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5 Geometrical Optics

5.1 Introductory Remarks

The surface of an object that is either self-luminous or externally illuminated behaves as if it consisted of a very large number of radiating point sources. Each of these emits spherical waves; rays emanate radially in the direction of energy flow, that is, in the direction of the Poynting vector. In this case, the rays *diverge* from a given point source S, whereas if the spherical wave were collapsing to a point, the rays would of course be *converging*. Generally, one deals only with a small portion of a wavefront. ***A point from which a portion of a spherical wave diverges, or one toward which the wave segment converges, is known as a focus of the bundle of rays.***

Figure 5.1 depicts a point source in the vicinity of some arrangement of reflecting and refracting surfaces representing an *optical system*. Of the infinity of rays emanating from S, generally speaking, only one will pass through an arbitrary point in space. Even so, it is possible to arrange for an infinite number of rays to arrive at a certain point P, as in Fig. 5.1. If for a cone of rays coming from S there is a corresponding cone of rays passing through P, the system is said to be **stigmatic** for these two points. The energy in the cone (apart from some inadvertent losses due to reflection, scattering, and absorption) reaches P, which is then referred to as a **perfect image** of S. The wave could conceivably arrive to form a finite patch of light, or **blur spot**, about P; it would still be an image of S but no longer a perfect one.

It follows from the Principle of Reversibility (p. 110) that a point source placed at P would be equally well imaged at S, and accordingly the two are spoken of as **conjugate points**. In an *ideal optical system*, every point of a three-dimensional region will be perfectly (or stigmatically) imaged in another region, the former being the **object space**, the latter the **image space**.

Most commonly, the function of an optical device is to collect and reshape a portion of the incident wavefront, often with the ultimate purpose of forming an image of an object. Notice that inherent in realizable systems is the limitation of being unable to collect all the emitted light; a system generally accepts only a segment of the wavefront. As a result, there will always be an apparent deviation from rectilinear propagation even in homogeneous media—the waves will be *diffracted*. The attainable degree of perfection of a real imaging optical system will be **diffraction-limited** (there will always be a blur spot, p. 467). As the wavelength of the radiant energy decreases in comparison to the physical dimensions of the optical system, the effects of diffraction become less significant. In the conceptual limit as $\lambda_0 \to 0$, rectilinear propagation obtains in homogeneous media, and we have the idealized domain of **Geometrical Optics.*** Behavior that is specifically attributable to the wave nature of light (e.g., interference and diffraction) would no longer be observable. In many situations, the great simplicity arising from the approximation of Geometrical Optics more than compensates for its inaccuracies. In short, *the subject treats the controlled manipulation of wavefronts (or rays) by means of the interpositioning of reflecting and/or refracting bodies, neglecting any diffraction effects.*

* *Physical Optics* deals with situations in which the nonzero wavelength of light must be reckoned with. Analogously, when the de Broglie wavelength of a material object is negligible, we have *Classical Mechanics*; when it is not, we have the domain of *Quantum Mechanics*.

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