

| Table 18-1 | |
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| Indices of Refraction for Yellow Light ($\lambda = 589 \text{ nm}$ in vacuum) | |
| Medium | n |
| Vacuum | 1.00 |
| Air | 1.0003 |
| Water | 1.33 |
| Ethanol | 1.36 |
| Crown glass | 1.52 |
| Quartz | 1.54 |
| Flint glass | 1.62 |
| Diamond | 2.42 |

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1. A laser beam in air is incident upon ethanol at an angle of incidence of 37.0° . What is the angle of refraction?

2. Light in air is incident upon a piece of crown glass at an angle of incidence of 45.0° . What is the angle of refraction?

3. Light passes from air into water at 30.0° to the normal. Find the angle of refraction.

4. Light in air is incident upon a diamond facet at 45.0° . What is the angle of refraction?

7. Index of Refraction A ray of light in air has an angle of incidence of 30.0° on a block of unknown material and an angle of refraction of 20.0° . What is the index of refraction of the material?

8. Speed of Light Could an index of refraction ever be less than 1? What would this imply about the speed of light in that medium?

9. Speed of Light What is the speed of light in chloroform ($n = 1.51$)?

5. A block of unknown material is submerged in water. Light in the water is incident on the block at an angle of incidence of 31° . The angle of refraction of the light in the block is 27° . What is the index of refraction of the material of the block?

15. A 2.25-cm-tall object is 8.5 cm to the left of a convex lens of 5.5-cm focal length. Find the image position and height.

16. An object near a convex lens produces a 1.8-cm-tall real image that is 10.4 cm from the lens and inverted. If the focal length of the lens is 6.8 cm, what are the object position and height?

17. An object is placed to the left of a convex lens with a 25-mm focal length so that its image is the same size as the object. What are the image and object positions?

19. Calculate the image position and height of a 2.0-cm-tall object located 25 cm from a convex lens with a focal length of 5.0 cm. What is the orientation of the image?

22. A convex lens with a focal length of 22.0 cm is used to view a 15.0-cm-long pencil located 10.0 cm away. Find the height and orientation of the image.

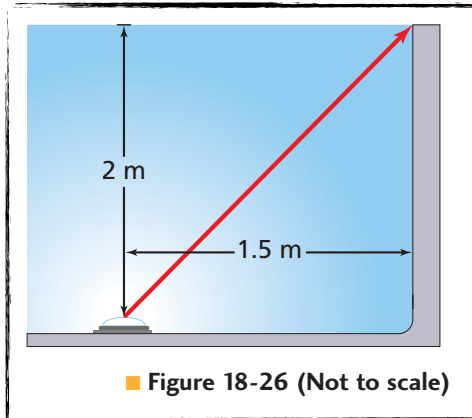
23. A stamp collector wants to magnify a stamp by 4.0 when the stamp is 3.5 cm from the lens. What focal length is needed for the lens?

68. Light travels from flint glass into ethanol. The angle of refraction in the ethanol is 25.0° . What is the angle of incidence in the glass?

69. A beam of light strikes the flat, glass side of a water filled aquarium at an angle of 40.0° to the normal. For glass, $n=1.50$.

a. At what angle does the beam enter the glass?

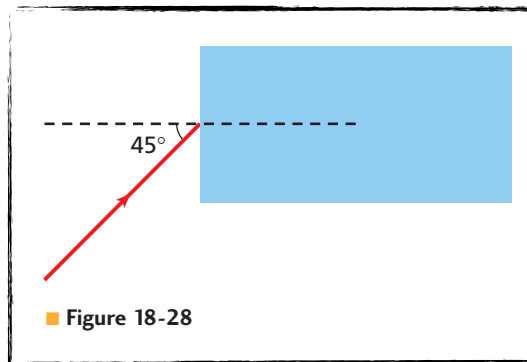
b. At what angle does the beam enter the water?



73. A light source is located 2.0 m below the surface of a swimming pool and 1.5 m from one edge of the pool, as shown in Figure 18-26. The pool is filled to the top with water.

- At what angle does the light reaching the edge of the pool leave the water?
- Does this cause the light viewed from this angle to appear deeper or shallower than it actually is?

79. The speed of light in a clear plastic is $1.90 \times 10^8 \text{ m/s}$. A ray of light strikes the plastic at an angle of 22.0° . At what angle is the ray refracted?



80. A light ray enters a block of crown glass, as illustrated in Figure 18-28. Use a ray diagram to trace the path of the ray until it leaves the glass.

88. A diverging lens has a focal length of 15.0 cm. An object placed near it forms a 2.0-cm-high image at a distance of 5.0 cm from the lens.

- What are the object position and object height?

The diverging lens is now replaced by a converging lens with the same focal length.

- What are the image position, height, and orientation? Is it a virtual image or a real image?