversely proportional to the pressure on it, provided the temperature was unchanged—was an Englishman, born in Ireland, being born at Lismore Castle in 1627. We are indebted to him for many researches in connection with air pressure and volume.

The 17th and 18th centuries were memorable ones in physics; experimental science was put upon a firmer basis, and speculative philosophy and physics temporarily parted company. Throughout the 18th and 19th centuries the studies were extended and applied to our every-day life. Without the investigations into the elastic properties of materials carried out by Hooke, Young, Poisson and Rayleigh, to pick out the leading early workers in the subject, the Sydney Harbour Bridge would not have been built. It would not be a bad idea if yet another tablet on that structure gave the names and exploits of all the physicists, from earliest times, who have helped in its construction. It would be an imposing array, and could end with the names of those applied physicists of today, the designers and builders, who have learnt and made use of the collected pure research work of centuries of study of mechanics and the properties of matter.

It would be rash to name the outstanding physicists associated with mechanics and the properties of matter in the 20th century. The boundaries have never existed between different sections in physics, and the sections are quite interdependent today. We might allude to the work in connection with seismology, and mention at least a dozen men of equal importance; to geophysics, and give you another dozen; to hydrostatics, pneumatics, hydrodynamics, and give you another dozen. They can

best be given separate articles later—must be, in fact, as we wish to do more than mention their names.

Today we are intensely interested, so far as mechanics is concerned, in very mathematical work, such as comes under the heading of multidimensional space, and relativity; and in our studies of the properties of matter we are drawn into experiments and speculations as to the nature of matter and of energy, that may lead to very big advances in the future.
