

1. a. $\sin 30^\circ = 0.50$

b. $\sin 60^\circ = 0.87$

c. $\sin 45^\circ = 0.71$

d. $\sin 12.6^\circ = 0.218$

e. $\sin 74.4^\circ = 0.963$

f. $\sin 0^\circ = 0$

g. $\sin 90^\circ = 1$

h. $\sin 20^\circ = 0.34$

2. a. $\sin^{-1}(0.342) = 20.0^\circ$

b. $\sin^{-1}(0.643) = 40.0^\circ$

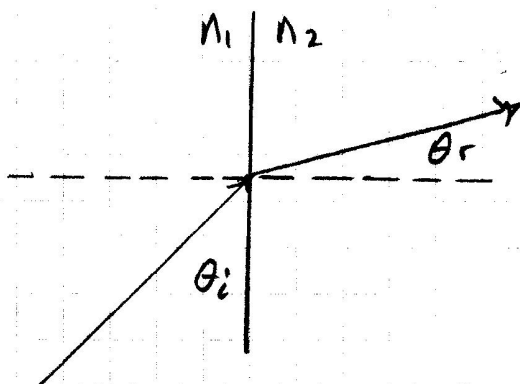
c. $\sin^{-1}(0.700) = 44.4^\circ$

d. $\sin^{-1}(0.333) = 19.5^\circ$

e. $\sin^{-1}(1.00) = 90^\circ$

3. $n_1 = 1.000$
Air

$n_2 = 2.42$
diamond



$\theta_i = \theta_1$
 $\theta_r = \theta_2$

$\theta_i = 60^\circ$

$\theta_r = ?$

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

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

$\theta_2 = \sin^{-1} \left(\frac{n_1}{n_2} \sin \theta_1 \right)$

$= \sin^{-1} \left(\frac{1.000 \sin 60^\circ}{2.42} \right)$

$= \sin^{-1}(0.35786)$

$= 21.0^\circ$

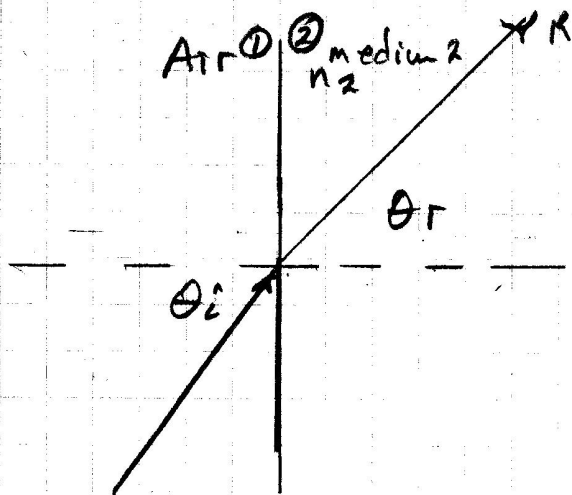
$\theta_r = 21.0^\circ$

4.

$n_2 = 1.30$

$n_1 = 1.000$

air



$\theta_r = 45^\circ$

$\theta_i = ?$ in air

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

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

$\theta_1 = \sin^{-1} \left(\frac{n_2}{n_1} \sin \theta_2 \right)$

$= \sin^{-1} \left(\frac{1.30}{1.000} \sin 45^\circ \right)$

$\theta_1 = 66.8^\circ$

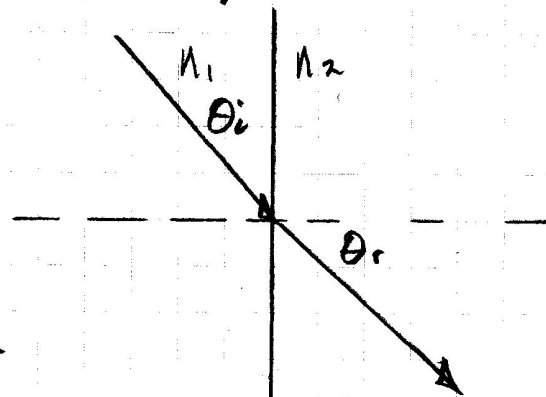
5.

$\theta_i = 50^\circ = \theta_1$

$\theta_r = 40^\circ = \theta_2$

$n_1 = 1.000$ air

$n_2 = ?$

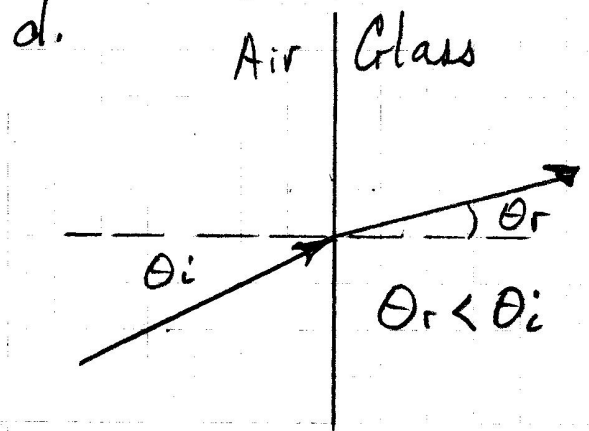
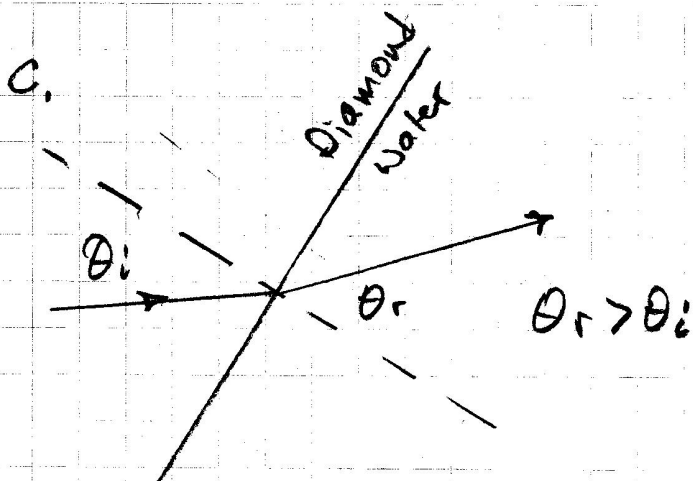
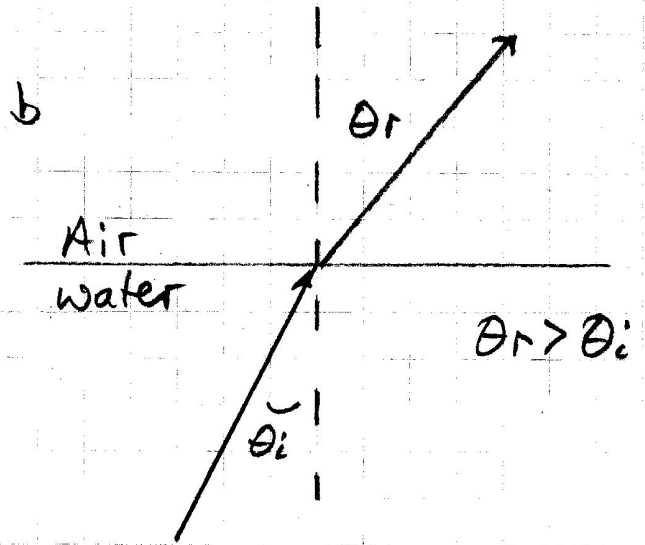
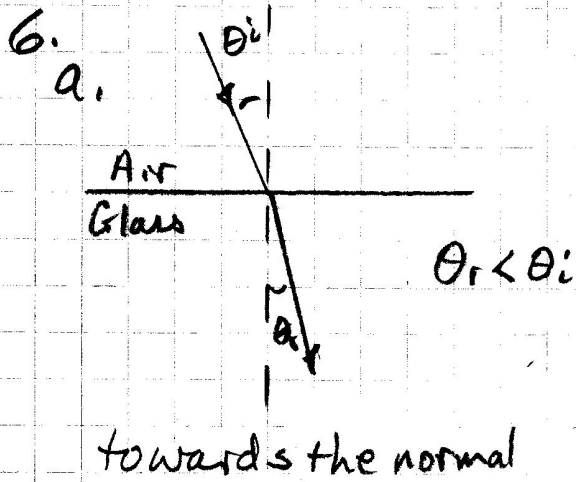


$n_1 \sin \theta_1 = n_2 \sin \theta_2$

$n_2 = n_1 \frac{\sin \theta_1}{\sin \theta_2} = 1.000 \frac{\sin(50^\circ)}{\sin 40^\circ} = 1.19$

$n_2 = 1.2$

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7. $\theta_i = \theta_1 = 30^\circ$ } air
 $n_1 = 1.000$

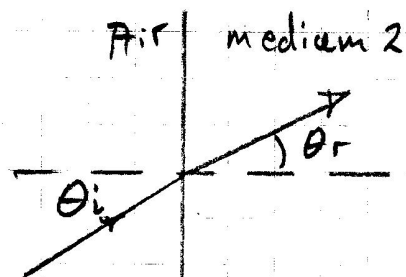
$\theta_2 = \theta_r = ?$

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

$\theta_2 = \sin^{-1} \left(\frac{n_1 \sin \theta_1}{n_2} \right) = \sin^{-1} \left(\frac{1.000 \sin 30^\circ}{n_2} \right) = \sin^{-1} \left(\frac{0.50}{n_2} \right)$

a. $\theta_2 = \sin^{-1} \left(\frac{0.5}{1.33} \right) = 22^\circ$

b. $\theta_2 = \sin^{-1} \left(\frac{0.5}{2.42} \right) = 11.9^\circ$



7. (cont'd)

$$\theta_2 = \sin^{-1}\left(\frac{0.5}{1.36}\right) = 21.6^\circ$$

$$\theta_2 = \sin^{-1}\left(\frac{0.5}{1.92}\right) = 15.1^\circ$$

$$8. \theta_2 = \theta_1 = 10^\circ \quad \theta_1 = \theta_i = ?$$

$$a. \quad n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$\theta_1 = \sin^{-1}\left(\frac{n_2 \sin \theta_2}{n_1}\right)$$

$$a. \quad n_1 = 2.42 \quad n_2 = 1.000$$

$$\theta_1 = \sin^{-1}\left(\frac{1.000 \sin 10^\circ}{2.42}\right) = 4.11$$

$$b. \quad n_1 = 1.000 \quad n_2 = 2.42$$

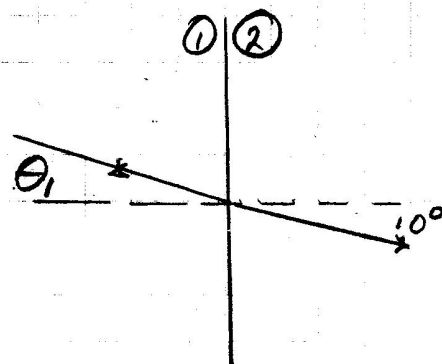
$$\theta_1 = \sin^{-1}\left(\frac{2.42 \sin 10^\circ}{1.000}\right) = 24.8^\circ$$

$$c. \quad n_1 = 1.000 \quad n_2 = 1.33$$

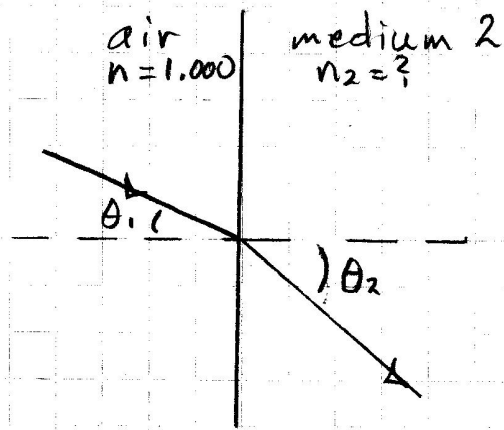
$$\theta_1 = \sin^{-1}\left(\frac{1.33 \sin 10^\circ}{1.000}\right) = 13.4^\circ$$

$$d. \quad n_1 = 1.33 \quad n_2 = 2.42$$

$$\theta_1 = \sin^{-1}\left(\frac{2.42 \sin 10^\circ}{1.33}\right) = 18.4^\circ$$



9.



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

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

a. $\theta_1 = 40^\circ$ $\theta_2 = 30^\circ$

$$n_2 = 1.000 \frac{\sin 40^\circ}{\sin 30^\circ} = 1.29$$

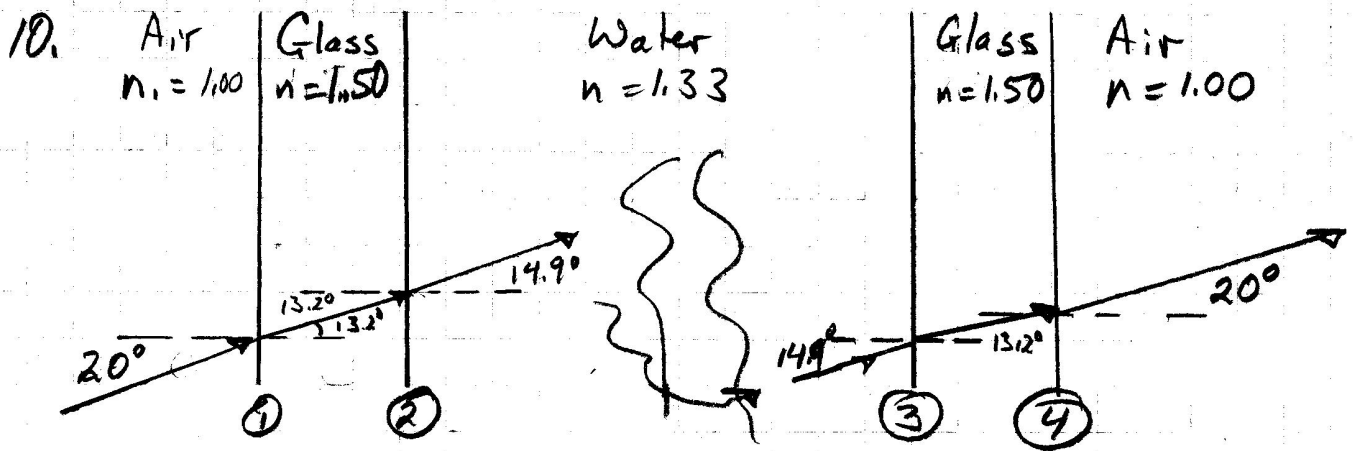
b. $\theta_1 = 30^\circ$ $\theta_2 = 12^\circ$

$$n_2 = 1.000 \frac{\sin 30^\circ}{\sin 12^\circ} = 2.40$$

c. $\theta_1 = 77^\circ$ $\theta_2 = 50^\circ$

$$n_2 = 1.000 \frac{\sin 77^\circ}{\sin 50^\circ} = 1.27$$

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Each interface has incident & refracted rays.

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

$$\theta_2 = \sin^{-1} \left(\frac{n_1 \sin \theta_1}{n_2} \right)$$

Interface ① $n_1 = 1.000$ $n_2 = 1.50$ $\theta_i = 20^\circ$

$$\theta_2 = \sin^{-1} \left(\frac{1.000 \sin 20^\circ}{1.50} \right) = 13.2^\circ \quad \boxed{\theta_r = 13.2^\circ}$$

Interface ② $n_1 = 1.50$ $n_2 = 1.33$ $\theta_i = 13.2^\circ$

The previous angle of refraction becomes the angle of incidence at the next interface.

$$\theta_2 = \sin^{-1} \left(\frac{1.50 \sin 13.2^\circ}{1.33} \right) = 14.9^\circ \quad \boxed{\theta_r = 14.9^\circ}$$

Interface ③ $n_1 = 1.33$ $n_2 = 1.50$ $\theta_i = 14.9^\circ$

$$\theta_2 = \sin^{-1} \left(\frac{1.33 \sin 14.9^\circ}{1.50} \right) = 13.2^\circ \quad \boxed{\theta_r = 13.2^\circ}$$

Interface ④ $n_1 = 1.50$ $n_2 = 1.00$ $\theta_i = 13.2^\circ$

$$\theta_2 = \sin^{-1} \left(\frac{1.50 \sin 13.2^\circ}{1.000} \right) = 20^\circ \quad \boxed{\theta_r = 20^\circ}$$

11. $v = 2.67 \times 10^8 \text{ m/s}$

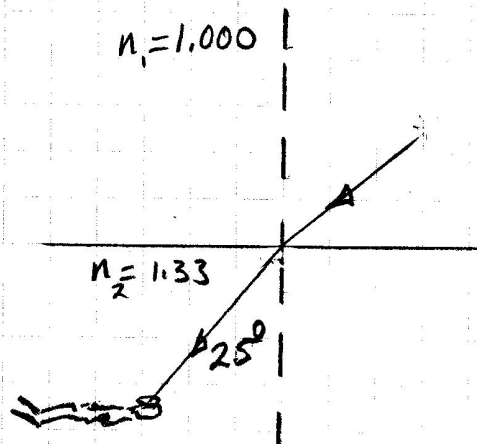
$$n = \frac{c}{v} = \frac{3.00 \times 10^8 \text{ m/s}}{2.67 \times 10^8 \text{ m/s}} = 1.12$$

$$n = 1.12$$

Water has an index of refraction

$n = 1.33$ water has a higher index of refraction.

12.



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

$$\theta_1 = ? \quad \theta_2 = 25^\circ$$

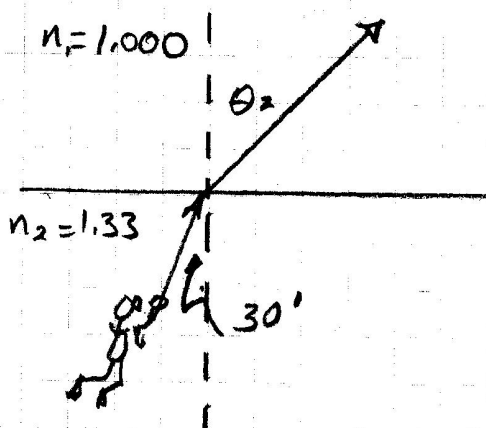
$$n_1 = 1.000 \quad n_2 = 1.33$$

$$\theta_1 = \sin^{-1} \left(\frac{n_2 \sin \theta_2}{n_1} \right)$$

$$= \sin^{-1} \left(\frac{1.33 \sin 25^\circ}{1.000} \right)$$

$$\theta_1 = 34.1^\circ$$

13.



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

$$\theta_1 = 30^\circ \quad \theta_2 = ?$$

$$n_1 = 1.33 \quad n_2 = 1.000$$

$$\theta_2 = \sin^{-1} \left(\frac{n_1 \sin \theta_1}{n_2} \right)$$

$$\theta_2 = \sin^{-1} \left(\frac{1.33 \sin 30^\circ}{1.000} \right) = 41.7^\circ$$

$$\theta_2 = 41.7^\circ$$