# Chapter II
# Light Theories in Early Physics[1]

Even though in this book I am interested mainly in the physical conceptions of Maxwell and his contemporaries, I nonetheless must add a few chapters on light theories and related subjects to describe the large framework of meaning in which Maxwell and his contemporaries as scientists worked. I shall take the relevant information again from histories of physics and limit myself again to a bare minimum in so doing. I shall here not make a great effort to explain the interpretive character of the relevant theories and paradigms, even though in the following ages they have become for many scientists "privileged texts," which generated influential "text traditions" as we shall see.

## Article 1. Action-at-a-Distance and Ether in Early Modern Physics[2]

During the 19th century most physicists still accepted the ether hypothesis, even though there was no common agreement on the ether's physical properties. But after 1900 most scientists began to reject the hypothesis and claimed it to be an unnecessary assumption in mechanics to explain the observed phenomena. The special theory of relativity had shown that many of the physical properties once attributed to the ether can equally well be ascribed to space and time. The traditional notion that space and time are unchangeable, passive constituents of the universe, neither affecting nor being affected by dynamic changes occurring in the material universe must be given up, because a dynamic space-time-continuum can take the place of the postulated pair of continua, namely "empty space" and a "dynamic ether."[3]

The idea of one single, all-pervasive ether may have originated with Descartes, who defended such an ether in 1638,[4] and whose ideas had a dominant influence on all later physical theories of the ether. Descartes appealed to an ether to avoid action-at-a-distance in his mechanistic cosmology,

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[1] For the historical data discussed in this and the next two chapters, see Sir Edmund Whittaker: *A History of the Theories of Aether and Electricity.* 2 vols. (New York: Harper and Brothers, 1960), vol. 1.

[2] For what follows, see: Whittaker, I, pp. 1–32.

[3] A.D. Fokker. *Tijd en Ruimte. Traagheid en Zwaarte. Chronogeometrische Inleiding tot Einstein's Theorie* (Zeist: Uitgeversmaatschapij W. de Haan, 1960), Voorrede en Hoofdfstuk I, pp. vii–x, 1–14, and *passim.*

[4] Whittaker, I, pp. 4–9.

believing that all physical forces are communicated only by the contact of particles of matter on other particles in their immediate neighborhood. He appealed to the ether in his cosmology as well as in his theory of light. Yet his theory of light was quickly challenged by several leading physicists on the basis of work done by Roemer, Hooke and others. But in cosmology and other parts of mechanics many scientists, following both Descartes and Newton, continued to subscribe to some conception of an ether to explain gravitation. And when in the 18th Century many scientists began to concern themselves systematically with electricity and magnetism, soon many scholars appealed again to one or even more ethers to explain the relevant phenomena discovered. Yet it was particularly in research on light and colors, where Newton's corpuscular theory was eventually replaced by the wave theory, that the ether theory became solidly established.

For a long time one had assumed that the ether is some kind of a fluid, yet eventually many scientists began to believe that the ether had to be a solid substance, qualitatively similar to or even identical with elastic solids, such as glass or steel. But when this conception appeared in conflict with the result of several experiments, one gave it up and stated that the ether must be qualitatively different from ordinary solid matter.

The manner in which solid objects move through the ether was the subject of much speculation and experimentation. This was the case particularly during the period in which the ether was taken to be a solid; and it continued to be an important subject of discussion for more than one century. The existence of an ether taken as an invisible and intangible, imponderable substance, which takes a causal part in the motions of the planets and other physical processes, has been defended by a number of ancient philosophers. Some authors then postulated many ethers, each one occupying its own region in space.

In *modern physics*, the term "ether" was used to designate a hypothetical substance filling all space, including the volumes occupied by ordinary matter and serving to transmit the forces which one material object exerts upon an other, that is located at some distance, so as to avoid having to admit action-at-a-distance.

We shall return to this discussion in due time, but we must now first return to Descartes's mechanics.

## Article 2. The Light Theory of Descartes[5]

Among philosophers Descartes is best known for his *Discourse on the Method of Righly Conducting the Reason and Seeking for Truth in the Sciences* of 1637 and his *Meditations on First Philosophy* (1641). *The Rules for the Direction of the Mind* had been written in 1628 but was published only in 1647. Yet among scientists Descartes may be best known for his works on mathematics, optics and mechanics. The publication of some of his scientific treatises, such as his comprehensive *Traité du monde*,[6] had to be suspended because of the condemnation of Galileo; the work was not published until 1677. In the study of nature Descartes was deeply influenced by the mechanistic philosophy of Democritus. According to this mechanistic view all phenomena of nature are to be explained by means of the size, shape, form, and movement of smallest indivisible material elements, called *atomoi*; these small bodies can influence each other in their movements only by contact. It is thus understandable that to explain the phenomena observed in the realms of magnetism, electricity, light, and gravity Cartesians continued to appeal to some mediating substance whose smallest particles could fill the spaces between the particles of regular matter.

In other words, by eliminating all processes involving action-at-a-distance as a possible explanation of physical phenomena, Descartes was forced to defend the view that the spaces between regular bodies and their particles, and indeed the whole space, could not be void. It must be occupied partly by ordinary material things, such as regular bodies, air, etc.; but the cracks and crevices between the particles of these bodies as well as the entire rest of space, had to be filled with particles of a much more subtle kind. Space was thus for Descartes, a *plenum*, completely occupied by a medium, which, even though not perceptible to the senses, is capable of transmitting forces and exerting effects on the material bodies immersed in it, the ether. Descartes assumed that the particles of the ether are continually in motion. Yet as there is no empty space for the moving particles to move into, each particle must move by taking the place vacated by another particle of the ether, which itself is also in motion. This means that the movement of one single particle of the ether involves the

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[5]Ibid., pp. 9–13. See also Frederick Copleston, *A History of Philosophy*. Vol. IV: *Modern Philosophy: Descartes to Leibniz* (Garden City, NY: Doubleday, 1960), pp. 74–146.

[6] For the works of Descartes see: C. Adam and P. Tannery, eds., *Oeuvres de Descartes*, 13 vols. (Paris, 1897-1913). *Philosophical Works of Descartes Rendered into English by E.S. Haldane and G.R.T. Ross in Two Volumes* (New York, Dover, 1931), vol. 1. In what follows here I quote from the work by Whittaker.

motion of an entire closed chain of particles. Furthermore, in this view, the motions of these closed chains constitute vortices, which have important functions in his conception of the cosmos.

Descartes was convinced that the effects produced by means of contact and collision could explain all physical phenomena so that in his physics no other agencies would be necessary. Furthermore, since he had absolute confidence in his mathematical method, he believed that experimental verification would have no constitutive place in his mechanics. In his physics what is needed only is that for every phenomenon of nature one construct a *mechanical model* whose functioning can produce that phenomenon as its necessary result. One may even conceive of the entire cosmos as an immense machine so that all happenings in the material world can be predicted by mathematical calculation.

In Descartes's physics matter is characterized not by impenetrability, or by any quality recognizable by the senses, but only and simply by extension. For Descartes extension constitutes matter and matter constitutes space. As a matter of fact, the basis of all things of nature is a primitive, elementary, and unique type of matter, boundless in extent and infinitely divisible. In the process of the development of the universe, as we know it, three different forms of matter have developed, which correspond to the luminous matter of the sun, the transparent matter of interplanetary space, and the opaque and dense matter of the earth and the planets. "For, seeing that the sun and the fixed stars emit light, the heavens transmit it, and the earth, the planets, and the comets reflect it, it appears to me that there is ground for using these three qualities of luminosity, transparency, and opacity, in order to distinguish the three elements of the visible world."[7]

According to Descartes's theory, the sun is the center of an immense vortex formed of the first kind of matter. The vehicle that carries light in interplanetary space is matter of the second kind, composed as it is of a closely packed assemblage of globules, whose size is intermediate between those of the vortex matter and those of ponderable matter. These globules as well as all the matter of the first kind, are constantly straining away from the centers around which they turn, owing to the centrifugal force of the vortices,[8] so that the globules, which are in contact with, and press against each other, tend to move outwards, although they cannot do so actually.[9] It is the transmission of this

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[7] *Principles of Philosophy*, III, sect. 52. Quoted by Whittaker, I, p. 9.
[8] *Principles*, III, p. 63. Whittaker, p. 9.
[9] *Principles*, III, p. 65. Whittaker, Ibid.

pressure which constitutes light; the action of light therefore extends on all sides around the sun and the fixed stars, and travels instantaneously to any distance.[10]

Descartes appears to assume that the diversities of color and light are due to different ways in which the matter moves.[11] The general explanation of the nature of light on the basis of these principles was amplified in a discussion of reflection and refraction. In this discussion Descartes could make use of discoveries and insights of other people, including Kepler, Snell and others.

Even though Desartes's system in many of its features was still very crude, it did give an explanation of the law of reflection, that the angles of incidence and reflection are equal, as well as of the general law of refraction, namely that the sines of the angles of incidence and refraction are to each other in a ratio depending on the media involved. It also presented definite mechanical conceptions of physical activities and applied these to so wide a range of phenomena, that it did stimulate the spirit of inquiry and in some degree even prepared the way for more accurate theories to be discovered soon by others.

As far as the theory of light itself was concerned, Descartes's conceptions rapidly displaced those that had been current in the Middle Ages. Yet the validity of his explanation of refraction was called into question by Pierre de Fermat (1601-1665). Fermat had introduced a new, fundamental law from which he proposed to deduce the paths of rays of light: *The Principle of Least Time*, at first formulated in the form "Nature always acts by the shortest course." Much to his surprise, Fermat discovered that light moves more slowly in dense than in rare media, contrary to Descartes's supposition.[12]

Later it would turn out that Fermat's result was correct, and of high permanent interest. Yet the principles from which it was derived were metaphysical rather than physical in nature, and thus they were of little use for the purpose of framing a mechanical explanation of light of the kind Descartes was looking for. It is thus understandable that Fermat's work had little influence on the original success of Descartes's wave theory. The first serious criticism of Descartes's theory of light came from the mechanism and atomism introduced by Gassendi who following Democritus had claimed that the universe is constituted of material atoms, which themselves were taken to be eternal and unchangeable, moving around in empty space. Democritus's atomistic mechanism was originally severely attacked and rejected, because of its radical materialism and its negative implications for morality and theology. Yet soon

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[10] *Principles*, IV, p. 195. Whittaker, Ibid.
[11] Cf. Whittaker, pp. 9–10.
[12] Ibid., pp. 11–12.

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