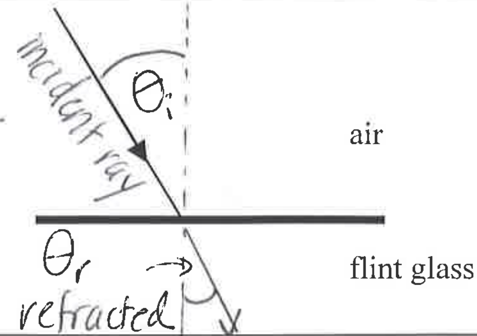
Snell's Law of Refraction

Snell's Law (Law of Refraction)

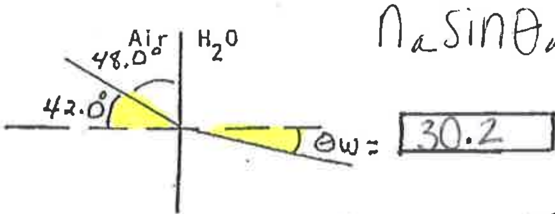
$n_1 \sin\theta_1 = n_2 \sin\theta_2$ $\qquad \frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1}$

Use Snell's law to construct the refracted ray on the diagram at right.



p.486 - has indices of refraction

Use a Snell's law to determine and draw the path light takes in the material as shown. *Note: Indices are in the text. Also, not all interfaces are horizontal. Dotted lines are the normal lines.*

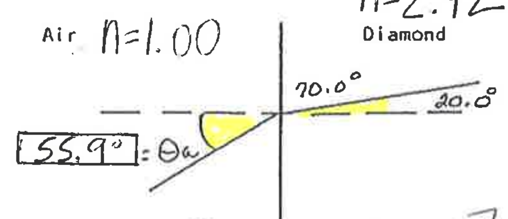


$n_a \sin\theta_a = n_w \sin\theta_w$

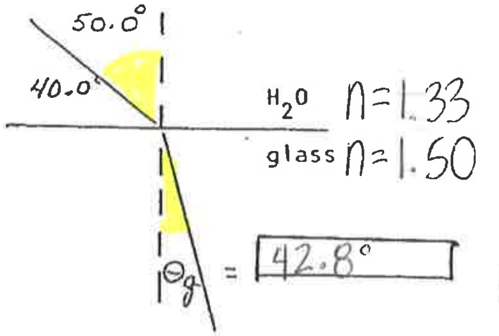
$n_{air} = 1.00$

$n_{water} = 1.33$

$\theta_w = \sin^{-1}\left[\frac{n_a \sin\theta_a}{n_w}\right]$

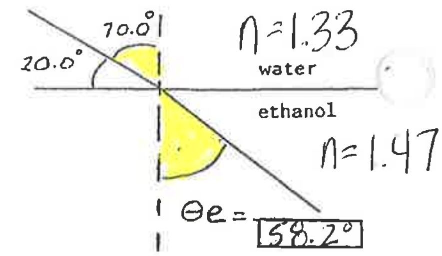


$\theta_a = \sin^{-1}\left[\frac{2.42 \sin(20.0)}{1.00}\right]$



show all work on WS # 6

$\theta_g = \sin^{-1}\left[\frac{n_w \sin\theta_w}{n_g}\right]$



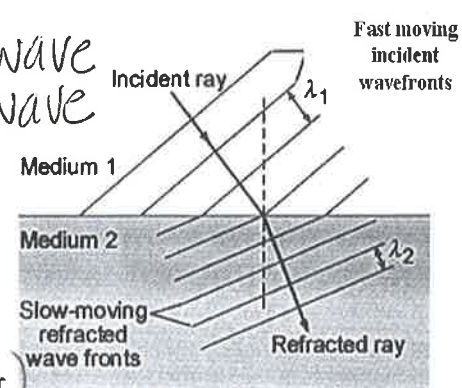
$\theta_e = \sin^{-1}\left[\frac{1.33(\sin 70.0°)}{1.47}\right]$

problems are the same as WS # 6

Refraction and Wavelength

Why does refraction occur?

because one part of the incident wave changes speed before the rest of the wave



As the wave enters a more optically dense medium . . .

wavelength decreases
speed decreases, but the frequency (or the period) remains the same

Relationship:

(light) $c = \lambda f$ $\qquad v = \lambda f$ (all waves)

$n = \frac{c}{v}$ $\qquad \frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1} = \frac{c_1/v_1}{c_2/v_2} = \frac{v_2}{v_1} = \frac{\lambda_2 f_2}{\lambda_1 f_1}$

A beam of monochromatic yellow light with a frequency of 5.09×10^{14} Hz enters a block of diamond from air.

$n_{air} = 1.00$

$n_d = 2.42$

a) What is the frequency of the light in the diamond?

same = 5.09×10^{14} Hz

b) What is the wavelength of the light in air?

$\lambda = \frac{c}{f} = \frac{3.00 \times 10^8 \text{ m/s}}{5.09 \times 10^{14} \text{ Hz}} = 5.89 \times 10^{-7} \text{ m} = 589 \times 10^{-9} \text{ m} = \boxed{589 \text{ nm}}$

c) What is the wavelength of the light in the diamond?

$\frac{n_a}{n_d} = \frac{\lambda_d}{\lambda_a} \quad \lambda_d = \frac{n_a \lambda_a}{n_d} = \boxed{243 \text{nm}}$

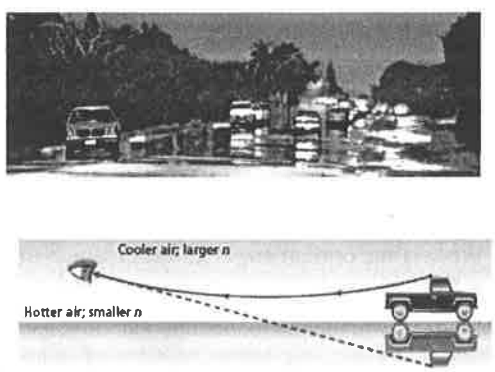
d) What is the speed of the light in the diamond?

$V_d = \frac{c}{n_d} = \frac{3.00 \times 10^8 \text{ m/s}}{2.42} = \boxed{1.24 \times 10^8 \frac{m}{s}}$

Optical Effects due to Refraction

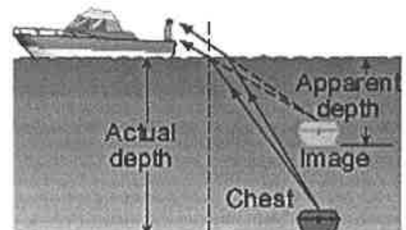
eye thinks rays from the pencil in water are in a different place due to refraction

Mirages

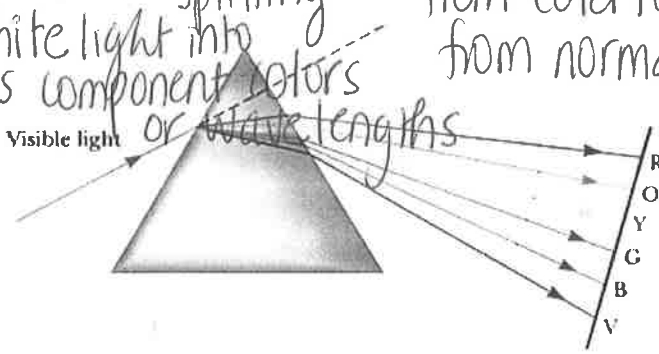


hot air has a lower "n", so as light goes from cold to hot air it speeds up or bends away from normal

Apparent Depth



Dispersion: splitting white light into its component colors or wavelengths



Red: bends the least away from normal

Violet: bends the most away from the normal

Explanation: Each frequency of light has a slightly different index of refraction or the amount it bends.

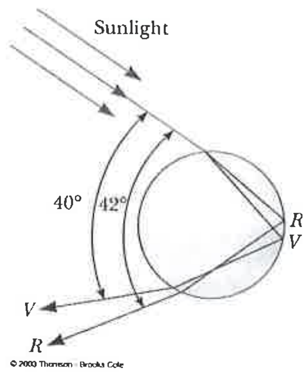
Dispersion Rule:

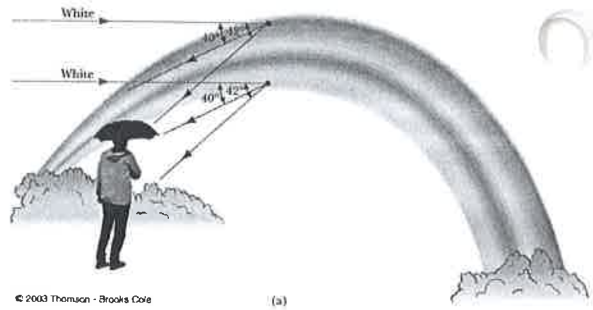
Red Resists Refraction

Blue Bends Best

Rainbows Caused by Dispersion

Rainbows are due to sunlight from over an observer's shoulder being refracted by water droplets in the air. Each color is refracted by a different amount with the result being the dispersion of the light into its component colors.



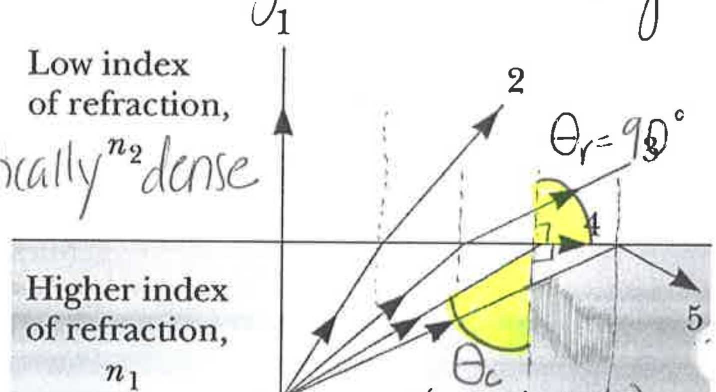


Total Internal Reflection

Total Internal Reflection: the complete reflection of light at a boundary (no refraction)

Conditions for Total Internal Reflection:

1. ray of light must travel from a medium that is more optically dense to a medium that is less optically dense
2. ray must strike the boundary at an angle greater than the critical angle



Critical Angle (θc): angle of incidence for which the angle of refraction 90°

Formula:

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

$= n_2 \sin(90°)$

$n_1 \sin\theta_c = n_2 (1)$ $\quad \theta_c = \sin^{-1}\left[\frac{n_2}{n_1}\right]$

$n_a = 1.00 \quad n_w = 1.33$

1. What is the critical angle as light exits from water into air?

$\theta_{c_w} = 48.8°$

$\sin^{-1}\left[\frac{n_a}{n_w}\right]$

$n_g = 1.50$

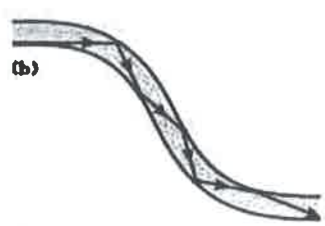
2. What is the critical angle as light exits from ~~water into~~ crown glass? into water.

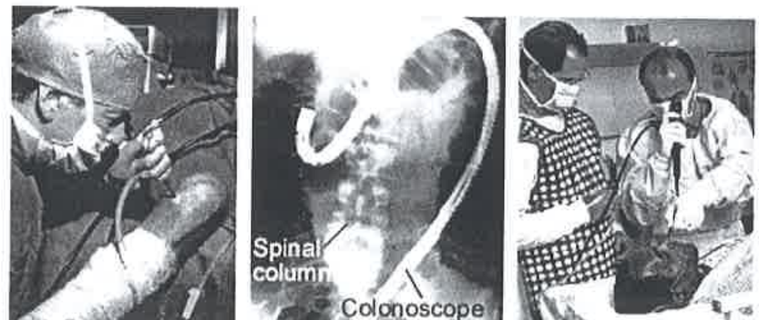
$\sin^{-1}\left[\frac{1.33}{1.50}\right]$

$= 62.5°$

Applications of Total Internal Reflection

Fiber Optic Cables





How do fiber optic cables work?

total internal reflection

light beam carrying coded signals strikes the boundary at an angle greater than the critical angle