THE PRINCIPLE OF HUYGHENS AND THE DIFFRACTION OF LIGHT

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1. INTRODUCTION

WHEN we speak of the diffraction of light, we have in mind certain effects which are observed when the free propagation of light is modified or influenced by the presence of obstacles in its path. It is clear that the nature of the obstacles, including especially their optical properties and their configuration in space, would determine these effects. Surprisingly enough, theories of diffraction have found general acceptance in which these factors receive very inadequate consideration. This situation is connected with the historical development of the subject and has arisen out of a misunderstanding of the ideas originally put forward by Huyghens in his celebrated Treatise on Light. A precis of the first three chapters of that treatise was given in a recent article in *Current Science*, and it was shown that the so-called principle of Huyghens as enunciated by later authors and made use by them as a basis for the theory of diffraction finds no warrant or support in the treatise. Huyghens did indeed introduce the concept of particular or partial waves and made effective use of it. But these partial waves of Huyghens had definite physical origins and the role which they played could therefore be readily understood. In these respects they differed radically from the ideas ascribed to him by later authors.

Theories clothed in the language of mathematical analysis have not infrequently found supporters and gained acceptance even though the physical ideas on which they are based are unsustainable. Kirchhoff's so-called rigorous formulation of the principle of Huyghens is a case of this kind. A statement often made and generally believed is that the Kirchhoff theory describes the experimental facts of the diffraction of light in a satisfactory manner. This belief has undoubtedly contributed to an uncritical acceptance of the ideas on which that theory is based. It is one of the objects of the present communication to show that it is indeed possible to make Huyghens' concept of partial waves the basis for a treatment of diffraction problems. This leads to results which are in agreement with the facts of experiment but are quite different from those indicated by the Kirchhoff theory. It follows that the latter theory is unsustainable and must accordingly be laid aside.

2. THE WAVE-OPTICS OF HUYGHENS

Huyghens sought in his treatise to explain the three most familiar facts of geometrical optics on the basis of wave principles, *viz.*, that the rays of light are propagated in straight lines; that the angles of incidence and reflection are equal; and that in refraction the ray is bent according to the law of sines. His explanations rest on the assumptions which he made regarding the structure of the luminiferous medium and the nature of light waves. His arguments led him to infer that in a homogeneous medium, each little piece of the primary wave emerging from a source of light is capable of travelling in a direction normal to itself more or less independently and that the primary wave-front is the locus or surface at which all the little pieces of which it is made up arrive together at the same instant. The same idea underlies Huyghens' explanation of the laws of reflection and refraction. Each piece of the original wave-front on reaching the boundary between two media is unable to continue on its original course by reason of the velocity of light being different in them. Accordingly it takes fresh paths, one in each of the two media, the direction of travel being such that the pieces of the original wave-front which are diverted from their path can all join up together again to form new wave-fronts in each medium. The latter requirement leads immediately to the equality of the angles of incidence and reflection in the first medium and to the law of sines for refraction into the second medium. This explanation was put into geometric form by Huyghens and is both simple and convincing. Regarded as a physical theory, it is highly successful, since it demonstrates that the refractive indices of the two media are in the inverse ratio of the velocities of light in them.

Examining the ideas of Huyghens in detail, it becomes apparent that his explanation of the rectilinear propagation of light cannot possibly serve as a starting point for a theory of diffraction. On the other hand, his theory of reflection and refraction does offer itself as a basis. For, it makes use of the idea that each element of area of the boundary between two media on which light is incident is a source of partial or secondary waves in the two media. Conceptually, these waves can diverge from each element in various directions, but the requirement