Ray Optics and Optical Instruments — CBSE Pattern Test 2

Class 12 Physics · 90 minutes · 40 marks · Sections A–D with answer key · Narayan Gurukul Academy

Test 2 — CBSE Pattern (90 minutes, 40 marks)

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General Instructions: (1) This paper has four sections — Section A (1 × 10), Section B (2 × 4), Section C (3 × 4) and Section D (5 × 2) — total 40 marks. Time allowed: 90 minutes.
(2) All questions are compulsory. No overall choice is given; internal choice, where allowed, is clearly marked.
(3) For MCQ questions choose the single correct option; for VSA answers write a single line.
(4) Take g = 10 m/s^2. All symbols carry their usual meaning. Use of a calculator is not permitted.

Section A — MCQ & VSA (10 × 1 = 10 marks)

1. A concave mirror is placed on a horizontal table with its axis directed vertically upward, and a point object is placed at its centre of curvature C (auto-collimation). If the mirror is now filled with water (n = 4/3), the image will be

   (A) real, remaining at C
   (B) real, located between C and the focus
   (C) virtual, located between C and O
   (D) real, located between C and O

2. A point source O is placed vertically below the centre of a circular plane mirror, and the rays reflected from it illuminate a circular area A on the ground. When a glass slab is introduced between the mirror and the source, the new illuminated area on the ground is

   (A) A
   (B) greater than A
   (C) less than A
   (D) cannot say — information insufficient

3. In the figure, ABC is the cross section of a right-angled prism and BCDE is the cross section of a glass slab of refractive index μ_2. The value of μ_2 such that light incident normally on the face AB does not cross the face BC is

   (A) $\mu_2 \geq 5/3$
   (B) $\mu_2 \leq 3/2$
   (C) $\mu_2 \geq 6/5$
   (D) $\mu_2 < 2/3$

4. A small source of light is placed 4 m below the surface of a liquid of refractive index 5/3. The minimum diameter of a disc placed on the liquid surface so as to cut off all the light coming out is

   (A) 3 m
   (B) 4 m
   (C) 6 m
   (D) 10 m

5. A point source of light is placed at a distance h below the surface of a large deep lake (n = 4/3). The percentage of light energy that escapes directly from the water surface is (neglect partial reflection)

   (A) 50%
   (B) 25%
   (C) 20%
   (D) 17%

6. When an object is at distances u_1 and u_2, the images formed by the same thin lens are real and virtual, respectively, and of the same size. The focal length of the lens is

(A) $\sqrt{(u_1 u_2)}$
(B) $(u_1 + u_2)/2$
(C) $u_1 u_2/(u_1 + u_2)$
(D) $2u_1 u_2/(u_1 + u_2)$

7. State Snell's law of refraction.
8. Why can a convex mirror never form a real image of a real object?
9. Define the angular magnification of a simple microscope.
10. State the condition under which total internal reflection occurs.

Section B — Short Answer I (4 × 2 = 8 marks)

11. A ray of light is incident on one mirror of two plane mirrors inclined at 70°. After one reflection it falls on the second mirror and emerges parallel to the first mirror. Find the angle of incidence, from the geometry of the reflections.

12. A concave mirror of focal length 20 cm has a point source kept at its focus, and a screen is placed 60 cm from the source. Compare the intensity of illumination on the screen with the mirror present and with it removed.

13. A parallel beam of light is incident on a system of two convex lenses of focal lengths $f_1 = 20$ cm and $f_2 = 10$ cm. Find the separation between the two lenses so that the rays after refraction from both lenses get un-deviated.

14. The magnification produced by the objective lens of a compound microscope is 20 and that of the eyepiece is 3. If the length of the tube is 25 cm, find the focal lengths of the objective and eyepiece lenses for the final image at infinity.

Section C — Short Answer II (4 × 3 = 12 marks)

15. A circular plane mirror is placed coaxially above a point source O, both inside a glass slab assembly, such that a circular area A on the ground receives light by reflection. A glass slab of refractive index μ is now inserted between the mirror and the source. Using an on-axis ray diagram, explain how the illuminated area changes and justify your answer.

16. A concave mirror is placed on a horizontal table with its axis vertical. A point object is placed at its centre of curvature C and a real image forms at C. Using the mirror formula and the concept of refraction by a parallel-sided water layer, show that when the mirror is filled with water the image becomes real but moves toward the pole.

17. A right-angled prism made of glass (μ_1) rests on a glass slab (μ_2). Light incident normally on the face AB strikes the face BC. Obtain the criterion on μ_2 so that the ray does not cross BC (assume total internal reflection to be the deciding mechanism).

18. A ray is incident at 53° on a prism and emerges at 37°. If the angle of incidence is changed to 50°, show that the emergence angle lies between 37° and 53°; hence give the possible value of the angle of emergence.

Section D — Long Answers (2 × 5 = 10 marks)

19. (a) Derive the lens maker's formula $1/f = (n - 1)(1/R_1 - 1/R_2)$ for a thin lens, stating the simplifying assumptions. (b) A double-convex lens of glass ($n = 1.6$) having equal radii of curvature 30 cm is placed in water ($n = 1.33$). Find its focal length in water.

20. (a) Draw a labelled ray diagram of a compound microscope and derive its magnifying power when the final image is formed at infinity. (b) An objective of focal length 2.0 cm and an eyepiece of focal length 6.25 cm are separated by 15 cm. Compute the magnifying power for the final image at infinity.

Answer Key (Marking Scheme)

Q1 – (D) real, located between C and O (the water layer refracts the rays so the effective object for the mirror shifts upward). Q2 – (A) A (inserting the slab leaves the geometry of reflected rays from the mirror unchanged, so the patch is unaltered). Q3 – (A) $\mu_2 \geq 5/3$ (TIR governs the passage at BC; with $\sin^{-1}(3/5) = 37°$, the slab index must be high enough to prevent crossing). Q4 – (C) 6 m (critical angle c = $\sin^{-1}(1/(5/3)) = 37°$; r = 4 tan 37° = 3 m, diameter 6 m). Q5 – (D) 17% (fraction escaped = (1 − cos c)/2 with sin c = 3/4). Q6 – (B) $(u_1 + u_2)/2$ (equal-size real and virtual images Ò this symmetric lens position).

Q7 – $n_1 \sin i = n_2 \sin r$; the incident and refracted rays and the normal all lie in the same plane. Q8 – A convex mirror diverges incident rays, so the reflected rays never converge to a point on the incident side — a real object always yields a virtual image. Q9 – The ratio of the angle subtended by the image at the eye to that subtended by the object at the near point (M = 1 + D/f). Q10 – Light must travel from a denser to a rarer medium and the angle of incidence must exceed the critical angle.

Q11 – Geometry of two reflections at 70°-inclined mirrors gives the angle of incidence = 50° (well-known three-mirror relation). Q12 – With the mirror present the rays are turned back onto the screen within the aperture of the mirror, raising the intensity; the effective ratio ≈ 10 : 1 (aperture/focus condition with f = 20 cm, source–screen 60 cm). Q13 – For un-deviated transmission the second lens must have its focus at the image point of the first: separation = $f_1 + f_2$ = 30 cm. Q14 – Final image at infinity: M_e = D/f_e = 3 Òf_e = 25/3 ≈ 8.33 cm; tube length L = v_o + f_e = 25 Òv_o = 16.67 cm; M_o = v_o/|u_o| = 20 Òu_o| = 0.83 cm; 1/f_o = 1/v_o + 1/|u_o| Òf_o ≈ 0.79 cm.

Q15 – Inserting the slab between source and mirror changes the apparent position of O as seen through the slab, shifting the virtual object for the mirror; on-axis ray diagram shows the patch radius (hence area) is unchanged because the slab merely translates rays parallel to themselves. Q16 – With the mirror empty, object at C gives the image at C. Water (n = 4/3) above the mirror acts as a parallel-sided refracting layer, making the light appear to come from beyond C; the real image moves toward the pole (between C and O). Q17 – At face BC the ray must undergo TIR: sin i_BC ≥ μ_2/μ_1. With the prism geometry and the given critical condition, this reduces to $\mu_2 \geq 5/3$ for the light not to cross. Q18 – For a symmetric prism, change of incidence from 53° (emergent 37°) toward 50° slightly raises both refraction angles; the emergent angle stays between 37° and 53°, the only listed value between them being 38° and 40° — the feasible one is 38°.

Q19 – (a) Applying $n_2/v - n_1/u = (n_2 - n_1)/R$ to both surfaces of a thin lens and adding (lens in air) gives $1/f = (n - 1)(1/R_1 - 1/R_2)$; assumptions: thin lens, paraxial rays, n_air = 1. (b) In water: n_rel = 1.6/1.33 ≈ 1.203 and 1/f_w = n_rel − 1 times $(1/R_1 - 1/R_2)$ = 0.203 × (2/30) Òf_w ≈ 74 cm. Q20 – (a) M = (v_o/|u_o|)(D/f_e) → (v_o/|u_o|)(D/f_e) for final image at infinity. (b) v_o = L − f_e = 15 − 6.25 = 8.75 cm, 1/u_o = 1/8.75 − 1/2 Òu_o ≈ −2.59 cm, m_o ≈ 3.38, and M = 3.38 × (25/6.25) ≈ 13.5.