FREE SAMPLE: THE FIRST QUESTION

Question One (13 marks)

(a) A concave (converging) mirror has a focal length of 12.0 cm. An object 5.00 cm tall stands 21.6 cm in front of the mirror, on the principal axis.

(i) Calculate the image distance and the height of the image.

(ii) Describe the image: is it real or virtual, upright or inverted, enlarged or diminished?

[4 marks]

(b) A converging (convex) lens of focal length 25.0 cm forms an image of an object 4.00 cm tall placed 75.0 cm from the lens.

(i) Calculate where the image forms and its height.

(ii) State whether the image is real or virtual, upright or inverted, enlarged or diminished, and explain how you can tell from your calculations.

[4 marks]

(c) In a fibre-optic cable (high-index core), light travelling in the core (n = 1.62) strikes the boundary with the cladding (n = 1.52) at an angle of incidence of 72.8°.

(i) Calculate the critical angle.

(ii) Explain whether the light stays inside the core or leaves it.

[5 marks]

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THE WORKED ANSWER TO THAT QUESTION

Question 1 (13 marks) [Light and images]

(a) A concave (converging) mirror has a focal length of 12.0 cm. An object 5.00 cm tall stands 21.6 cm in front of the mirror, on the principal axis. (i) Calculate the image distance and the height of the image. (ii) Describe the image: is it real or virtual, upright or inverted, enlarged or diminished?

(a) Answer: (i) di = 27.0 cm, hi = −6.25 cm; (ii) real, inverted, enlarged

- Evidence level: Merit (use the mirror equation and magnification, then describe the image from the signs).
- (i) $\frac{1}{f}$ = 1/do + 1/di gives 1/di = 1/12.0 − 1/21.6, so di = 27.0 cm (positive: in front of the mirror, so real).
- Magnification m = −di/do = −1.25, so the image height hi = m × ho = −1.25 × 5.00 = −6.25 cm.
- (ii) The image is real, inverted and enlarged.

> **KEY TAKEAWAY**
> Curved mirrors: $\frac{1}{f}$ = 1/do + 1/di and m = −di/do; a positive di means a real image on the object's side, a negative m means inverted, and |m| > 1 means enlarged.

(b) A converging (convex) lens of focal length 25.0 cm forms an image of an object 4.00 cm tall placed 75.0 cm from the lens. (i) Calculate where the image forms and its height. (ii) State whether the image is real or virtual, upright or inverted, enlarged or diminished, and explain how you can tell from your calculations.

(b) Answer: (i) di = 37.5 cm, hi = −2.00 cm; (ii) real, inverted, diminished

- Evidence level: Merit (use the lens equation and magnification and interpret the signs).
- (i) $\frac{1}{f}$ = 1/do + 1/di so di = 37.5 cm.
- m = −di/do = −0.500, so hi = −0.500 × 4.00 = −2.00 cm.
- (ii) di is positive so the image is real; m is negative so it is inverted; |m| is less than 1 so it is diminished.

> **KEY TAKEAWAY**
> Convex lenses: the same equations as mirrors, but a positive di now means the image is on the far side of the lens (real); an object inside the focal length gives an upright, enlarged, virtual image.

(c) In a fibre-optic cable (high-index core), light travelling in the core (n = 1.62) strikes the boundary with the cladding (n = 1.52) at an angle of incidence of 72.8°. (i) Calculate the critical angle. (ii) Explain whether the light stays inside the core or leaves it.

(c) Answer: (i) θc = 69.8°; (ii) the light is totally internally reflected and stays inside

- Evidence level: Excellence (find the critical angle and apply the conditions for total internal reflection).
- (i) sin θc = n_2/n_1 = 1.52 ÷ 1.62 = 0.938, so θc = 69.8°.
- Achievement: (ii) States whether the angle of incidence is bigger or smaller than the critical angle.
- Merit: Links to the outcome: 72.8° is greater than the critical angle, so the light is totally internally reflected.

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• Excellence: Full explanation: total internal reflection needs light going from the higher refractive index (core) to the lower (cladding) AND an angle of incidence above θc. Both conditions are met, so the light stays inside the core, reflecting at the boundary with no loss through it.

KEY TAKEAWAY

Total internal reflection needs two things: light moving from a higher to a lower refractive index and an angle of incidence greater than the critical angle $\sin^{-1}(n_2/n_1)$.

LOS: Light and images (91170)

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