



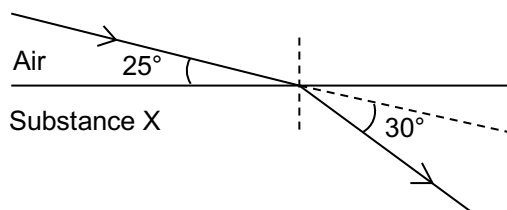
2026 Sec 3 Physics Assignment 2.2 ANSWERS
Optics - Refraction and Total Internal Reflection

1 The diagram shows the path of a ray of light travelling from air into a substance X.

(a) Determine the angle of incidence and the angle of refraction r .

$$i = 90^\circ - 25^\circ = \underline{65^\circ}$$

$$r = 90^\circ - 25^\circ - 30^\circ = \underline{35^\circ}$$



(b) Calculate the refractive index of the substance X.

$$n_{air} \sin \theta_{air} = n_X \sin \theta_X$$

$$(1.00) \sin 65^\circ = n_X \sin 35^\circ$$

$$n_X = \frac{\sin 65^\circ}{\sin 35^\circ} = 1.58 \quad (3 \text{ s.f.})$$

refractive index of X = 1.58

2 Two substances A and B have refractive indices of 1.90 and 1.25 respectively.

(a) For a light ray travelling from air into each substance,

- (i) measure the angles of incidence and
- (ii) calculate the angles of refraction.

(b) Construct the refracted rays and label the angles of incidence and refraction below.

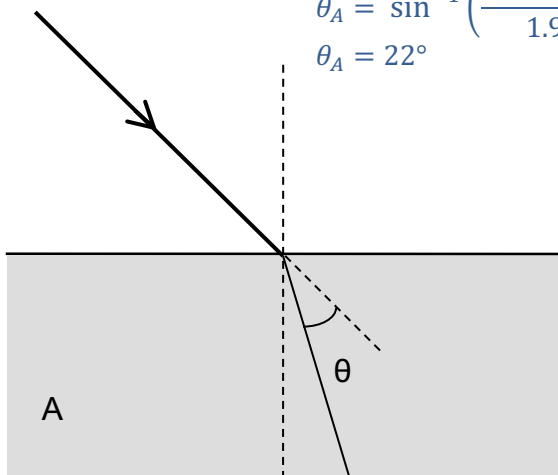
$$i = 45^\circ$$

$$n_{air} \sin \theta_{air} = n_A \sin \theta_A$$

$$1.00 \sin 45^\circ = 1.90 \sin \theta_A$$

$$\theta_A = \sin^{-1} \left(\frac{1.00 \sin 45^\circ}{1.90} \right)$$

$$\theta_A = 22^\circ$$



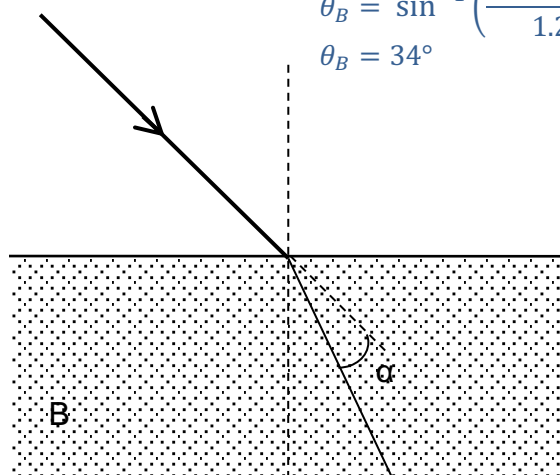
$$i = 45^\circ$$

$$n_{air} \sin \theta_{air} = n_B \sin \theta_B$$

$$1.00 \sin 45^\circ = 1.25 \sin \theta_B$$

$$\theta_B = \sin^{-1} \left(\frac{1.00 \sin 45^\circ}{1.25} \right)$$

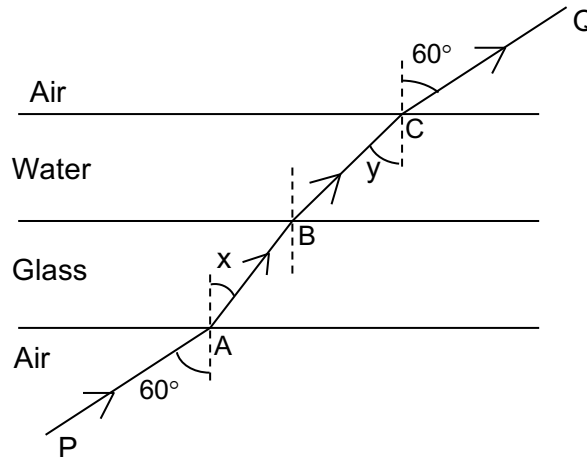
$$\theta_B = 34^\circ$$



(c) Based on your calculations above, explain which substance would cause light to refract more.

In A, the change in direction for the ray, θ , is greater than that for B, α , for the same angle of incidence. Therefore, A causes light to refract more.

- 3 The diagram below shows a horizontal slab of glass of uniform thickness with a layer of water above it. A ray of light PQ is incident upwards on the lower surface of the glass and is refracted successively at A, B and C, the points where it crosses the boundaries.



Given that the refractive index of glass is 1.52 and that of water is 1.35, calculate:

- (a) angle x

Consider point A.

$$n_{air} \sin 60^\circ = n_{glass} \sin x$$

$$(1.00) \sin 60^\circ = (1.52) \sin x$$

$$\sin x = \frac{\sin 60^\circ}{1.52}$$

$$x = 34.7^\circ$$

$$x = \underline{34.7^\circ}$$

- (b) angle y

Consider point C.

$$n_{air} \sin 60^\circ = n_{water} \sin y$$

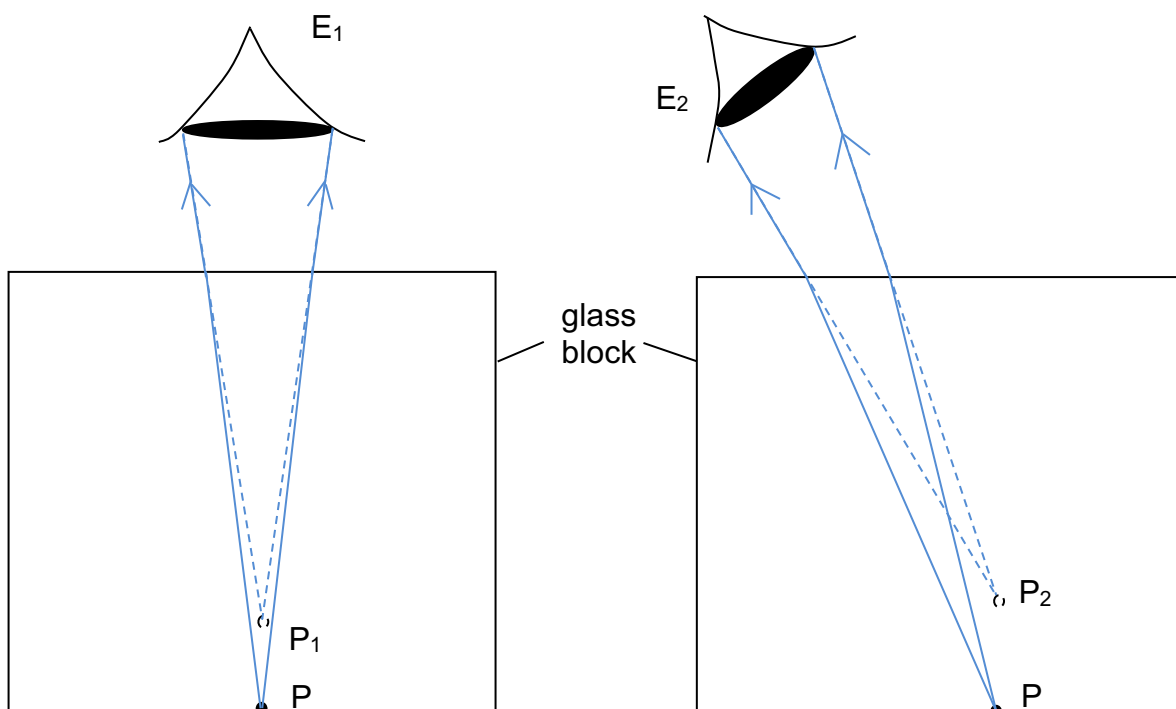
$$(1.00) \sin 60^\circ = (1.35) \sin y$$

$$\sin y = \frac{\sin 60^\circ}{1.35}$$

$$y = 39.9^\circ$$

$$y = \underline{39.9^\circ}$$

- 4 Construct cones of light to show how the eye E_1 sees the image P_1 and eye E_2 sees the image P_2 of a point P under the glass block.



- 5 A ray of light is incident at an angle of 60° at the midpoint O of the plane face AB of a semi-circular glass block, as shown in Fig. 3.1. The refractive index of the glass is 1.55.

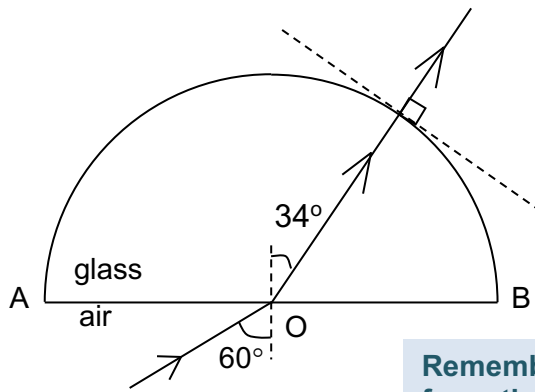


Fig. 3.1

Remember that every light ray from the centre of the circle hits the circumference perpendicularly!

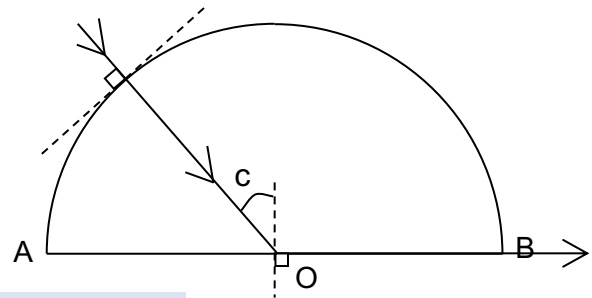


Fig. 3.2

- a. Calculate the angle of refraction r of this ray at O.

$$n_{\text{glass}} \sin r = n_{\text{air}} \sin \theta_{\text{air}}$$

$$(1.55) \sin r = (1.00) \sin 60^\circ$$

$$\sin r = \frac{\sin 60^\circ}{1.55}$$

$$r = 34^\circ$$

$$r = 34^\circ$$

- b. Draw the path of this ray from O on Fig. 3.1 until it emerges into the air. Mark the angle of refraction r at O.
- c. Calculate the critical angle c for the glass-air boundary.

$$n_{\text{glass}} \sin c = n_{\text{air}} \sin 90^\circ$$

$$(1.55) \sin c = 1$$

$$\sin c = \frac{1}{1.55}$$

$$c = 40^\circ$$

$$c = 40^\circ$$

- d. On Fig. 3.2, draw the path of a ray, which travels through the curved surface of the glass to O in such a way that it strikes the face AB at an angle of incidence equal to the critical angle c . Label the critical angle c and complete the path(s) of this ray after it has struck the surface AB at O.

- 6 The diagram below which is not drawn to scale, shows the path of a ray of light through one corner of a piece of ice.

Calculate

- (a) the angle of incidence i on the face AB.

$$i = 90^\circ - 18^\circ = \underline{72^\circ}$$

Always the angle between the incident ray and the normal at the point of incidence

- (b) the angle x on the face AB given that the refractive index of ice is 1.43.

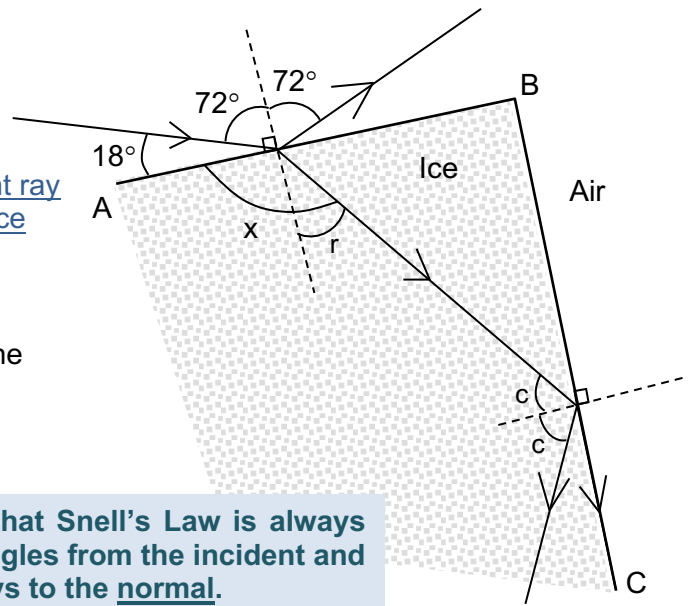
$$(1.43) \sin r = (1.00) \sin 72^\circ$$

$$\sin r = \frac{\sin 72^\circ}{1.43}$$

$$r = \underline{42^\circ}$$

$$x = 90^\circ + r = \underline{132^\circ}$$

Remember that Snell's Law is always about the angles from the incident and refracted rays to the normal.



- (c) On the diagram:

- mark the critical angle c for the ice-air boundary.
- draw the paths of two additional rays which occur due to partial reflection.