

Reflection and Transmission

When light traveling through air is incident upon the surface of a transparent material, such as glass, a fraction of the light will be reflected and a fraction will be transmitted into the material. See

Figure 1. The exact values of these fractions depend on a variety of factors. The most notable factors include the angle of incidence (denoted by θ_i in **Figure 1**) and the index of refraction of air and the index of refraction of the material that the light is approaching. The index of refraction of air is approximately 1.00. The index of refraction values of other materials are shown in **Table 1.** **Figure 2** below shows the dependence of the percent reflection upon the angle of incidence for light traveling through air and approaching four different materials.

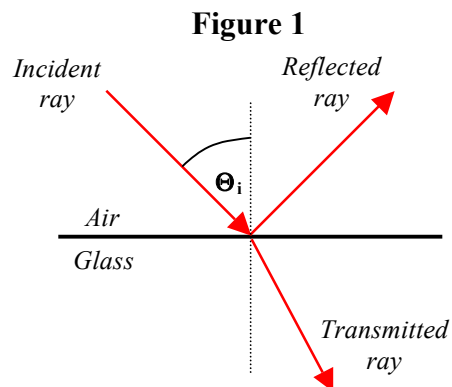


Table 1

Material	Index of Refraction
1 = Water	1.33
2 = Glass (crown)	1.52
Glass (flint)	1.62
Sapphire	1.77
3 = Zircon	1.94
4 = Diamond	2.42

NOTE: numbers 1, 2, 3 and 4 above correspond to numbers on graphs.

The above examples are for light moving from air into another material. If the situation is reversed - that is, light moves from some material into air - a dramatic difference is observed. This is shown in **Figure 3.** For each material, there is an angle that is noticeably less than 90° at which 100% reflection occurs. This angle is known as the **critical angle**. For any angle of incidence greater than the critical angle, 100% of the light undergoes reflection and 0% of the light transmits across the boundary. The value of the critical angle is dependent upon the index of refraction of the material. Thus, different materials have different critical angle values.

Figure 2

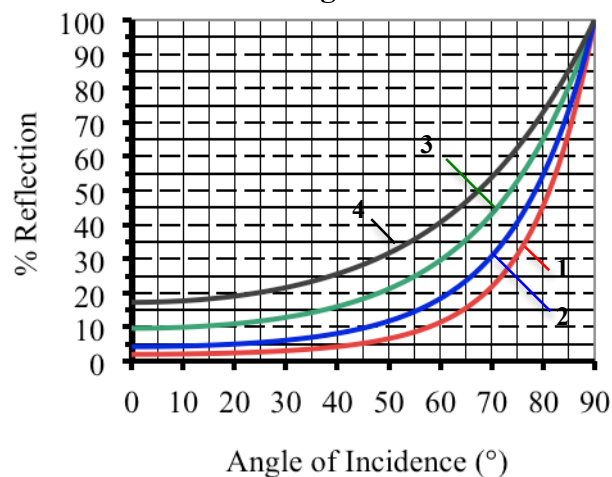
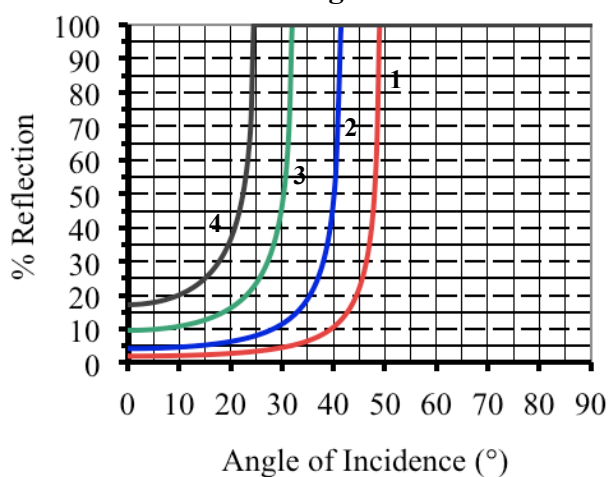
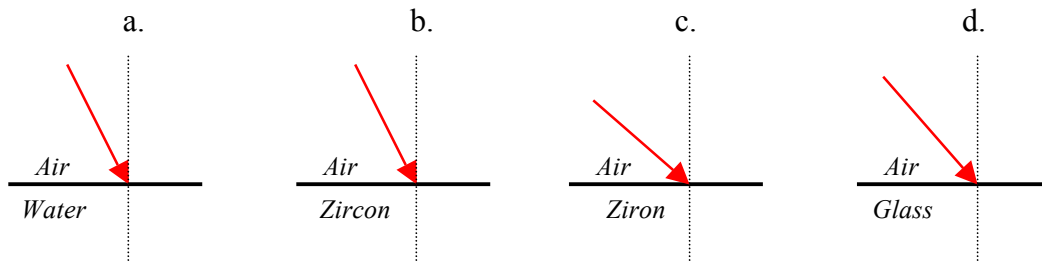


Figure 3



Questions:

- Which statement describes the relationship between the angle of incidence (Θ_i) and the percentage of light that reflects when traveling from water to air?
 - The percentage of light reflection is less at higher angles of incidence.
 - There is a greater percentage of light reflection at higher angles of incidence.
 - Lower angles of incidence result in more reflection and less transmission of light.
 - The percentage of light reflection remains relatively unaffected by incident angles.
- What percentage of light is reflected at the air-to-water surface when the angle of incidence is 80° ?
 - Approximately 45%.
 - Approximately 55%.
 - Approximately 65%.
 - Approximately 87%.
- What percentage of light is reflected at the air-to-crown glass surface when the angle of incidence is 70° ?
 - Approximately 22%.
 - Approximately 30%.
 - Approximately 43%.
 - Approximately 84%.
- What angle of incidence would result in 40% reflected light at the air-to-crown glass surface?
 - Approximately 8° .
 - Approximately 68° .
 - Approximately 74° .
 - Approximately 78° .
- Light is traveling through air towards *material X*. According to **Table 1** and **Figure 2**, what is the effect of the index of refraction of *material X* upon the percent of light that reflects at the surface?
 - The percent reflection is greatest for smaller values of the index of refraction.
 - The percent reflection is greatest for higher values of the index of reflection.
 - The index of refraction seems to have no effect upon the percent reflection.
 - While there is an effect, the actual pattern as to how index of refraction affects the percent reflection is not a predictable pattern.
- Estimate a value for the percent reflection for light that travels from air towards flint glass, approaching the surface at an angle of incidence of 60 degrees.
 - Approximately 11%.
 - Approximately 19%.
 - Approximately 29%.
 - Approximately 82%.
- Which one of the following light rays would experience the greatest amount of reflection?



8. Consider the following light rays.

Light Ray	Surface	Angle of Incidence ($^{\circ}$)
A	Air to Water	50
B	Air to Crown Glass	40
C	Air to Zircon	40
D	Air to Diamond	20

Which light ray would have the lowest percent reflection?

- Light ray A.
 - Light ray B.
 - Light ray C.
 - Light ray D.
9. According to **Figure 3**, what is the percent reflection that is experienced by a light ray traveling through zircon and approaching air at an angle of incidence of 30° ?
- Approximately 11%
 - Approximately 13%
 - Approximately 27%
 - Approximately 45%
10. Consider the following light rays.

Light Ray	Situation	θ_i ($^{\circ}$)
A	Light Traveling from Air to Diamond	20
B	Light Traveling from Diamond to Air	20

Based on **Figure 2** and **Figure 3**, which statement most accurately compares the percent reflection for these two light rays?

- Light ray A encounters the greatest percent reflection at the surface.
 - Light ray B encounters the greatest percent reflection at the surface.
 - The percent reflection is very close to the same value for these two light rays.
 - There is no way to make such a comparison; more information would be needed.
11. Based on the information in **Table 1** and **Figure 3**, what is the critical angle value for a light ray traveling from sapphire to air?
- Approximately 28°
 - Approximately 32°
 - Approximately 35°
 - Approximately 41°
12. Consider the following light rays.

Light Ray	Surface	θ_i ($^{\circ}$)
A	Crown Glass to Air	40
B	Diamond to air	30
C	Air to Zircon	50

Based on the data presented in **Figure 2** and **Figure 3**, which light ray will **not** undergo reflection of light at the surface?

- Light ray A.
- Light ray B.
- Light ray C.
- Nonsense! All three light rays will reflect.