Solutions

Each answer shows the steps, then the **result**.

2.1

- the angle of incidence equals the angle of reflection, both measured from the normal

2.2

- any three of: virtual; the same size as the object; 5 cm behind the mirror (the same distance as the object is in front); laterally inverted

2.3

- $n = \sin i / \sin r$

$$n = \frac{0.80}{0.50} = \mathbf{1.6}$$

2.4

- $\sin r = \sin i / n$

$$\sin r = \frac{0.766}{1.4} = 0.547$$

- $r = \mathbf{33}^\circ$

2.5

- $\sin c = 1/n$

$$\sin c = \frac{1}{2.4} = 0.417 \Rightarrow c = \mathbf{25}^\circ$$

2.6

- it is totally internally reflected: none of the light leaves the glass and the angle of reflection equals the angle of incidence
- use: optical fibres (or prisms in binoculars, or road and bicycle reflectors)

2.7

- focal length: the distance from the centre of the lens to the principal focus
- principal focus: the point on the principal axis where rays parallel to the axis meet after passing through the lens

2.8

- between the lens and its principal focus (closer to the lens than F)
- the image is enlarged, upright and virtual

2.9

- violet, indigo, blue, green, yellow, orange, red
- monochromatic light is light of a single frequency (a single colour)

3.1 D

- the critical angle is $\sin^{-1}(1/1.5) = 42°$, and $45°$ is larger, so the ray cannot escape
- **A** describes light entering glass; **B** is refraction below the critical angle; **C** happens only exactly at $42°$

3.2 A

- a plane mirror image is virtual, the same size, and laterally inverted
- it is never real (**B**, **D**) and never diminished (**C**)

3.3

(a) $\sin c = 1/n$

$$\sin c = \frac{1}{1.5} = 0.667 \Rightarrow c = \mathbf{42}°$$

(b) the ray is totally internally reflected at the flat face

- because $50°$ is greater than the critical angle of $42°$

(c) $\sin r = \sin i/n$

$$\sin r = \frac{0.643}{1.5} = 0.429$$

- $r = \mathbf{25}°$

(d) any two of: optical fibres for telephone and internet signals; prisms in binoculars or periscopes; reflectors on bicycles and roads; endoscopes in medicine

(e) it slows down

3.4

(a) ray from the top of the object parallel to the axis, refracting at the lens through the far F

- ray from the top of the object through the centre of the lens, undeviated
- the two rays cross 12 cm beyond the lens, 4 cm below the axis, so the image I is 12 cm from the lens

(b) real, inverted and enlarged

(c) the object is now inside F, so the image becomes virtual and upright, on the same side of the lens as the object

- it is still enlarged

(d) the eye focuses light from a distant object in front of the retina

- the diverging lens spreads the rays out before they enter the eye, so they now meet on the retina

3.5

(a) a band of colours (a spectrum) from red to violet

- the effect is dispersion

(b) violet

- it has the highest frequency (shortest wavelength), and the glass slows and bends higher-frequency light more

(c) the image is virtual

- the reflected rays only appear to come from behind the mirror, so no light actually passes through the image position and none can fall on a screen there