HUYGENS' DIOPTRICA

Oeuvres complètes de Christiaan Huygens publiées par la Société Hollandaise des Sciences. Tome treizième. *Dioptrique.* 1653; 1666; 1685–1692. La Haye, Martinus Nijhoff, 1916. pp. i–clxviii; 1–905. 4to.

The monumental edition of the correspondence and writings of Christiaan Huygens was undertaken in 1888 by the Dutch Society of Sciences. The volume here under review, containing Huygens's original contributions to dioptrics and comprising with introduction, notes, etc., more than a thousand pages, is in every way worthy of its illustrious author. Unstinted praise should be bestowed on both the editor and the publisher, who have spared no pains in making this invaluable work as authoritative, complete and convenient as possible.

The manuscript of Huygens's writings on *Dioptrica* consists of detached sheets, 166 in all, the oldest portions of which date back to 1652, when Huygens was 23 years old. Almost until the end of his life in 1695, he was continually adding to it, revising it and sometimes planning to rewrite it entirely. By the end of 1653 he had composed a first draft of his *Tractatus de refractione et telescopiis* (pp. 1–271). At intervals during the following twelve years he was often at work on the same material, but for one reason or another its publication was constantly delayed. About 1665 he began to study more systematically the theory of spherical aberration; the results of these investigations are contained in the second part of the *Dioptrica* under the title of *De aberratione radiorum a foco* (pp. 273–353). About 1672, or perhaps a little later, we hear of his being again at work on his treatise on dioptrics with renewed ardour. By this time Newton's explanation of the phenomena of dispersion had been published. Its importance and its bearing on his own problems was quickly perceived by Huygens to the extent of modifying some of his views. Meanwhile, the undulatory theory had been born in his mind, and he was planning a more extensive treatise involving a revision and rearrangement of his previous manuscripts on dioptrics. In 1677 he found the explanation of double refraction in Iceland spar, which he naturally regarded as the most beautiful confirmation of his new theory of light. In comparison his earlier work in dioptrics seemed to him of secondary importance. Consequently, he determined to publish first a treatise on the wave theory of light with its principal applications, but without entering in detail into the theory of mirrors and lenses. This was the origin of his famous *Traité de la lumière.* Although it was not published until 1690, it was practically completed in 1678, and had been read before the Academy of Sciences in Paris in 1679. The third part of the *Dioptrica,* entitled *De telescopiis et microscopiis* (pp. 443–511), seems to have been composed in 1685. Apparently Huygens could never make up his mind to publish his optical theories and researches because he was continually adding fresh discoveries and gaining new insight and new points of view. In 1692 the work was still unfinished and at that time Huygens writes to Leibnitz: "il y a bien des choses

à demesler dans cette Dioptrique, et il s'en est offert tousjours de nouvelles, jusqu'à cette heure, qu'il me semble d'avoir tout penetré, quoy que je n'aye pas encor achevé de tout escrire." And so, as a matter of fact, Huygens's *Dioptrica* was never actually completed, and was not published at all until after his death. The greater part of it was included in De Volder and Fullenius's edition of Huygens's *Opuscula posthuma* published in Leiden in 1703. Unfortunately, not a few of Huygens's most valuable theorems never saw the light until long after they were obtained. Consequently he lost the priority of a number of important discoveries.

In this volume the text of the *Dioptrica* is given in Latin with facsimile cuts of Huygens's original diagrams and illustrations. On the opposite page there is a French translation. In an introduction of 167 pages, the editor has reviewed the entire work in detail. The text itself is clarified and expounded by notes and comments. In short the reader has every aid that could be desired, including a complete and accurate index of the whole contents.

One of the chief fascinations in a lifelong work like the *Dioptrica* is to trace in it the voyages of a great and original mind. The reader is continually surprised not only by the impresses of genius which have been left on these pages, but perhaps most of all by the almost startling modernness of many of Huygens's conceptions, as was long ago remarked by the late Professor Silvanus P. Thompson, reminding us again and again how little in advance of men like Newton and Huygens we are even in the twentieth century. The outburst of optical science which followed the invention of the telescope, and which constitutes a kind of Elizabethan Era in the history of scientific discovery, seems, so to speak, to flash forth anew from between the covers of this volume, and we catch some spark of the joyous enthusiasm that possessed those eager men who first employed the telescope and the microscope. Somehow too from an occasional scornful allusion to the opinions of some of his predecessors or contemporaries, at least one reader has been led to suspect that Huygens had a human side also and did not suffer fools gladly!

Amid such a mass of material, it is difficult to single out one thing for special comment rather than another. Certainly it is worth noting with what elegance and skill—far in advance of his contemporaries in this respect—Huygens derives from the law of refraction the fundamental characteristics of optical imagery in the limiting case when the effective rays are nearly normal to the refracting surface. If these propositions had been published about 1653 when they were first obtained by Huygens, he would certainly have had the priority for them. They were communicated in an anagram to the Royal Society in 1669, but at that very time Dr. Isaac Barrow's *Lectiones opticæ* was in the press, in which were to be found essentially the same theorems derived in a different way. But Huygens had the idea of equivalent lenses which Barrow did not. When the *Dioptrica* was first published in 1703, other writers also, notably Molyneux in England, had given rules which were practically the same as those of Huygens.

Of much interest too is Huygens's way of defining and measuring the magnifying power of an optical instrument, by which he means the ratio

of the apparent size of the object as seen through the instrument to its apparent size as presented to the unaided eye. Whether or not Huygens is entitled to priority for the announcement of the fact that the magnifying power of a telescope is equal to the ratio of the focal lengths of object-glass and ocular, he attached so much importance to it that he proves it in at least three different ways in the section on telescopes and microscopes which constitutes the third part of the *Dioptrica*. Neither Kepler nor Des Cartes had understood this relation clearly. In this connection speaking of Des Cartes, Huygens says that although it is hard to believe it of a man who was so intelligent and so well informed in these matters, nevertheless he got off the track in his demonstrations of the nature and effect of the telescope and was guilty of writing things on this subject to which no meaning can be attached!

A theorem which deserves to rank as one of the most beautiful generalizations of theoretical physics, and which can be extended to the theory of radiation in general, is contained in Proposition VI in the second book of the first part of Huygens's *Tractatus de refractione et telescopiis* (see pp. 198, ff.); it may be stated as follows:

"If an object is viewed through a system of any number of lenses, and if the positions of the eye and the object are mutually interchanged without disturbing the lens-system itself, the apparent size of the object will be the same as before, and the image will be erect or inverted as before."

This will be immediately recognized as equivalent to the theorem given by Robert Smith in his *Compleat System of Opticks* (Cambridge, 1738) as the first corollary to be deduced from Roger Cotes's celebrated proposition about the "apparent distance" of an object as viewed through a system of thin lenses. Smith does not mention Huygens's name in connection with this corollary, perhaps inadvertently; for undoubtedly at that time (1738) Smith must have known of Huygens's proposition. There can be no question that Huygens is entitled to the priority here. As early as 1653 Huygens, writing to Kinner von Löwenthurm, communicated this theorem as one of the principal discoveries which he proposed to publish in his treatise on refraction and telescopes; and in 1669 he included it in the anagrams which he sent to the Royal Society. The theorem itself was not actually published until 1703, but its importance was not appreciated and it was soon forgotten or ignored. One of the many services performed by the learned editor of this volume of Huygens's works is to put this matter in its right light, because the theorem in question is one, and by no means the least, of Huygens's titles to fame. Huygens himself constantly makes use of this general principle in the solution of special problems, and modern workers will find it serviceable in the same way.

Doubtless few persons are aware nowadays that Huygens made valuable contributions to science also in the realm of physiological optics, as may be seen by looking into this volume. Most physicists are content, so to speak, to deliver radiant energy to the eye and leave it to its fate; unfortunately, comparatively few of them like Young and Helmholtz have thought it worth while to pursue the investigation further and to study the intricate phenomena of vision. Not so Huygens; he at least was keenly alive to the fact that at the other end of his microscope or telescope a

human eye was adjusted, and that visual perception is the chief thing after all. He was perfectly aware that the magnifying power of the instrument depended on the idiosyncrasies of the eye of the individual. Apparently far more accurately than Des Cartes or any of his own contemporaries, Huygens was acquainted with both the anatomical and optical structure of the eye; and he had the clearest notions about the office of the pupil and the mechanism of accommodation. The essential theory of binocular vision and depth perception was grasped by Huygens. He explains in the clearest manner how in order to see an object single with both eyes the two images on the retina must be formed at "corresponding points", although apparently he did not perceive that a solid object looks different to each eye; otherwise he might have anticipated Wheatstone and Brewster in the invention of the stereoscope. In the article on the eye and vision in the first part of the *Dioptrica* there is a description of a "simplified eye" formed by two concentric hemispheres of unequal radii. The curved surface of one of these hemispheres corresponds to the cornea and that of the other to the retina of the eye. There is a singular resemblance between Huygens's "simplified eye" and the "reduced eye" conceived by Listing in 1845, as is pointed out by the editor on page cxliv of the *Avertissement.*

After all, perhaps what impresses the reader most amid all this wealth of material is not so much the theories which are propounded and developed with such rare insight and skill, as the marvellous versatility and resourcefulness of the author and the variety of observations and experiments which underlie the whole and form the solid structure of the edifice itself. To his extraordinary mechanical ability and ingenuity Huygens owed much of his remarkable accomplishment; with him to conceive was to execute, no matter what practical obstacles might lie in the way. To this day we read with astonishment of those prodigious "aerial telescopes" with their poles and pulleys which he constructed and mounted with his own hands and with which he made some of his great discoveries in astronomy. Huygens's name is usually associated in our minds with refracting telescopes; but he devoted much study also to reflectors and preferred Newton's type of instrument to those of Gregory and Cassegrain. Many pages in the volume before us are devoted to the theory of the compound microscope and Huygens's "observations microscopiques."

But enough has been said to give the reader at least some idea of the character and scope of Huygens's optical researches. No wonder that he published comparatively little during his busy lifetime! Before he could get his thoughts safely on paper, a whole vista of new ideas begins to distract and fascinate him. New discoveries give ever a new turn to his earlier imaginings, and so he hastens onwards still eager in the pursuit of knowledge when death overtakes him at last at the summit of his great career.

Felix qui potuit rerum cognoscere causas.

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