Physics 11-03 Refraction — *Name:* _____

Refraction

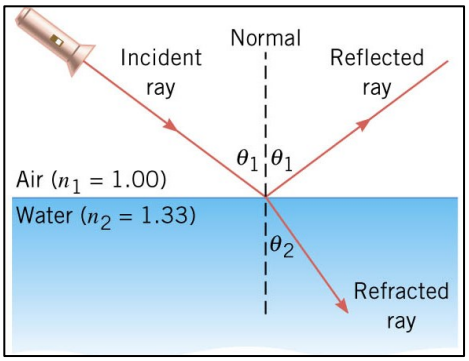
- Speed of light in a vacuum: $c = 3.00 \times 10^8 \frac{m}{s}$
- Light travels _____ through materials due to light _____, absorbed by, emitted by, and scattered by _____.

Index of Refraction

- _____to indicate relative _____ of light in a _____

$$n = \frac{c}{v}$$

- When light hits the surface of a material part of it is _____
- The other part goes into the _____
- The transmitted part is _____ (_____)



Snell's Law (The Law of Refraction)

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

Where n_1 = index of refraction of incident, n_2 = index of refraction of second, θ_1 = angle of incidence (to normal), θ_2 = angle of refraction (to normal)

You shine a laser into a piece of clear material. The angle of incidence is 35°. You measure the angle of refraction as 26°. What is the material?

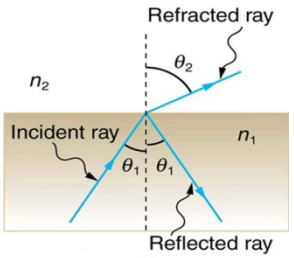
What is the speed of light in the material?

Table 25.1 Index of Refraction in Various Media

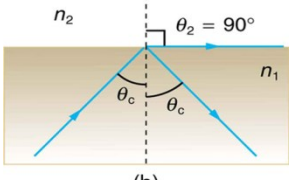
Medium	*n*
Gases at 0°C , 1 atm	
Air	1.000293
Carbon dioxide	1.00045
Hydrogen	1.000139
Oxygen	1.000271
Liquids at 20°C	
Benzene	1.501
Carbon disulfide	1.628
Carbon tetrachloride	1.461
Ethanol	1.361
Glycerine	1.473
Water, fresh	1.333
Solids at 20°C	
Diamond	2.419
Fluorite	1.434
Glass, crown	1.52
Glass, flint	1.66
Ice at 20°C	1.309
Polystyrene	1.49
Plexiglas	1.51
Quartz, crystalline	1.544
Quartz, fused	1.458
Sodium chloride	1.544
Zircon	1.923

Total Internal Reflection

- When light hits an _____ between two types of _____ with different indices of _____
  - Some is _____, Some is _____
- Critical angle
  - Angle of _____ where _____ angle is _____
  - Angles of incidence _____ than this cause the _____ angle to be _____ the material. This can't happen, so _____ refraction occurs.
    - $\theta_c = \sin^{-1}\frac{n_2}{n_1}$ where $n_1 > n_2$



(a)



What is the critical angle from cubic zirconia (n=2.16) to air? Will an angle of 25° produce total internal reflection?

Dispersion

- Each _____ of light has a different _____ of refraction
  - Red — _____ Violet — _____
  - When light is refracted, the violet bends more than red, which _____ the colors
- Rainbows
  - _____ by _____ with internal _____
  - Rainbows are always the _____ direction from the sun

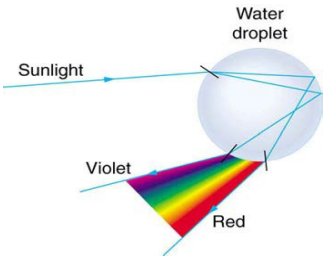


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Table 25.2 Index of Refraction *n* in Selected Media at Various Wavelengths

Medium	Red (660 nm)	Orange (610 nm)	Yellow (580 nm)	Green (550 nm)	Blue (470 nm)	Violet (410 nm)
Water	1.331	1.332	1.333	1.335	1.338	1.342
Diamond	2.410	2.415	2.417	2.426	2.444	2.458
Glass, crown	1.512	1.514	1.518	1.519	1.524	1.530
Glass, flint	1.662	1.665	1.667	1.674	1.684	1.698
Polystyrene	1.488	1.490	1.492	1.493	1.499	1.506
Quartz, fused	1.455	1.456	1.458	1.459	1.462	1.468

Practice Work

1. Diffusion by reflection from a rough surface is described in this chapter. Light can also be diffused by refraction. Describe how this occurs in a specific situation, such as light interacting with crushed ice.
2. Will light change direction toward or away from the perpendicular when it goes from air to water? Water to glass? Glass to air?
3. Explain why an object in water always appears to be at a depth shallower than it actually is? Why do people sometimes sustain neck and spinal injuries when diving into unfamiliar ponds or waters?
4. A high-quality diamond may be quite clear and colorless, transmitting all visible wavelengths with little absorption. Explain how it can sparkle with flashes of brilliant color when illuminated by white light.
5. The most common type of mirage is an illusion that light from faraway objects is reflected by a pool of water that is not really there. Mirages are generally observed in deserts, when there is a hot layer of air near the ground. Given that the refractive index of air is lower for air at higher temperatures, explain how mirages can be formed.
6. What is the speed of light in water? In glycerine? (OpenStax 25.5) $\mathbf{2.25 \times 10^8\ m/s,\ 2.04 \times 10^8\ m/s}$
7. Calculate the index of refraction for a medium in which the speed of light is 2.012×10^8 m/s, and identify the most likely substance based on Table 25.1. (OpenStax 25.7) **1.490, polystyrene**
8. In what substance in Table 25.1 is the speed of light 2.290×10^8 m/s? (OpenStax 25.8) **ice**
9. Components of some computers communicate with each other through optical fibers having an index of refraction n = 1.55. What time in nanoseconds is required for a signal to travel 0.200 m through such a fiber? (OpenStax 25.11) **1.03 ns**
10. What is the angle of refraction when light in air strikes the surface of plexiglass at 30°? (RW) **19.6°**
11. What is the angle of refraction when light in water strikes the surface of fluorite at 25°? (RW) **23.1°**
12. Suppose you have an unknown clear substance immersed in water, and you wish to identify it by finding its index of refraction. You arrange to have a beam of light enter it at an angle of 45.0°, and you observe the angle of refraction to be 40.3°. What is the index of refraction of the substance and its likely identity? (OpenStax 25.13) **1.46, fused quartz**
13. (a) Verify that the critical angle for light going from diamond to air is 24.4°. (b) What is the critical angle for light going from zircon to air? (OpenStax 25.21) **24.4°, 31.3°**
14. You can determine the index of refraction of a substance by determining its critical angle. (a) What is the index of refraction of a substance that has a critical angle of 68.4° when submerged in water? What is the substance, based on Table 25.1? (b) What would the critical angle be for this substance in air? (OpenStax 25.25) **Fluorite, 44.2°**
15. A ray of light, emitted beneath the surface of an unknown liquid with air above it, undergoes total internal reflection as shown in Figure 1. What is the index of refraction for the liquid and its likely identification? (OpenStax 25.26) **1.50, Benzene**

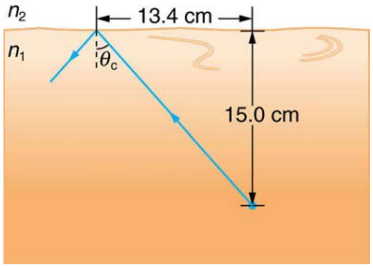

Figure 1

16. (a) What is the ratio of the speed of red light to violet light in diamond, based on Table 25.2? (b) What is this ratio in polystyrene? (c) Which is more dispersive? (OpenStax 25.28) **1.020, 1.012, diamond**
17. A beam of white light goes from air into water at an incident angle of 75.0°. At what angles are the red (660 nm) and violet (410 nm) parts of the light refracted? (OpenStax 25.29) **46.5°, 46.0°**