8.7: Geometrical Optics Placeholder

I would not like the reader to miss, behind all these details, the main feature of the Fresnel diffraction, which has an overwhelming practical significance. Namely, besides narrow diffraction "cones" (actually, parabolic-shaped regions) with the lateral scale $\delta x \sim (\lambda z)^{1/2}$, the wave far behind a slit of width $a >> \lambda$, δx, repeats the field just behind the slit, i.e. reproduces the unperturbed incident wave inside it, and has a negligible intensity in the shade regions outside it. An evident generalization of this fact is that when a plane wave (in particular an electromagnetic wave) passes any opaque object of a large size $a >> \lambda$, it propagates around it, by distances z up to $\sim a^2/\lambda$, along straight lines, with virtually negligible diffraction effects. This fact gives the strict foundation for the notion of the wave ray (or beam), as the line perpendicular to the local front of a quasi-plane wave. In a uniform media such ray follows a straight line,[43] but it refracts in accordance with the Snell law at the interface of two media with different values of the wave speed ν, i.e. different values of the refraction index. The concept of rays enables the whole field of geometric optics, devoted mostly to ray tracing in various (sometimes very complex) systems.

This is why, at this point, an E&M course that followed the scientific logic more faithfully than this one, would give an extended discussion of the geometric and quasi-geometric optics, including (as a minimum[44]) such vital topics as

- the so-called lensmaker's equation expressing the focus length f of a lens via the curvature radii of its spherical surfaces and the refraction index of the lens material,

- the thin lens formula relating the image distance from the lens via f and the source distance,

- the concepts of basic optical instruments such as glasses, telescopes, and microscopes,

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However, since I have made a (possibly, wrong) decision to follow the common tradition in selecting the main topics for this course, I do not have time/space left for such discussion. Still, I am using this "placeholder" pseudo-section to relay my deep conviction that any educated physicist has to know the geometric optics basics. If the reader has not been exposed to this subject during their undergraduate studies, I highly recommend at least browsing one of the available textbooks.[45]

Reference

[43] In application to optical waves, this notion may be traced back to at least the work by Hero (a.k.a. Heron) of Alexandria (circa 1-70 AD). Curiously, he correctly described light reflection from one or several plane mirrors, starting from the completely wrong idea of light propagation from the eye of the observer to the observed object.

[44] Admittedly, even this list leaves aside several spectacular effects, including such a beauty as conical refraction in biaxial crystals – see, e.g., Chapter 15 of the textbook by M. Born and E. Wolf, cited in the end of Sec. 7.1.

[45] My top recommendation for that purpose would be Chapters 3-6 and Sec. 8.6 in Born and Wolf. A simpler alternative is Chapter 10 in G. Fowles, Introduction to Modern Optics, 2nd ed., Dover, 1989. Note also that the venerable field of optical microscopy is currently revitalized by holographic/tomographic methods, using the scattered wave's phase information. These methods are especially productive in biology and medicine – see, e.g., M. Brezinski, Optical Coherence Tomography, Academic Press, 2006, and G. Popescu, Quantitative Phase Imaging of Cells and Tissues, McGraw-Hill (2011).