1.2 LAWS OF GEOMETRICAL OPTICS

Natural phenomena described by geometric optics obey the following three laws.

1.2.1 Law of rectilinear motion

In a homogeneous transparent medium light travels in a straight line. This just says that in a transparent medium there is nothing for the light to bounce around as it would do in a translucent medium.

1.2.2 Law of reflection

When light is incident on an interface between two media, some or all of it comes back to the first medium. The phenomenon is called reflection and the returned ray is called the **reflected ray** while the starting ray is called the **incident ray**. Depending on whether the interface is smooth over the width of the ray the reflected light may be directed in one direction or may be diffused and directed randomly in many directions as illustrated in Fig. 1.12.

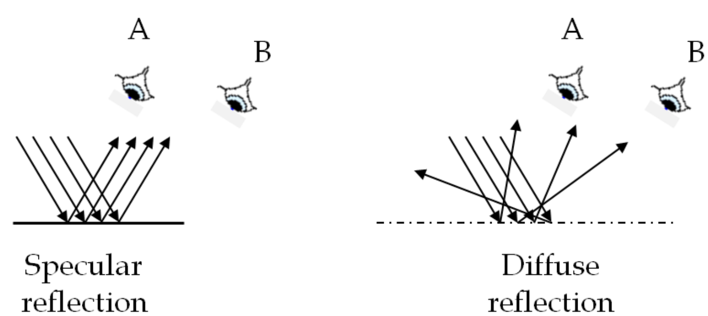

Figure 1.12: Specular and diffuse reflection. In specular reflection, only eye A is in a position to receive the reflected light while diffused reflected light can reach both eyes A and B.

When the interface is smooth the reflected ray is sharp whose direction is symmetrical with respect to the incident ray. Such a reflection is called **specular reflection**, from the word Speculum for mirror in Latin. This is what happens when a visible light ray is reflected from a mirror or from a highly polished plane metal surface such as the reflecting surface of an aluminum foil. When the reflection is not sharp it is called a **diffuse reflection**, e.g. reflection from a ground glass. You are reading this book from a diffuse reflected light from the paper, which makes it possible to read the same letter from different angles.

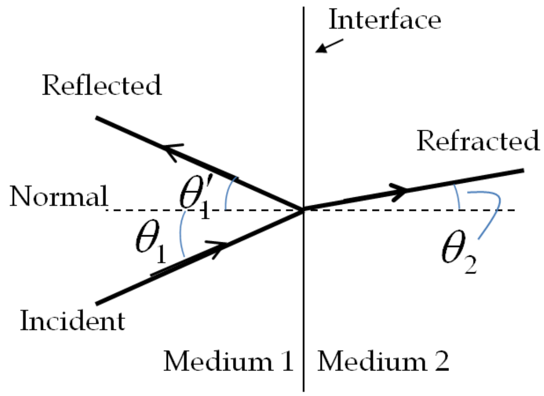

Figure 1.13: Geometric optics at an interface of two media.

The angles of incidence and reflected rays are usually stated with respect to a **normal** to the interface as shown in Fig. 1.13. The angle θ_1 between the incident ray and the normal is called the **angle of incidence**, and the angle θ_1' between the reflected ray and the normal is called the **angle of reflection**. The law of reflection asserts that the two angles are equal to each other.

$$\boxed{\text{Angle of reflection, } \theta_1' = \text{Angle of incidence, } \theta_1.} \tag{1.14}$$

1.2.3 Law of refraction or Snell's Law

At the interface of two media some or the entire incident light manages to enter the second medium. The light ray in the second medium is called the **refracted ray**. The direction of the refracted ray is given by the angle (θ_2) the ray makes with the normal as shown in Fig. 1.13. The **angle of refraction** θ_2 is related to the angle of incidence and the refractive indices n_1 and n_2 of the two media by the **law of refraction**, also called the **Snell's law**.

$$\boxed{n_1 \ \sin\theta_1 = n_2 \ \sin\theta_2.} \tag{1.15}$$

According to Snell's Law, if $n_2 < n_1$ then $\theta_2 > \theta_1$ and if $n_2 > n_1$ then $\theta_2 < \theta_1$ as shown in Fig. 1.14. Thus, if a ray of light in air ($n_1 = 1.0$) is incident on water ($n_2 = 1.33$), it will bend towards the normal, but if a ray of light enter water from its path in glass ($n_1 = 1.5$), it will bend away from the normal.

Example 1.2.1. Refraction at Air/Water Interface. Find the angle of refraction when light from air is incident on it with an angle of incidence 60°.

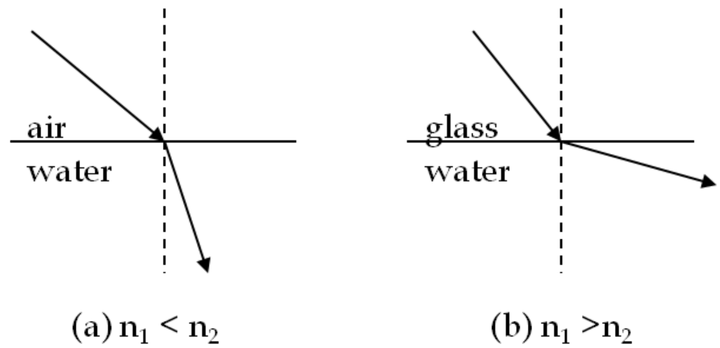

Figure 1.14: Refraction at two type of interfaces.

Solution. We use Snell's law, $n_1 \ \sin\theta_1 = n_2 \ \sin\theta_2$. Here $n_1 = 1$, $n_2 = \frac{4}{3}$, $\theta_1 = 60°$. Therefore,

$$\theta_2 = sin^{-1}\left(\frac{n_1}{n_2}\sin\theta_1\right) = 41°.$$