Solutions to Problems Sets of Chapter 23

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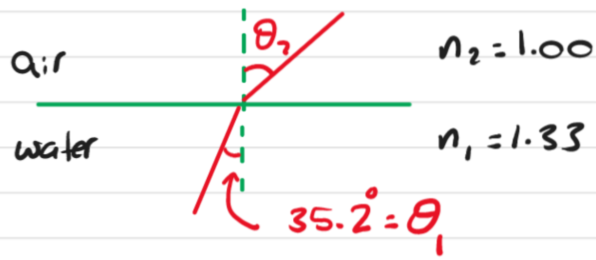
Q25] $n = \frac{c}{v} \Rightarrow v = \frac{c}{n}$, $c = 3.00 \times 10^8$ m/s

Material	Index of refraction	v (m/s)
Ethyl Alcohol	1.36	2.20×10^8
Lucite	1.52	1.97×10^8
Crown Glass	1.5	2.00×10^8

Q26] $v = 0.82\, v_{water} \Rightarrow \frac{c}{n} = 0.82 \frac{c}{n_{water}}$

$\therefore n = \frac{1}{0.82} n_{water} = \frac{1.33}{0.82} = 1.62$

Q28]



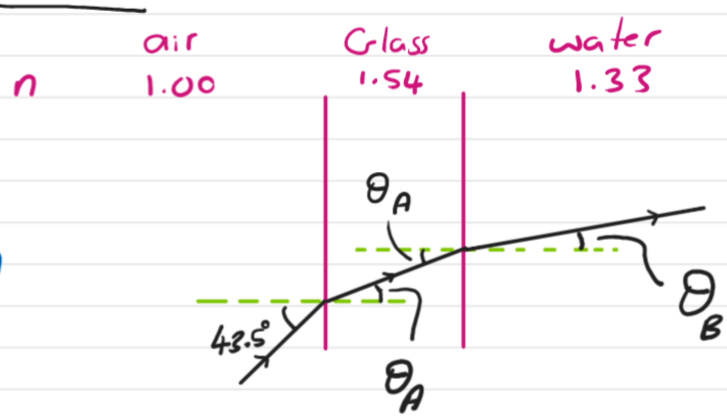
Snell's law

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

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

$= \frac{1.33}{1.00} \sin 35.2° = 50.1°$

Q31]



a) air → glass

$n_{air} \sin 43.5 = n_w \sin\theta_A$

$\sin\theta_A = \frac{1}{1.54} \sin 43.5°$

$\therefore \theta_A = 26.6°$

b) glass → water ⇒

$n_{glass} \sin\theta_A = n_w \sin\theta_B$

$\sin\theta_B = \frac{1.54}{1.33} \sin 26.6° \Rightarrow \sin\theta_B = 31.2°$

c) air → water

$n_{air} \sin 43.5^\circ = n_{water} \sin\theta$

$\sin\theta = \frac{1}{1.33} \sin 43.5^\circ \Rightarrow \theta = 31.2^\circ$ same as in (b).

Note air → glass → water

air → glass
$n_{air} \sin 43.5 = n_{glass} \sin\theta_A$ — (1)

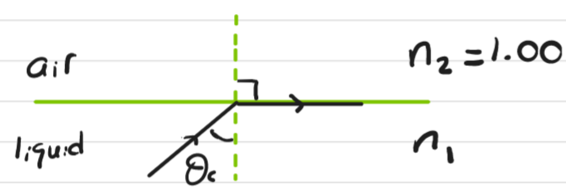
glass → water
$n_{glass} \sin\theta_A = n_w \sin\theta$ — (2)

From (1) and (2) $\Rightarrow$ $n_{air} \sin 43.5 = n_w \sin\theta$
which is exactly what we got when light passed from air → water directly.
So, passing through glass has no effect on the refraction angle through water.

the refraction angle through water.

Q34]

For total internal reflection
$n_2 < n_1$

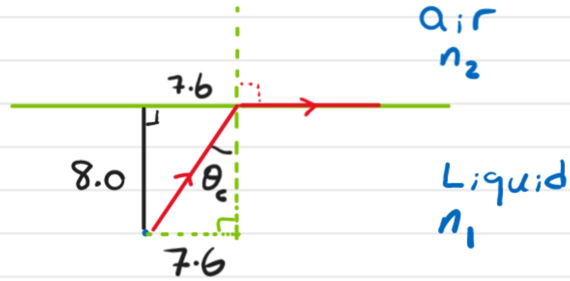


$n_1 \sin\theta_c = n_2 \sin 90^\circ$

$\sin\theta_c = \sin 47.2^\circ = \frac{n_2}{n_1} \sin 90^\circ$

$\therefore n_1 = \frac{n_2}{\sin 47.2^\circ} = \frac{1}{\sin 47.2^\circ} = \underline{1.36}$

Q36]



From figure:

$$\tan\theta_c = \frac{7.6}{8.0} = 43.53^\circ$$

$$n_1 \sin\theta_c = n_2 \sin 90^\circ$$

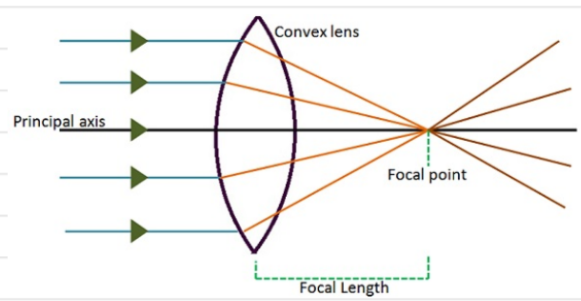
$$\therefore \quad n_1 = \frac{1}{\sin\theta_c} = \frac{1}{\sin 43.53^\circ}$$

$$n_1 = 1.45$$

Q40]

Rays coming from the sun are parallel as shown.

The sun (object) is so far from the lens $\Rightarrow d_o \to \infty$



$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\frac{1}{f} = \frac{1}{\infty} + \frac{1}{d_i} \Rightarrow \frac{1}{f} = 0 + \frac{1}{d_i} \Rightarrow f = d_i = 16.5 \text{ cm}$$

Image is formed at the focal point.

$$P = \frac{1}{f} = \frac{1}{16.5\times10^{-2}} = 6.1 \text{ D}$$

← diopter $\left(\frac{1}{m}\right)$

Q42] $d_o = 1.55$ m

$d_i = 48.3$ cm $= 0.483$ m

on other side of the lens ⇒ real image and the lens is a converging lens and d_i is positive

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o} = \frac{1}{0.483} + \frac{1}{1.55}$$

$\therefore f = 0.368$ m

Q45] converging lens ⇒ $f = +28$ cm

stamp ⇒ real object ⇒ $d_o = 16$ cm

$d_o < f$ ⇒ image must be virtual

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o} \Rightarrow \frac{1}{28} = \frac{1}{d_i} + \frac{1}{16}$$

$$\therefore \frac{1}{d_i} = \frac{1}{28} - \frac{1}{16} \Rightarrow d_i \simeq -27 \text{ cm}$$

d_i is negative ⇒ virtual object.

$$m = -\frac{d_i}{d_o} = -\frac{(-27)}{16} \simeq 1.7$$

m is positive ⇒ upright virtual image.

$|m| > 1$ ⇒ magnified.

Q48] real image ⇒ converging lens.

(a) $f = +5.00$ cm

image is real and inverted (converging lens)

$\therefore m = -\frac{d_i}{d_o} = -2.5$

$\therefore d_i = 2.5 d_o$

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o} \Rightarrow \frac{1}{5.00} = \frac{1}{2.5 d_o} + \frac{1}{d_o} = \frac{1}{d_o}\left(\frac{1}{2.5} + 1\right)$$

$\therefore d_o = 7.00$ cm $= 70.0$ mm

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(b) Virtual and magnified ⇒ lens is a converging lens (also called positive lens)

A diverging lens (also called negative lens) cannot form magnified images. Negative (concave) lenses always form reduced images.

$m = +2.5$ (virtual image)

$$2.5 = \frac{-d_i}{d_o} \Rightarrow d_i = -2.5\, d_o$$

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o} = \frac{1}{-2.5d_o} + \frac{1}{d_o} = \frac{1}{d_o}\left(-\frac{1}{2.5} + 1\right)$$

$$d_o = \left(1 - \frac{1}{2.5}\right) f = 30 \text{ mm.}$$

Q50] $f = +32$ cm , $d_o = ?$

real image $\Rightarrow$ inverted and m is negative

$m = -1$.

$$m = -\frac{d_i}{d_o} = -1 \Rightarrow d_i = d_o$$

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o} \Rightarrow \frac{1}{32} = \frac{1}{d_o} + \frac{1}{d_o} \Rightarrow d_o = 64 \text{ cm}$$

Q53] converging lens $\Rightarrow$ $f = +85$ cm

real image $\Rightarrow$ inverted

$$m = -\frac{d_i}{d_o} = -3.25 \Rightarrow d_i = 3.25\, d_o$$

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o} \Rightarrow \frac{1}{85} = \frac{1}{3.25\, d_o} + \frac{1}{d_o}$$

$$\frac{1}{85} = \frac{1}{d_o}\left(\frac{1}{3.25} + 1\right) \Rightarrow d_o \simeq 111.2 \text{ cm.}$$

$$d_i + d_o = 3.25\, d_o + d_o = (3.25 + 1)\, d_o \simeq 472.6 \text{ cm}$$

Q79]

Left lens: It acts as a magnifying lens
⇒ convex lens with a magnified virtual image.

The eye (or face) (object) is close to the lens ⇒ $d_o < f$ ⇒ virtual image.

Right lens: the image of the eye (or face) is reduced

⇒ lens is a diverging lens that formed a virtual reduced image.