FULLY WORKED SOLUTIONS

Chapter 15: Seeing the light

Chapter questions

1. $\lambda = v/f = 30/200 = 0.15$ m

2. $\lambda = 6$ m, $f = 1/3$ Hz

   $v = f\lambda = 6 \times 1/3 = 2$ m s^{-1}

3. $\lambda = 1.3$ m, $v = 330$ m s^{-1}

   $f = v/\lambda = 330/1.3 = 254$ Hz

4. $n_X = 3 \times 10^8/2.1 \times 10^8 = 1.43$

5. f in window glass $= f$ in air

   $f = v/\lambda = 3 \times 10^8/4.20 \times 10^{-7} = 7.14 \times 10^{14}$ Hz

6. $v = c/n_{diamond} = 3 \times 10^8/2.42 = 1.24 \times 10^8$ m s^{-1}

7. $n_w = 1.33$, $n_g = 1.53$, $\theta_g = 49°$

   $\sin \theta_w = n_g \sin \theta_g/n_w = 1.53 \times \sin 49°/1.33 = 0.87$

   $\theta_w = 60°$

8. $\sin \theta_w = n_a \times \sin \theta_a/n_w = 1 \times \sin 15°/1.33 = 0.195$

   $\theta_w = 11.2°$

9. $\theta_a = 60°$, $n_a = 1$, $n_g = 1.51$

   $\sin \theta_g = n_a \sin \theta_a/n_g = 1 \times \sin 60°/1.51 = 0.574$

   $\theta_g = 35°$

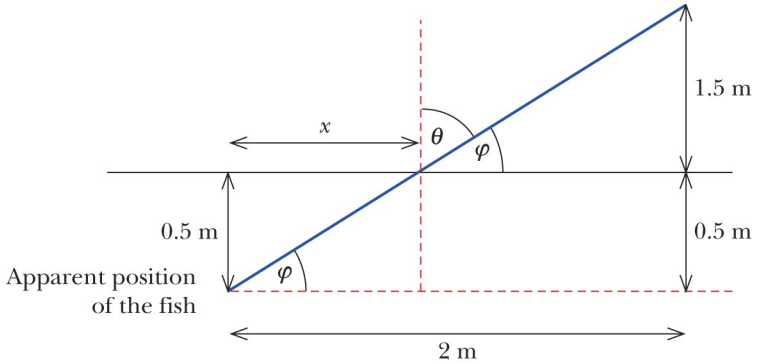
   $x = 4 \tan 35° = 2.8$ cm

Review questions

9. $v = 4$ m s^{-1}, f $= 10$ s^{-1}

   $$\lambda = \frac{v}{f} = \frac{4}{10} = 0.4 \text{ m}$$

10. We can construct the following diagram:



Let x be the horizontal distance of the fish from the normal.

$$\tan \varphi = \frac{2}{2} = 1$$

$$\varphi = 45°$$

$$x = \frac{0.5}{\tan 45°} = 0.5 \text{ m}$$

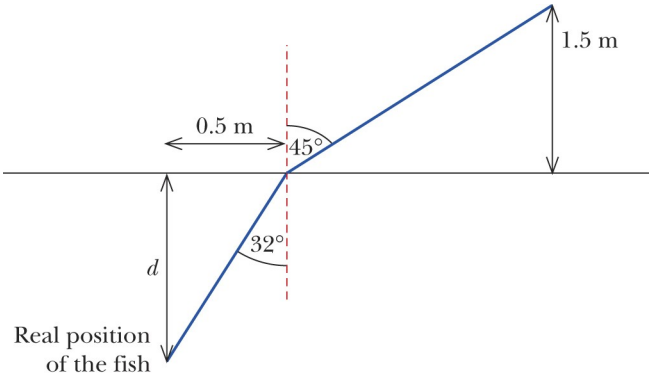
$\theta_1 = 90° - 45° = 45°$

$n_1 = 1, n_2 = 1.33, \theta_1 = 45°$

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

$1 \times \sin 45° = 1.33 \sin \theta_2$

$\theta_2 = 32°$



$$\tan 32° = \frac{0.5}{d}$$

$$d = \frac{0.5}{\tan 32°} = 0.8 \text{ m}$$

Therefore, the fish is located 0.8 m below the surface of the water.

12. (a) $\theta_1 = 30°, n_1 = 1, n_2 = 1.33$

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

$1 \times \sin 30° = 1.33 \times \sin \theta_2$

$\sin \theta_2 = 0.38$

$\theta = 22°$

(b) $\theta_1 = 40°, n_1 = 1, n_2 = 1.33$

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

$1 \times \sin 40° = 1.33 \times \sin \theta_2$

$\theta = 29°$

Therefore θ_2 is 7° larger.

13. 1 m

14. H I M O T U V W X

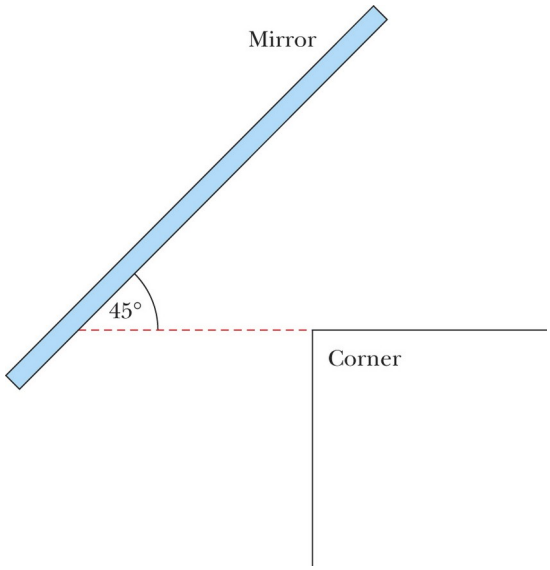
15. (a) Plot sin θ_1 on the y-axis and sin θ_2 on the x-axis. The gradient of the line of best fit will be equal to n_2/n_1 or, in this case, n_2.

(b)

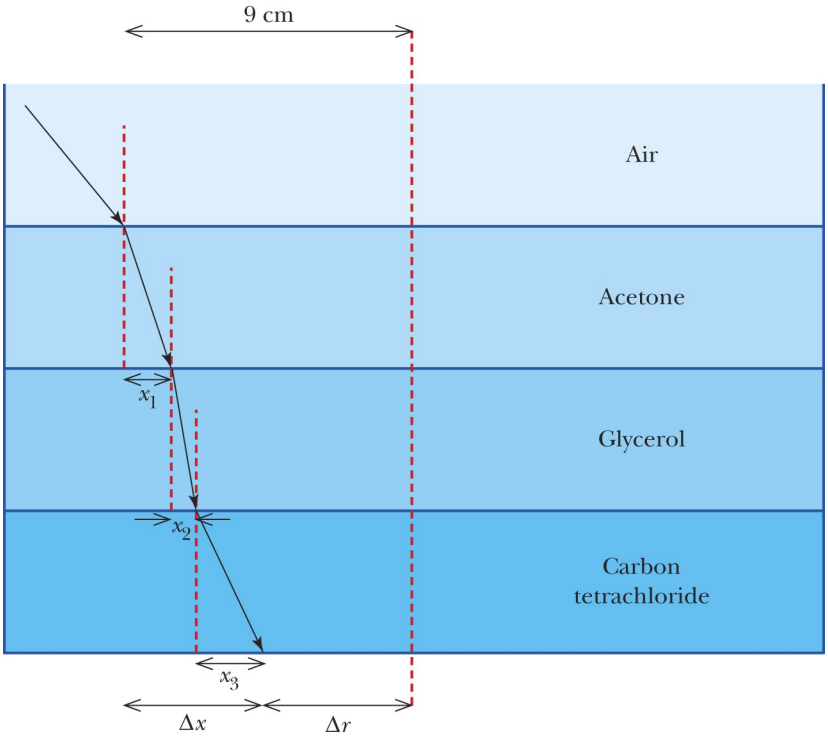
θ_1	θ_2	sin θ_1	sin θ_2	sin θ_1/sin θ_2
0	0	0	0	
10	6	0.174	0.105	1.6
20	12	0.342	0.208	1.6
30	18	0.5	0.309	1.6
40	24	0.643	0.407	1.6
50	29	0.766	0.485	1.6
60	33	0.866	0.545	1.6

Therefore $n_2 = 1.6$.

16.



17.



In going from air to the acetone layer:

$n_{air} \sin \theta_{air} = n_{acetone} \sin \theta_{acetone}$

$1 \times \sin 25° = 1.357 \times \sin \theta_{aetone}$

$\sin \theta_{aetone} = 0.311$

$\theta_{acetone} = 18.14°$

$x_1 = 1.5 \times \tan 18.14° = 0.492$ cm

In going from the acetone layer to the glycerol layer:

$n_{acetone} \sin \theta_{acetone} = n_{glycerol} \sin \theta_{glycerol}$

$1.357 \times \sin 18.14° = 1.474 \times \sin \theta_{glyerol}$

$\theta_{glycerol} = 16.6°$

$x_2 = 1.5 \times \tan 16.6° = 0.449$ cm

In going from the glycerol layer to the carbon tetrachloride layer:

$n_{glycerol} \sin \theta_{glycerol} = n_{carbon\ tetrachloride} \sin \theta_{carbon\ tetrachloride}$

$1.4746 \times \sin 16.6° = 1.4601 \times \sin \theta_{carbon\ tetrachloride}$

$\theta_{carbon\ tetrachloride} = 16.8°$

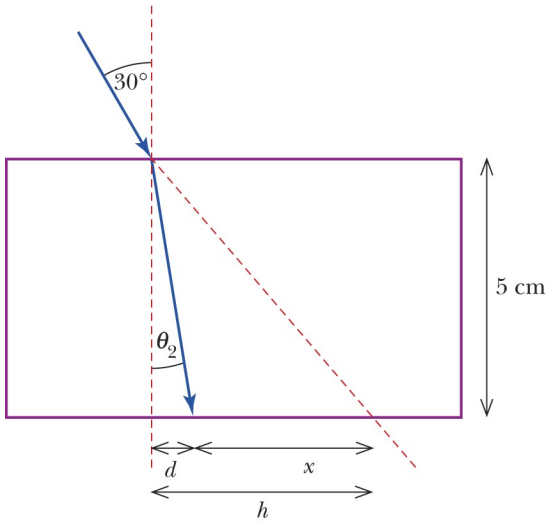
$x_3 = 1.5 \times \tan 16.8° = 0.452$ cm

$\Delta x = x_1 + x_2 + x_3 = 0.492 + 0.449 + 0.452 = 1.4$ cm

$\Delta r = 9$ cm $- 1.4$ cm $= 7.6$ cm.

The ray emerges 7.6 cm from the centre of the beaker.

18.



$\tan 30° = \frac{h}{5}$

$h = 5 \tan 30° = 2.88$ cm

To determine refracted angle:

$1 \sin 30° = 1.42 \sin \theta_2$

$\theta_2 = 20.6°$

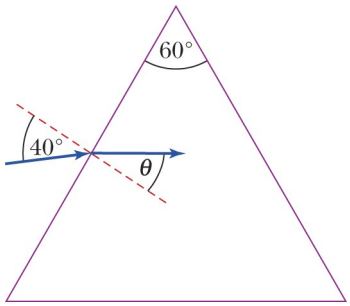
We can see in the diagram above that:

$\tan 20.6^\circ = \frac{d}{5}$

$d = 5 \tan 20.6^\circ = 1.88 \text{ cm}$

$x = h - d = 2.88 - 1.88 = 1$ cm

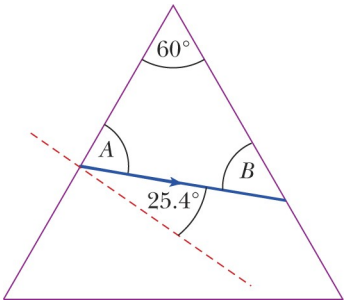
19.



$n_{air} \sin 40° = n_{glass} \sin \theta$

$1 \sin 40° = 1.50 \sin \theta$

$\theta = 25.4°$

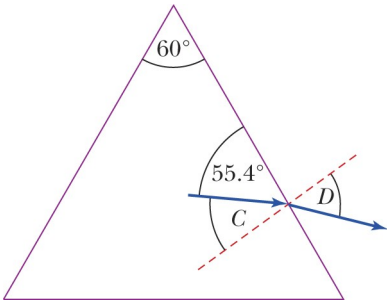


As $A + 25.4° = 90°$, then $A = 64.6°$

Also, as $60° + A + B = 180°$,

$60° + 64.6° + B = 180°$

so $B = 55.4°$



$C + 55.4° = 90°$, so $C = 34.5°$

$n_{glass} \sin C = n_{air} \sin D$

$1.50 \sin 34.5° = 1 \sin D$

$0.85 = \sin D°$

$D = 58.2°$