Class 12 Physics · Chapter 9: Ray Optics and Optical Instruments

Answer key and marking scheme · 20 marks · about 40 minutes · based on NCERT

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1. An object on the axis of a concave mirror of focal length 10 cm is moved from 30 cm to 20 cm in front of the mirror. During this move the image shifts through [1]

(a) 5 cm, towards the mirror
(b) 10 cm, away from the mirror
(c) 10 cm, towards the mirror
(d) 5 cm, away from the mirror

Answer: (d) f = −10 cm. At u = −30 cm, 1/v = −1/10 + 1/30 = −1/15, v = −15 cm. At u = −20 cm, 1/v = −1/10 + 1/20 = −1/20, v = −20 cm. The image moves from 15 cm to 20 cm in front of the mirror: 5 cm away from it, as the object moves 10 cm towards it.

2. The refractive indices of glass and of water with respect to air are 3/2 and 4/3. The refractive index of glass with respect to water is [1]

(a) 8/9
(b) 2
(c) 17/6
(d) 9/8

Answer: (d) n(glass, water) = n(glass, air) × n(air, water) = (3/2) × (3/4) = 9/8. 8/9 is the index of water with respect to glass.

3. The refractive index of a piece of glass with respect to air depends on [1]

(a) the wavelength of the light
(b) the angle of incidence
(c) the thickness of the glass
(d) the angle of refraction

Answer: (a) n21 is a property of the pair of media and depends on the wavelength of light, not on the angle of incidence. Because it differs for different colours, white light splits into its colours (dispersion).

4. A ray of light travelling towards the centre of curvature of a convex mirror strikes the mirror. After reflection the ray [1]

(a) passes through the principal focus
(b) travels parallel to the principal axis
(c) appears to come from the principal focus
(d) retraces its path

Answer: (d) A ray directed towards the centre of curvature meets the mirror along the normal (the radius), so the angle of incidence is zero and the ray is reflected back along its own path.

5. A refracting telescope in normal adjustment is 93 cm long and has a magnifying power of 30. The focal length of its eyepiece is [1]

(a) 3.0 cm
(b) 90 cm
(c) 3.1 cm
(d) 2.9 cm

Answer: (a) In normal adjustment the tube length is $f_o + f_e = 93$ cm and the magnifying power is $f_o/f_e = 30$, so $f_o = 30\ f_e$ and $31\ f_e = 93$ cm, $f_e = 3.0$ cm ($f_o = 90$ cm). 3.1 cm comes from dividing the length by 30, forgetting that the length also contains f_e; 90 cm is the objective.

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6. The critical angle of diamond with respect to air is about 24°, against about 41° for crown glass. Explain why a well-cut diamond sparkles far more than a piece of glass cut to the same shape. [2]

Light inside diamond meets a face at an angle greater than 24° far more often than inside glass, since the critical angle is so small. So light entering a cut diamond is totally reflected again and again at its faces and emerges only from a few faces, in bright concentrated beams; this multiple total internal reflection makes it sparkle. In glass, with $i_c \approx 41°$, much of the light escapes at the first faces it meets.

- small critical angle of diamond means most rays inside meet faces beyond i_c (1)
- repeated total internal reflection; light leaves through a few faces, bright (1)

7. A ray of light passes through an equilateral glass prism (n = 1.5) in the position of minimum deviation. Find the angle of incidence and the angle of minimum deviation. (Take sin 48.6° ≈ 0.75.) [2]

At minimum deviation r = A/2 = 30°. sin i = n sin r = 1.5 × 0.5 = 0.75, so i = 48.6°. Dm = 2i − A = 97.2° − 60° = 37.2°.

- r = A/2 = 30°, sin i = n sin r = 0.75, i = 48.6° (1)
- Dm = 2i − A = 37.2° (1)

8. Distinguish between a real image and a virtual image. Give one example of each formed by a concave mirror. [2]

A real image is formed where rays from a point actually meet after reflection or refraction; it can be received on a screen. A virtual image is formed where the rays only appear to diverge from when produced backwards; it cannot be received on a screen. A concave mirror forms a real (inverted) image of an object beyond its focus, and a virtual (erect, magnified) image of an object between its focus and its pole.

- real: rays actually meet; virtual: rays only appear to diverge from the point (1)
- examples: object beyond F gives real image; object between F and P gives virtual image (1)

9. A plano-convex lens is made of glass of refractive index 1.5, the radius of curvature of its curved face being 15 cm. (a) Find its focal length and power. (b) Where must an object be placed so that the lens forms a real image of the same size as the object? [3]

(a) For the plane face R = ∞. 1/f = (n − 1)(1/R1 − 1/R2) = 0.5 × (1/15 − 0) = 1/30, f = +30 cm. P = 1/0.30 m = +3.3 D. (b) A real image of the same size has m = v/u = −1, so v = −u. 1/v − 1/u = 1/f gives −2/u = 1/30, u = −60 cm: the object is 60 cm (that is, 2f) in front of the lens, and the image 60 cm behind it.

- f = +30 cm from the lens maker's formula with R2 = ∞ (1)
- P = +3.3 D (1)
- m = −1 gives u = −60 cm (2f), v = +60 cm (1)

10. A concave mirror forms a real image, three times the size of the object, on a screen placed 80 cm from the object. Find the object distance, the image distance and the focal length of the mirror. [3]

The image is real, so it is inverted: m = −v/u = −3, v = 3u. Both are in front of the mirror, with the image farther, so |v| − |u| = 80 cm: 3|u| − |u| = 80, |u| = 40 cm, |v| = 120 cm. With signs u = −40 cm, v = −120 cm. 1/f = 1/v + 1/u = −1/120 − 1/40 = −4/120, f = −30 cm: a concave mirror of focal length 30 cm.

- m = −3 gives v = 3u (1)
- |v| − |u| = 80 cm: u = −40 cm, v = −120 cm (1)
- 1/f = 1/v + 1/u, f = −30 cm (1)

11. An object 2.0 cm tall is placed 30 cm in front of a convex lens of focal length 20 cm. A concave lens of focal length 10 cm is to be placed coaxially on the other side of the convex lens so that the light leaving the concave lens is a parallel beam. How far from the convex lens must the concave lens be placed? Find the size and nature of the image formed by the convex lens alone. [3]

Convex lens: u1 = −30 cm, f1 = +20 cm: 1/v1 = 1/20 − 1/30 = 1/60, v1 = +60 cm; m1 = v1/u1 = −2, so this image is 4.0 cm tall, real and inverted. For the concave lens, the rays converging towards this image form a virtual object. Parallel light leaves a lens when its object is at a focal point; for f2 = −10 cm, 1/v2 = 1/f2 + 1/u2 = 0 needs u2 = +10 cm, that is the intermediate image must lie 10 cm beyond the concave lens. So the concave lens is placed 60 − 10 = 50 cm from the convex lens.

- v1 = +60 cm, m1 = −2 (1)
- u2 = +10 cm (virtual object at the focal point) for parallel emergent light (1)
- separation 50 cm; intermediate image 4.0 cm, real, inverted (1)

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