13.2: Ray and Wave Models of Propagation

> **Learning Objectives**
>
> By the end of this section, you will be able to:
>
> - Describe the condition which determines if electromagnetic wave propagation can be accurately described by the ray model.
> - List the ways in which light travels from a source to another location in the ray model.
> - List phenomena that the wave model of propagation describes better than the ray model.

The Ray Model

In the chapter on Electromagnetic Waves, you have already seen that electromagnetic energy can propagate in the form of waves. However, experiments show that when the electromagnetic wave interacts with an object that is several times as large as the wave's wavelength, it travels in straight lines and acts like a **ray**. The word "ray" comes from mathematics, and here means a straight line that originates at some point. The **ray model** describes the propagation path of the electromagnetic energy as straight lines.

If the electromagnetic wave is light, it is acceptable to think of light rays like the thin beams coming out of a laser. Its wave characteristics are not pronounced in such situations. Since the wavelength of visible light is less than a micron (a thousandth of a millimeter), it acts like a ray in the many common situations in which it encounters objects larger than a micron. For example, when visible light encounters anything large enough to observe with unaided eyes, such as a coin, it acts like a ray, with generally negligible wave characteristics. As we have seen, radio waves can have wavelengths of from tenths of meters to hundreds of meters, so the ray model is perhaps even more widely applicable in many circumstances for radio waves.

In this chapter, we start mainly with the ray characteristics in the context of light, as this approach is easiest to visualize. There are three ways in which light can travel from a source to another location (Figure 13.2.1): (1) It can come directly from the source through empty space, such as from the Sun to Earth. (2) It can also travel through various media, such as air and glass, to the observer. (3) Light can also arrive after being reflected, such as by a mirror. In all of these cases, we can accurately model the path of light as straight lines. Light may change direction when it encounters objects (such as a mirror) or in passing from one material to another (such as in passing from air to glass), but it then continues in a straight line or as a ray.

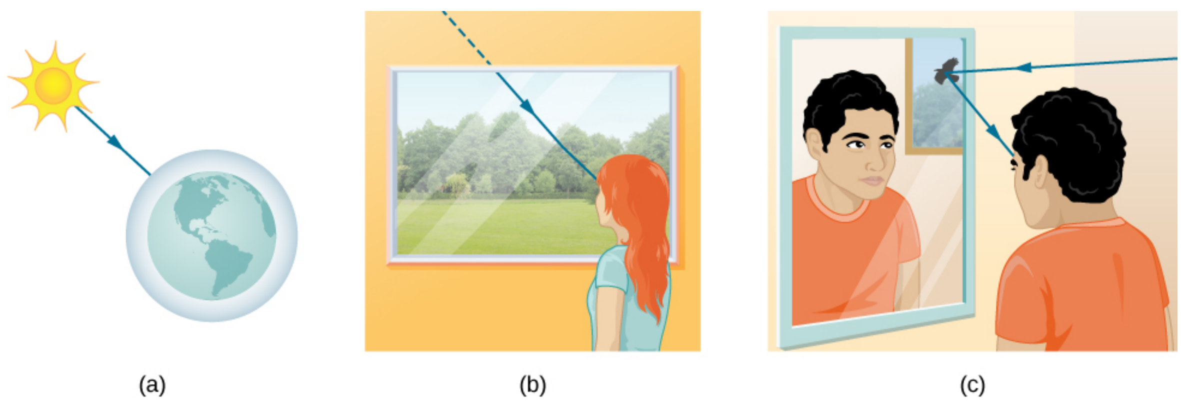

Figure 13.2.1: Three methods for light to travel from a source to another location. (a) Light reaches the upper atmosphere of Earth, traveling through empty space directly from the source. (b) Light can reach a person by traveling through media like air and glass. (c) Light can also reflect from an object like a mirror. In the situations shown here, light interacts with objects large enough that it travels in straight lines, like a ray.

Since light moves in straight lines, changing directions when it interacts with materials, its path is described by geometry and simple trigonometry. This part of optics, where the ray aspect of light dominates, is, therefore, called **geometric optics**. Two laws govern how light changes direction when it interacts with matter. These are the **law of reflection**, for situations in which light bounces off matter, and the **law of refraction**, for situations in which light passes through matter. We will examine more about each of these laws in upcoming sections of this chapter.

The Wave Model

When an electromagnetic wave interacts with objects that are comparable or smaller than its wavelength, then the ray model is no longer appropriate. In the context of light, when the wave aspect dominates, this part of optics is called **wave optics**. When the waves interact with objects or other waves, they can exhibit very prominent wave characteristics such as **diffraction** and **interference**. These phenomena will also be discussed in subsequent sections.
