Physics 30 – Lesson 8
Refraction of Light

/ 92

Practice problems

1.

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

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

$$\theta_2 = \sin^{-1}\left(\frac{1.00 \sin 24^\circ}{1.33}\right)$$

$$\boxed{\theta_2 = 17.8^\circ}$$

2.

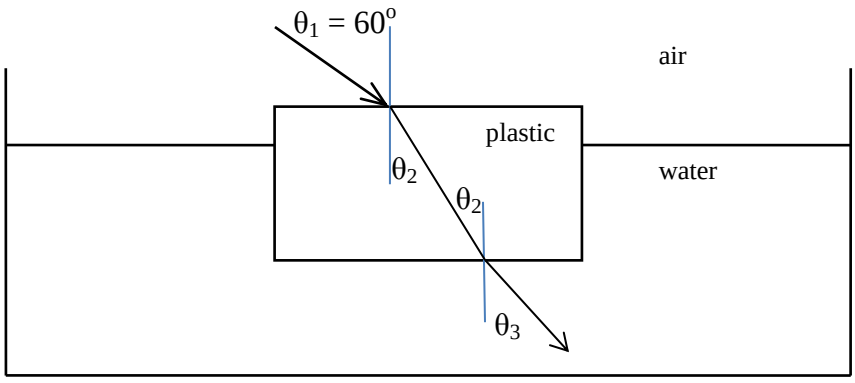
$$\frac{n_2}{n_1} = \frac{\sin\theta_1}{\sin\theta_2}$$

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

$$\theta_2 = \sin^{-1}\left(\frac{1.52 \sin 20^\circ}{1.00}\right)$$

$$\boxed{\theta_2 = 31.3^\circ}$$

3.



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

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

$$\theta_2 = \sin^{-1}\left(\frac{1.00 \sin 60^\circ}{1.52}\right)$$

$$\theta_2 = 34.733^\circ$$

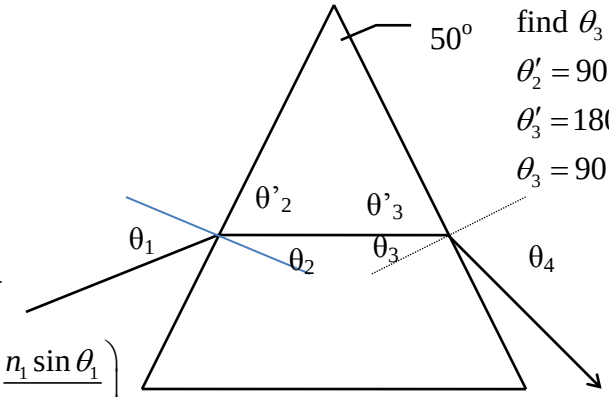
$$\frac{n_2}{n_3} = \frac{\sin\theta_3}{\sin\theta_2}$$

$$\theta_3 = \sin^{-1}\left(\frac{n_2 \sin\theta_2}{n_3}\right)$$

$$\theta_3 = \sin^{-1}\left(\frac{1.52 \sin 34.733^\circ}{1.33}\right)$$

$$\boxed{\theta_3 = 40.6^\circ}$$

4.



find θ_3

$\theta_2' = 90 - \theta_2 = 90 - 25.374 = 64.626$

$\theta_3' = 180 - 50 - \theta_2' = 180 - 50 - 64.626 = 65.374$

$\theta_3 = 90 - \theta_3' = 90 - 65.374 = 24.626$

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

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

$$\theta_2 = \sin^{-1}\left(\frac{1.00\sin 40^\circ}{1.50}\right)$$

$$\theta_2 = 25.374^\circ$$

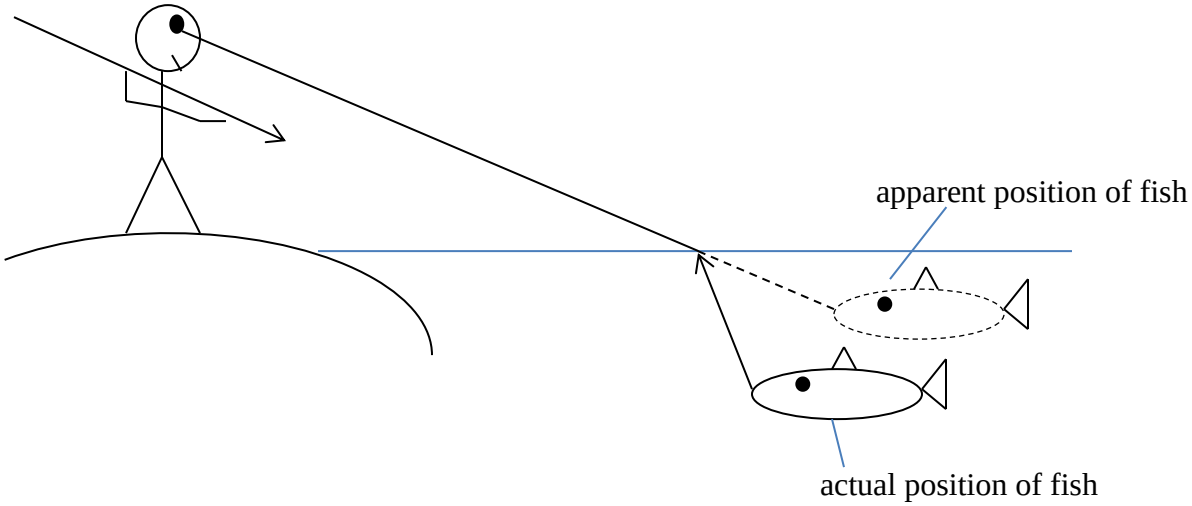
$$\frac{n_3}{n_4} = \frac{\sin\theta_4}{\sin\theta_3}$$

$$\theta_4 = \sin^{-1}\left(\frac{n_3 \sin\theta_3}{n_4}\right)$$

$$\theta_4 = \sin^{-1}\left(\frac{1.50\sin 24.626^\circ}{1.00}\right)$$

$$\boxed{\theta_4 = 38.7^\circ}$$

5.



6. At the critical incident angle the angle of refraction is 90°.

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

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

$$\theta_1 = \sin^{-1}\left(\frac{1.00\sin 90^\circ}{1.50}\right)$$

$$\boxed{\theta_c = 41.8^\circ}$$

7. At the critical incident angle the angle of refraction is 90^{o}.

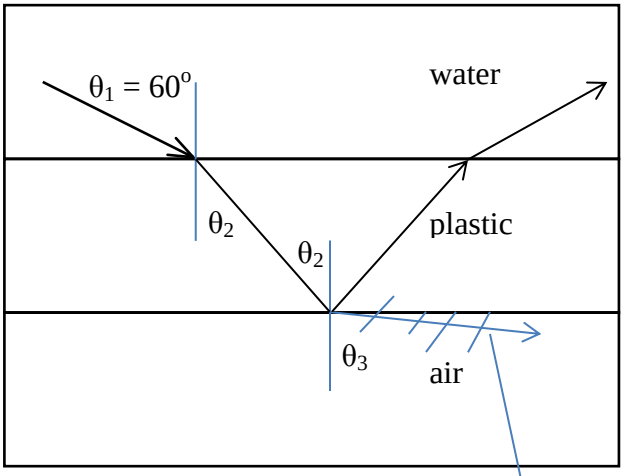
$$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1}$$

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

$$n_1 = \frac{1.33\sin 90^{\circ}}{\sin 56.2^{\circ}}$$

$$\boxed{n_1 = 1.60}$$

8. The angle of refraction in water is 60^{o} . If $n_{plastic} = 1.62$ trace the ray path through the system below.



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

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

$$\theta_2 = \sin^{-1}\left(\frac{1.33\sin 60^{\circ}}{1.62}\right)$$

$$\theta_2 = 45.32^{\circ}$$

$$\frac{n_2}{n_3} = \frac{\sin\theta_3}{\sin\theta_2}$$

$$\theta_3 = \sin^{-1}\left(\frac{n_2 \sin\theta_2}{n_3}\right)$$

$$\theta_3 = \sin^{-1}\left(\frac{1.62\sin 45.33^{\circ}}{1.00}\right)$$

$$\boxed{\theta_3 = \text{undefined} \therefore \text{ total internal reflection occurs}}$$

Assignment

1) $\frac{n_2}{n_1} = \frac{v_1}{v_2}$

/2 $\frac{n_2}{1.00} = \frac{3.00 \times 10^8 \, m/s}{2.0 \times 10^8 \, m/s}$

$\boxed{n_2 = 1.5}$

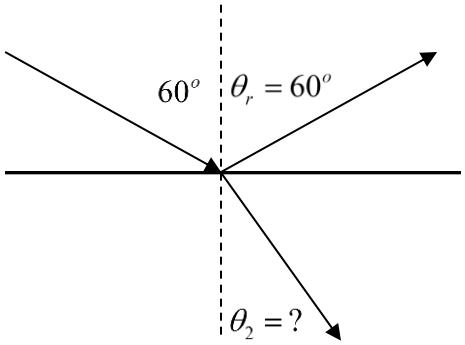
2) $\frac{v_{violet}}{v_{air}} = \frac{n_{air}}{n_{violet}}$

/4 $v_{violet} = \frac{n_{air} v_{air}}{n_{violet}}$

$v_{violet} = \frac{(1.00)3.0 \times 10^8 \, m/s}{1.53}$ $\quad$ $v_{red} = \frac{(1.00)3.0 \times 10^8 \, m/s}{1.52}$

$\boxed{v_{violet} = 1.96 \times 10^8 \, m/s}$ $\quad$ $\boxed{v_{red} = 1.97 \times 10^8 \, m/s}$

3)



/3 $\sin\theta_2 = \frac{n_1 \sin\theta_1}{n_2}$

$\theta_2 = \sin^{-1} \frac{1.00 \sin 60}{1.33}$

$\boxed{\theta_2 = 41^o}$

4) $\sin\theta_2 = \frac{n_1 \sin\theta}{n_2}$

/3 $\theta_2 = \sin^{-1} \frac{1.00 \sin 30}{1.52}$

$\boxed{\theta_2 = 19^o}$

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

/3 $n_2 = \frac{1.00 \sin 20}{\sin 10}$

$\boxed{n_2 = 1.97}$

6) /3

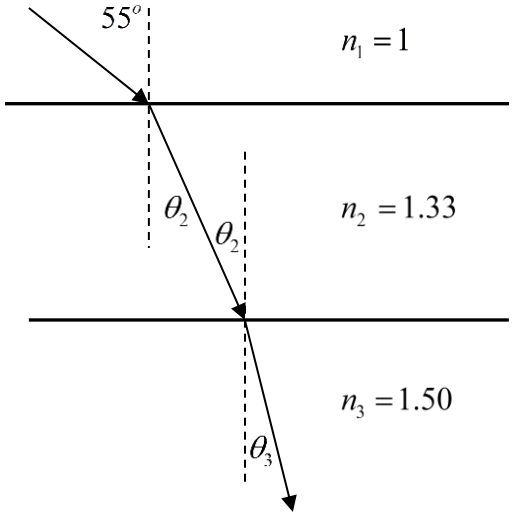
$$\frac{n_1}{n_2} = \frac{\lambda_2}{\lambda_1}$$

$$\lambda_2 = \frac{n_1 \lambda}{n_2}$$

$$\lambda_2 = \frac{1.0(570nm)}{1.33}$$

$$\boxed{\lambda_2 = 429nm}$$

7) /4



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

$$\theta_2 = \sin^{-1}\frac{1(\sin 55^o)}{1.33}$$

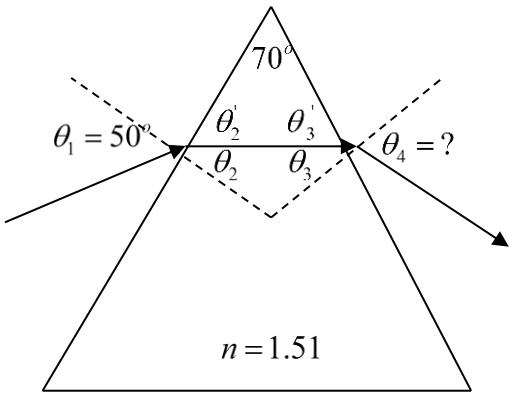
$$\theta_2 = 38^o$$

$$\sin\theta_3 = \frac{n_2 \sin\theta_2}{n_3}$$

$$\theta_3 = \sin^{-1}\frac{1.33(\sin 38^o)}{1.50}$$

$$\boxed{\theta_2 = 33^o}$$

8) /6



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

$$\theta_2 = \sin^{-1}\frac{1.00\sin 50.0}{1.51}$$

$$\theta_2 = 30.49^o$$

$$\theta_2' = 90 - 30.49 = 59.51$$

$$\theta_3' = 180 - \theta_i' - 70 = 180 - 59.51 - 70$$

$$\theta_3' = 50.49^o$$

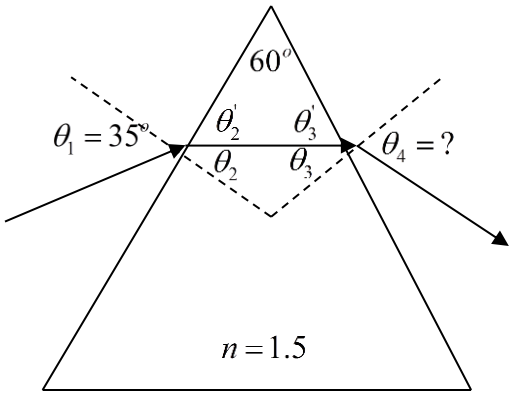
$$\theta_3 = 90 - 50.49 = 39.51^o$$

$$\sin\theta_4 = \frac{n_3 \sin\theta_3}{n_4}$$

$$\theta_4 = \sin^{-1}\frac{1.51(\sin 39.51^o)}{1.00}$$

$$\boxed{\theta_4 = 73.9^o}$$

9)



/6

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

$$\theta_2 = \sin^{-1}\frac{1(\sin 35)}{1.5}$$

$$\theta_2 = 22.5^o$$

$$\theta_3 = 60^o - 22.5^o = 37.5^o$$

$$\sin\theta_4 = \frac{n_3 \sin\theta_3}{n_4}$$

$$\theta_4 = \sin^{-1}\frac{1.5\sin 37.5^\circ}{1.00}$$

$$\boxed{\theta_4 = 66^o}$$

10)

$\theta_1 = 20^o$

$n_1 = 1.33$

$n_2 = 1.0$

$\theta_2 = ?$

/8

A)

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

$$\theta_2 = \sin^{-1}\frac{1.33\sin 20}{1.0}$$

$$\boxed{\theta_2 = 27^o}$$

B)

set $\theta_2 = 90^\circ$

$$\sin\theta_1 = \frac{n_2 \sin 90}{n_1}$$

$$\theta_1 = \sin^{-1}\frac{1.0}{1.33}$$

$$\boxed{\theta_1 = 48.8^o}$$

11)

a) in glass

$$\sin\theta_r = \frac{n_i \sin\theta_i}{n_r}$$

$$\theta_r = \sin^{-1}\frac{1.33\sin 30}{1.50}$$

$$\boxed{\theta_r = 26.3^o}$$

in air

$$\sin\theta_r = \frac{n_i \sin\theta_i}{n_r}$$

$$\theta_r = \sin^{-1}\frac{1.50\sin 26.3}{1.00}$$

$$\boxed{\theta_r = 42^o}$$

b) in glass

$$\sin\theta_r = \frac{n_i \sin\theta_i}{n_r}$$

$$\theta_r = \sin^{-1}\frac{1.33\sin 52}{1.50}$$

$$\boxed{\theta_r = 44.3^o}$$

in air

$$\sin\theta_r = \frac{n_i \sin\theta_i}{n_r}$$

$$\theta_r = \sin^{-1}\frac{1.50\sin 44.3}{1.00}$$

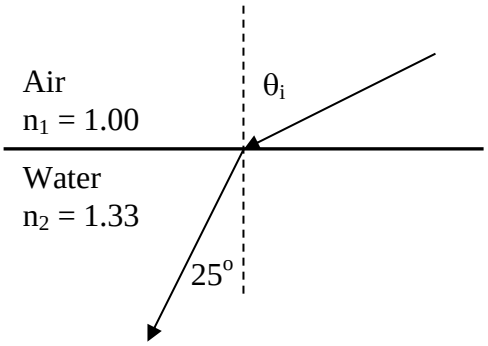
θ_r = error, not possible

$\boxed{\therefore \text{ no refracted ray}}$

/8

12)

/3



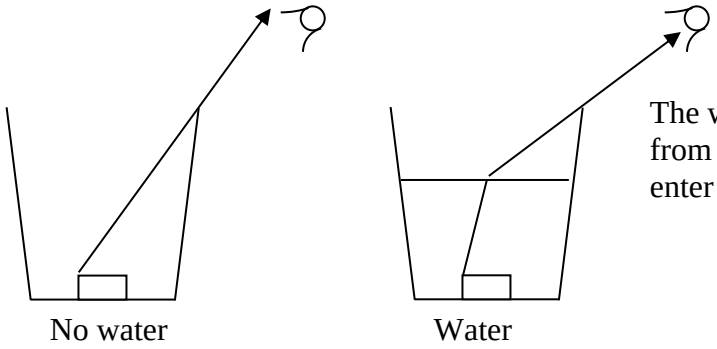
$$\sin\theta_i = \frac{n_2 \sin\theta_2}{n_i}$$

$$\theta_i = \sin^{-1}\frac{1.33\sin 25}{1.00}$$

$$\boxed{\theta_i = 34^o}$$

13)

/3



The water refracts the light from the penny so it can enter the eye

14) Hot air has a slightly different refraction index than cool air and therefore causes light to bend differently. The refraction is not uniform resulting in irregular bending of light.

/2

15)

/3

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

$$n_1 = \frac{1.0\sin 90}{\sin 40.5}$$

$$\boxed{n_1 = 1.54}$$

16)

/3

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

$$n_1 = \frac{1.0\sin 90}{\sin 61}$$

$$\boxed{n_1 = 1.14}$$

17)

/3

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

$$\theta_2 = \sin^{-1}\frac{5/2}{3/2}$$

$$\boxed{\theta_2 = 37^o}$$

18)

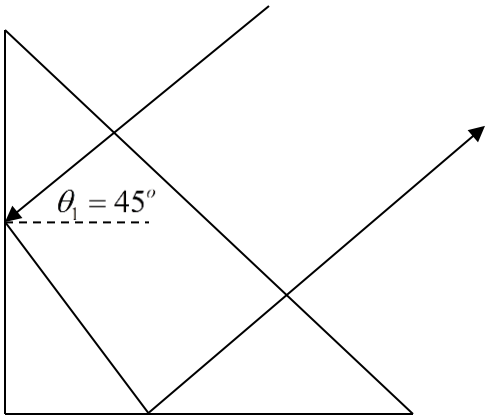
$$\sin\theta_2 = \frac{n_1 \sin\theta_1}{n_2}$$

$$\sin\theta_2 = \frac{1.50 \sin 45}{1.0}$$

/5

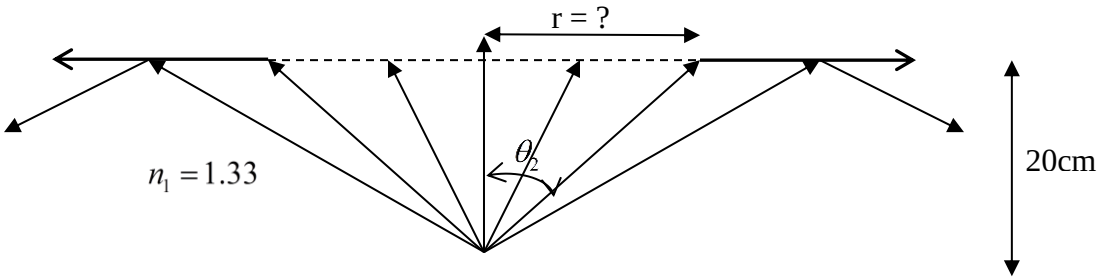
$\sin\theta_2 = 1.06 \leftarrow$ *impossible*

$\therefore$ total internal reflection



19)

/8



The rays that are not refracted are totally internally reflected

$$\theta_2 = \sin^{-1}\frac{n_2 \sin 90^o}{n_1}$$

$$\theta_2 = \sin^{-1}\frac{1.0 \sin 90^o}{1.33}$$

$$\theta_2 = 48.8^o$$

$$\tan\theta_2 = \frac{r}{20}$$

$$r = 20\tan\theta_2$$

$$r = 20\tan 48.8$$

$$r = 22.81cm$$

$$area = \pi r^2 = \pi(22.81cm)^2$$

$$\boxed{area = 1634cm^2}$$

20) The relationship between n_1, n_2, θ_1 and θ_2 is:

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

since $n_1 = 1.00$

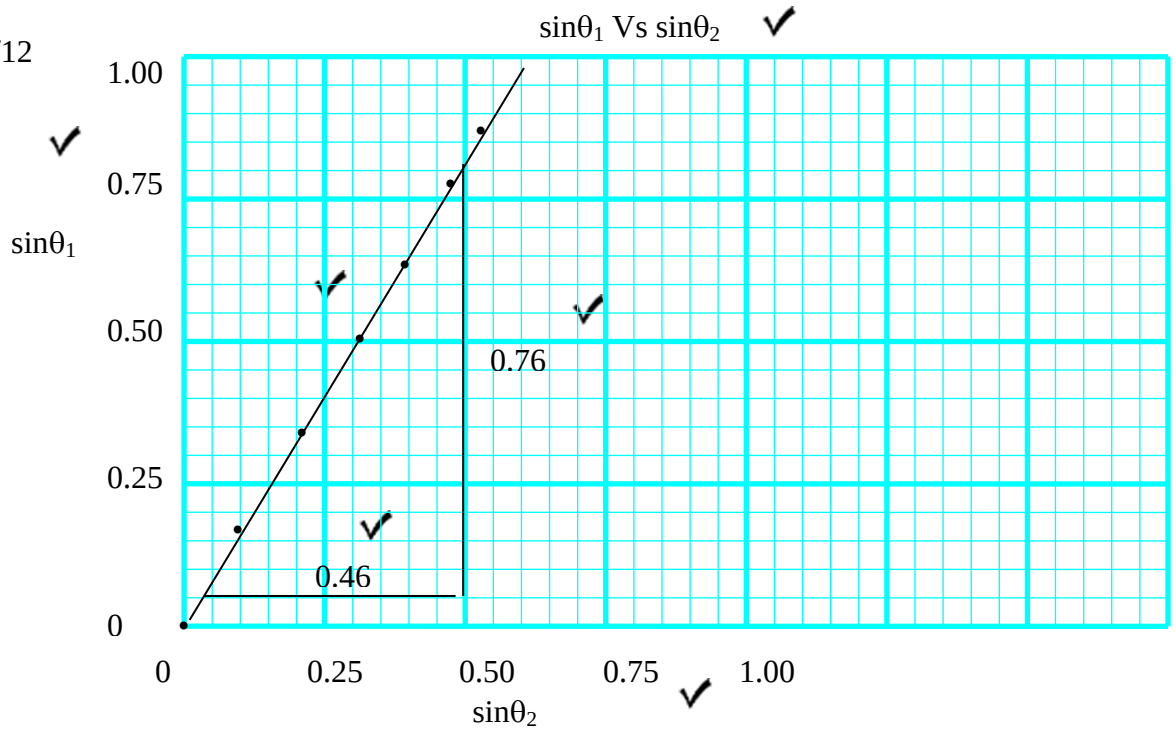
$$n_2 = \frac{\sin\theta_1}{\sin\theta_2}$$ $$slope = \frac{rise}{run}$$ ✓

Calculate the sine of the angles:

θ_1	$\sin\theta_1$	θ_2	$\sin\theta_2$
0^o	0.00	0^o	0.00
10^o	0.17	6^o	0.10
20^o	0.34	12^o	0.21
30^o	0.50	18^o	0.31
40^o	0.64	23^o	0.39
50^o	0.77	28^o	0.47
60^o	0.87	32^o	0.53

✓ ✓

/12



✓ ✓ ✓ ✓ ✓ ✓ ✓

$$slope = \frac{rise}{run}$$ ✓

$$n_2 = \frac{\Delta\sin\theta_1}{\Delta\sin\theta_2} = \frac{0.76}{0.47} = 1.6$$

$$\boxed{n_2 = 1.6}$$ ✓