Pre-Lab 4

Reflection and Refraction of Light

References

Physics 123:
Tipler & Mosca, *Physics for Scientists and Engineers, 6th edition,* Vol. 1 (Red book). Chapter 15, section 15-2, Chapter 16, section 16-1, especially Example 16-3.

Physics 116:
Walker, *Physics, 4th edition,* Vol. 3 (Orange book). Chapter 26, sections 26-1, 26-2, 26-5.

1. Refracted Light

The direction of light propagation changes abruptly when light encounters a reflective surface. If the angle of incidence is not zero, the direction also changes abruptly when light passes through a boundary between two different media such as between air and glass or glass and water. This results from the difference in the speed of light in the two media. The change in direction, or "bending", of light as it passes from one material into another is called ***refraction***.

Here are some definitions. The ***normal*** to a surface is a line that is perpendicular to that surface. The ***angle of incidence***, θ_i, is the angle between an incoming ray, or ***incident ray***, and the normal. The ***angle of refraction***, θ_r, is the angle between the ray leaving the surface, the **refracted ray**, and the normal. To avoid confusion with the use of θ_r for both the angle of refraction and the angle of reflection, your text uses θ_1 for the angle the incident ray makes with the normal in the first medium and θ_2 for the angle the refracted ray makes with the normal in the second medium. If a light ray travels from a material such as air where its speed is relatively large into a material such as glass, acrylic or water where its speed is less, the light ray will "bend" toward the normal.

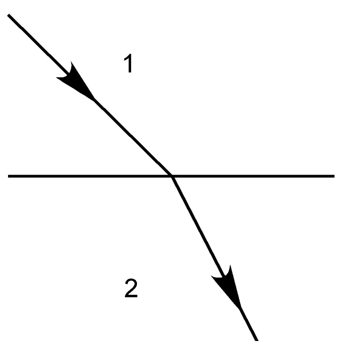


Fig. 5-A.1

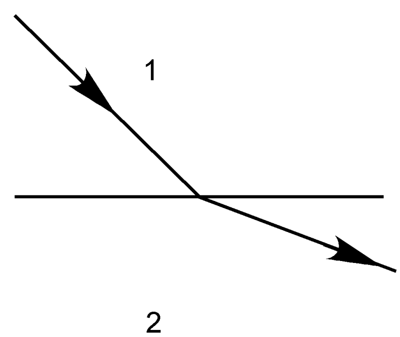


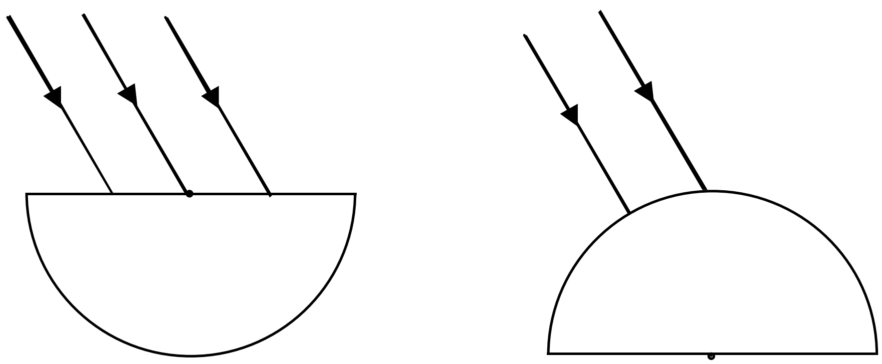
Fig 5-A.2

Notice the difference between the two diagrams in figure 5-A. In each case, the light travels from one medium into a second one in which the speed of light is different. In one case, the ray bends toward the normal and in the other it bends away from the normal.

1.1. In this diagram, (1) **draw** the normal for each case and **label** the angles of incidence and refraction θ_1 and θ_2; (2) **draw** a ray showing the **reflection** angle θ_r and **label** it. In which diagram does the **refracted** ray bend toward the normal and in which does it bend away from the normal? For each case, write "fast" or "slow" on the diagram to indicate the medium in which light travels faster or slower.

1.2. Figure 5.B shows rays incident on a semicircular piece of material in which light waves travel more slowly. (In lab, the medium will be clear acrylic plastic.) **Continue** each of the rays through this medium and out the other side. Each ray should bend appropriately. [Hints: The center of the semicircle is marked. It useful to know the location of the center when drawing a normal to the curved surface of the semicircle. **Draw** normals to the surfaces where the rays intersect the surface. Each ray passes through TWO surfaces. The angle of incidence is always the angle of the ray before it strikes the surface, and the angle of refraction is always the angle of the ray as it goes away from the surface.]

Fig. 5.B



2. Snell's Law

When light enters a refractive medium it slows down by an amount proportional to the material's ***refractive index*** *n*. In a vacuum (and pretty nearly so in air) the speed of light is *c*, equal to 2.998×10^8 m/s (to four significant figures). In a refractive medium such as glass, plastic or water, the speed of light $v = c/n$, and the refractive index *n* is typically about 1.5 for glass, 1.6 for polycarbonate plastic, and 1.3 for water (or ice). The refractive index also depends on the color of the light; for most common optical materials it is a little bit higher for blue light than for red light.

Snell's law is an equation that relates the angles of incidence and refraction to the refractive indices of the two materials on either side of a boundary. You can use it to measure the index of refraction of an unknown material by measuring these angles, and this is and exercise that you will perform in the lab.

Snell's law is written

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \, .$$

You can see that when the refractive index in one material is larger, the corresponding angle must be smaller in order to make both sides of the equation equal.