Index of Refraction & Snell's Law

Feb 12-5:01 PM

INDEX OF REFRACTION

The index of refraction of a material is the ratio of the speed of light in a vacuum to the speed of light in that material.

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

Quantity	Symbol	SI unit
index of refraction	n	none
speed of light in a vacuum	c	$\frac{\text{m}}{\text{s}}$ (metres per second)
speed of light in a specific medium	v	$\frac{\text{m}}{\text{s}}$ (metres per second)

Unit Analysis

$$\frac{\text{metres per second}}{\text{metres per second}} = \frac{\frac{\text{m}}{\text{s}}}{\frac{\text{m}}{\text{s}}} = \text{no unit}$$

Feb 12-5:02 PM

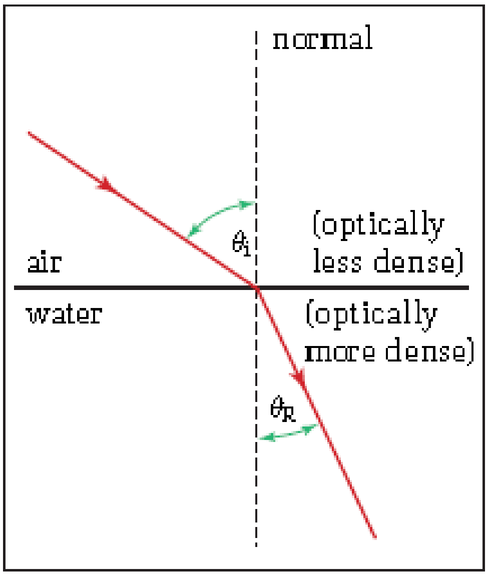
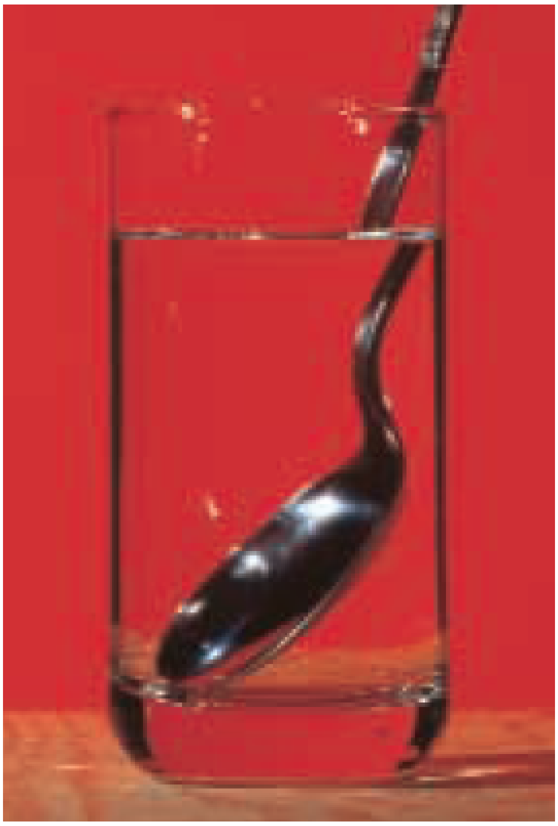


Figure 9.26 Light refracts (bends) toward the normal when passing from air into water.



Feb 12-5:27 PM

Table 9.2 Index of Refraction of Various Substances*

Substance	Index of Refraction (n)
vacuum	1.00000
gases at 0°C, 1.013×10^5 Pa	
hydrogen	1.00014
oxygen	1.00027
air	1.00029
carbon dioxide	1.00045
liquids at 20°C	
water	1.333
ethyl alcohol	1.362
glycerin	1.470
carbon disulfide	1.632

* Measured using yellow light, with a wavelength of 589 nm in a vacuum.

Substance	Index of Refraction (n)
solids at 20°C	
ice (at 0°C)	1.31
quartz (fused)	1.46
optical fibre (cladding)	1.47
optical fibre (core)	1.50
Plexiglas™ or Lucite™	1.51
glass (crown)	1.52
sodium chloride	1.54
glass (crystal)	1.54
ruby	1.54
glass (flint)	1.65
zircon	1.92
diamond	2.42

Feb 12-5:26 PM

SNELL'S LAW

The product of the index of refraction of the incident medium and the sine of the angle of incidence is the same as the product of the index of refraction of the refracting medium and the sine of the angle of refraction.

$$n_i \sin \theta_i = n_R \sin \theta_R$$

Quantity	Symbol	SI unit
index of refraction of the incident medium	n_i	unitless
angle of incidence	θ_i	none (degree is not a unit)
index of refraction of the refracting medium	n_R	unitless
angle of refraction	θ_R	none (degree is not a unit)

Feb 12-5:28 PM

Index of Refraction

Light travels from air into an unknown liquid at an angle of incidence of 65.0°. The angle of refraction is 42.0°. Determine the index of refraction of the unknown liquid.

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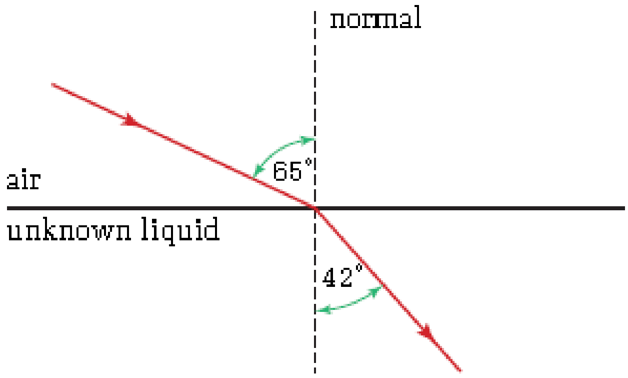


Feb 12-5:30 PM

Refraction and the Wave Model of Light

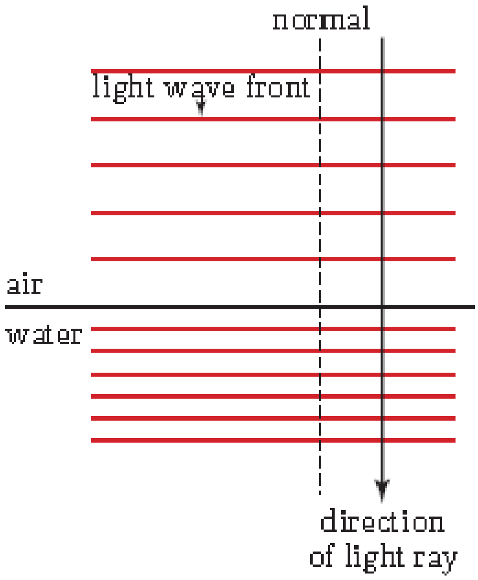


Figure 9.27 Plane light waves, represented by a ray, are travelling from air into water.

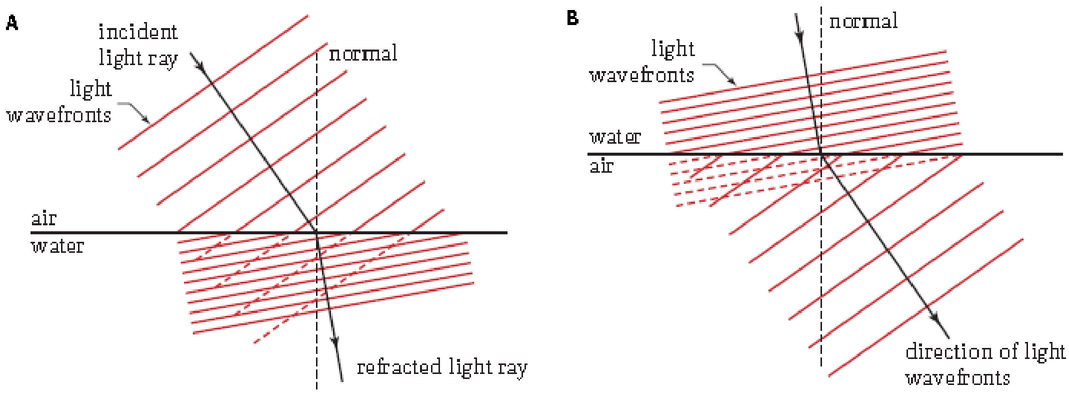
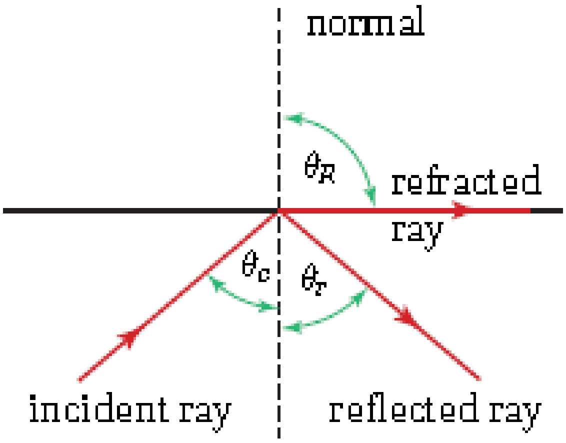


Figure 9.28 **(A)** The left edges of the wavefronts are bent backwards because the waves travel slower in the water than they do in air. **(B)** The left edges of the wavefronts bend forward, because the waves travel faster in air than in water.

Total Internal Reflection and the Critical Angle



Critical Angle
- when the angle of refraction is 90°

Determine the critical angle (θ_c) for diamond.

Feb 12-5:44 PM

TOTAL INTERNAL REFLECTION

The two conditions required for total internal reflection to occur are as follows.

- The light must travel from an optically more dense medium into an optically less dense medium.
- The angle of incidence must exceed the critical angle, θ_c, associated with the material.

Problems p. 410, #12-15

Feb 12-5:47 PM

Applications of Total Internal Reflection