HISTORY OF PHYSICS

In the history of the genesis of man's ideas on the nature of the physical world, it is difficult to arrive at an absolute beginning. Regardless of how far we penetrate into the past which prepared and suggested some scientific doctrine, we inevitably find opinions and ideas inspired, in their turn, by some forerunner, until the beginning is lost in the inscrutable past. As for physics, in this limited framework we can start only with the period when specific names are associated with the earliest development of scientific ideas. The Ionian period, that amazing flow of intellectual energy, paved the way for the fathers of Hellenic science. Physics, then closely linked with philosophy and astronomy, play an auxiliary role in man's ever paramount concern in cosmology and cosmogony.

Although physics as an independent field originated in the age of Renaissance and was associated with such giants as Galileo, Kepler, and Newton, even in this brief sketch it is indispensable to trace the fountainhead of this science, which is in the cornerstone of Western civilization. The port of Miletus in Ionia, on the eastern coast of the Aegean sea, can be singled out as among the most significant birthplaces of physical science. Located in a favorable geographic position, its flourishing commerce since the second millenium before our era provided an excellent clearing house between two river civilizations, Egypt and Mesopotamia. Exposing people to divergent ideas and traditions, it created an atmosphere of open-mindedness where new, unrestrained ideas could flourish. Consequently, several most unique rationalizing minds had their roots in this town alone.

Of the galaxy of great pioneers of Ionian science, Thales of Miletus (624-565 B.C.) stands out as a symbol of the era. Sir James Jeans maintains that most of the major achievements of physical science of our age can be traced back to the stream of knowledge started by this Ionian intellectual giant in Miletus. Pythagoras, Democritus, Anaxagoras, Aristarchos of Samos, to mention a few, represent as one historian exclaims, that "miracle of ancient Greece" that prepared and shaped the climax of Plato and Aristotle, who for two millenia were to inspire and guide, for better or worse, the evolution of physics.

Liberated from the mythology of pre-Socratic time, these ancient astounding thinkers represent every school of philosophy from the extreme idealism of illusion and nonexistence of the world of sense perception, in the Pythagorean-Platonic sense, to the atomism and materialism of Democritus and Anaxagoras with their doctrine of the primacy of matter in a universe manipulated by accidental mechanism. It has been said that everyone by nature is a disciple of either Plato or Aristotle, and Raphael in his famous painting of the School of Athens on the wall of the Vatican Palace appropriately illustrates Plato pointing upward and Aristotle downward to the ground. Thus, the Alexandrian School in Hellenistic Egypt with its lighthouse, Pharos, as a symbol irradiated the glory of Hellenic science for centuries, nourishing Western civilization with Euclides' *Stoicheia* and Ptolemy's *Almagest* which, outside the Bible, were the most widespread literary sources in physical science relegated to antiquity.

With the rise of Christianity, followed by Islam half a millenium later, interest in the studies of natural science was temporarily paralyzed, to be later zealously renewed under the aegis of the theology of the new religion. A convert to Christianity, St. Augustine (A.D. 354–430), later Bishop of Hippo, was a pioneer in the realization that Plato's ideas on sense delusion conveniently responded to the devout Christian's search for the salvation of the soul. Like Socrates and Sophists about a millenium previously, so St. Augustine also turned his back on nature and advised, "Return to thyself. In the inner man dwells truth." Thus, for a thousand years the men who guided the thought of the Western world did not observe out-of-doors and learn from natural phenomena. Monasteries became leading establishments where sedentary monks pored over volumes of Plato and Aristotle. More than half a millenium after St. Augustine, St. Thomas Aquinas (A.D. 1227–1274) petrified Aristotelian peripatetic scholasticism into an authoritarian *Summa Theologica* that included all the answers man should know on the nature of the physical world.

This marked the climax of the Middle Ages, described unjustly as "dark ages." Although theology was the queen of sciences, this period was not devoid of scientific activity because speculations in physics were constantly being nourished by the mystery of the *Primum Mobile*, a sphere beyond the fixed stars. It was this Prime Mover to which Aristotelians ascribed the first supernatural impulses or "impetus." How else could motion first have started? With the rise of Humanism, the rediscovery of Greek literature of antiquity revealed vast subjects dealing with fields other than theology. Invigorating new studies spread through Western Europe invading universities, not by-passing some monasteries. Bold, unusual views on the nature of the physical world and methods of investigation aroused the suspicion of watchful scholasticians but the age of Renaissance could not be diverted. Even the prominent ecclesiastic Oresme (1332–1382), Bishop of Lisieux, sustained the main interest by challenging the Aristotelian doctrine of the fixity of the earth. Nearly a century later this was continued by Cardinal Nicolas of Cusa who, like the Franciscan monk, Roger Bacon, in the thirteenth century also advocated experimentation in order to learn how the laws of nature operate. Very penetrating studies on the mystery of "violent" motion and inertia were accomplished long before their actual fruition with the appearance of Galileo and Newton.

Signs of a new era in physics were imminent with ideas of the universal genius, Leonardo da Vinci, maintaining like Democritus and Anaximander that the whole universe conforms to unalterable mechanical laws. The coming dawn was evident when Nicolaus Copernicus (1473–1543) came to study in Bologna and Padua. Being more an ancient Greek philosopher in his use of geometry in support of the heliocentric system, Copernicus at least prepared the way of Galileo (1564–1642), who finally mobilized all known physics with his inventive experimentalism that adumbrated the first full stream of scientific revolution. Symptomatically, Galileo's first work was on motion, *De motu*, a subject of great concern through the Middle Ages, and his was the final challenging blow to the Aristotelian doctrine, when he verified that force primarily produces acceleration instead of mere movement.

As a sign of continuity, Newton was born (1642–1727) the year Galileo passed away. The trend of mechanism of physical phenomena as a consequence of mathematical determinism reached its portentous finalization with the Galilean-Newtonian revolution. Newtonian classical physics, associated with the world view of the majestic Newtonian universe, eternal and infinite, was formulated in three laws of motion, climaxed by the universal law of gravitation. This physics continued in its progressive refinement until it was confirmed by the triumphant mathematical discovery of the planet Neptune by J. C. Adams and Leverrier in 1845. It was then considered the final shape of knowledge man was in position to realize. Previously, Laplace produced an overwhelming impression on the entire century when, in 1798, he used in his *Origin of the World System* his deterministic equations in the formulation of his hypothesis on the origin of the solar system.

With advancing crystallization, Newtonian physics radiated with a galaxy of great names, inspired builders of the classical view of the physical world. Only a few principal milestones can be indicated, each a giant of his own in a panoramic view of the glorious century of promise of a scientific paradise. From Laplace at the beginning of the nineteenth century, the epic unfolds from Avogadro to Faraday, from Carnot and Joule to Kelvin and Helmholtz, attaining its pre-Einsteinian peak in Maxwellian equations formulating the electromagnetic theory of light. These equations were impressively described by Boltzmann, himself at the cradle of thermodynamics, when he quoted from Goethe's *Faust*: "Who was the god who wrote these lines?" Yet, these equations so brilliantly describing natural processes, pointed inevitably to a deterministic and mechanistic universe. Although rigorous mechanicism had flourished in the past in varying degrees, Newton must be regarded as the founder of the mechanistic world view even though he had difficulty in harmonizing mechanistic natural philosophy with his belief in a God who not only created the world but also constantly preserves it. This mechanization of the world picture systematically led to the conception of God as a retired engineer, and it was only another step to His complete exclusion. Therefore, the universe was ultimately knowable and predictable. This *Weltanschauung* of triumphant physics encouraged the rise of materialistic philosophy, that actually shaped the dialectic materialism of Marx and Engels, which became the official doctrine of the ruling communist state in the twentieth century.

Newtonian physics was not destined to remain the last form in the evolution of physics. When it appeared to reach its perfection, as some leading physicists advocated, the turn of the twentieth century again witnessed another tidal wave that changed the course of physics. By 1895, this second scientific revolution started with discoveries of the first magnitude, containing unfathomable consequences for the future. Becquerel's radioactivity, Roentgen's x-rays, J. J. Thomson's electron, Planck's quantum, Bohr's atom, Rutherford's nucleus, Einstein's relativity and equality of mass and energy, represent a revolution that will carry the exploring mind incomparably farther into the mysteries of the universe than Copernicus, Galileo, Kepler, or even Newton ever dreamed of. Heisenberg's principle of indeterminacy in the realm of microphysics not only shatters the once cherished corpuscular-kinetic determinism but points to a microcosmos much more complex than what Whitehead called "provincialism in time and space," and as valid in Newtonian mechanism. Combining this with the staggering discoveries in astrophysical macrocosmos, the Dopplerian red shift of external galaxies, quasars, neutron stars, and black holes, we confront a truly unprecedented era of future centuries that will bring about unimaginable amendments in the physics we know today and its subsequent world view.

In this new perspective, the last half-century along which physical science has moved since the beginning of the second scientific revolution is not only greater than the three centuries since Newton but surpasses the distance separating the world view of Newton from that of Aristotle. Indeed, the revolution initiated with the beginning of the present century is far more penetrating, and the intellectual distance between Aristotle and Newton far smaller than the distance separating Laplace from the wizards of the new physics of our present years. This conclusion is drawn because Newton as well as Aristotle built their world views from facts borrowed from our sensory perceptions, which allow easy construction in our minds of their mental image. We never have and never can perceive either an electron, nucleus, or quantum. We build their representation by a highly complex procedure which does not guarantee their actual reality. The great pioneer of new physics, Ernst Mach, once stated: "The senses do not lie, but they do not tell us truth."

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