FREE EDITION · NOTES + 3 SAMPLE MCQS

CUET · PHYSICS · CLASS XII · CODE 322

Ray Optics and Optical Instruments

CUET unit: Ray Optics and Optical Instruments

By **UniDrill** · NCERT-grounded study material

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📌 Snapshot

- Establishes the ray-picture of light and develops a single Cartesian sign convention that unifies all formulae for spherical mirrors, refracting surfaces, and lenses.
- Derives the mirror equation `1/v + 1/u = 1/f` with `f = R/2`, the refraction relation at a spherical surface `n2/v − n1/u = (n2 − n1)/R`, the lens maker's formula, the thin lens formula, and the power/combination rules.
- Treats total internal reflection (critical angle, optical fibre, prism applications) and refraction through a prism, including the minimum-deviation formula `n21 = sin[(A + Dm)/2] / sin(A/2)`.
- Builds the principles of working of simple and compound microscopes and refracting/reflecting (Cassegrain) telescopes — frequent CUET territory because of clean formula-based numericals.
- CUET reliably tests sign convention, critical-angle calculations, lens/mirror numerical substitution, prism refractive-index problems, and magnification of microscope/telescope.

📖 Detailed Notes

2.1 Core concepts

- Light is the electromagnetic radiation in the visible range (~400–750 nm); in vacuum its speed `c = 2.99792458 × 10^8 m s^-1`, usually taken as `3 × 10^8 m s^-1`, and this is the highest attainable speed in nature (NCERT §9.1, p. 221).
- The ray picture treats a light wave as travelling along a straight line because the wavelength is much smaller than ordinary objects; a bundle of such rays is a beam (NCERT §9.1, p. 222).
- Laws of reflection: angle of reflection equals angle of incidence, and the incident ray, reflected ray, and the normal lie in the same plane; for spherical mirrors the normal is along the radius through the point of incidence (NCERT §9.2, p. 222).
- Cartesian sign convention: distances are measured from the pole/optical centre; distances along the direction of incident light are positive, those opposite are negative; heights above the principal axis are positive, below are negative (NCERT §9.2.1, p. 222–223).

- Focal length of a spherical mirror is the distance between focus F and pole P; for paraxial rays geometry gives `f = R/2` (NCERT §9.2.2, p. 223).
- Mirror equation derived from similar triangles: `1/v + 1/u = 1/f`; valid for both concave and convex mirrors and for real or virtual images (NCERT §9.2.3, p. 225).
- Linear magnification `m = h′/h = −v/u`; sign indicates whether the image is erect/virtual (positive) or inverted/real (negative) (NCERT §9.2.3, p. 226).
- Snell's law of refraction: `sin i / sin r = n21`, where `n21` is the refractive index of medium 2 with respect to medium 1; the incident ray, refracted ray and normal are coplanar (NCERT §9.3, p. 228).
- `n12 = 1/n21`, and for three media `n32 = n31 × n12`; optical density is not the same as mass density (e.g. turpentine is less mass-dense than water but optically denser) (NCERT §9.3, p. 228–229).
- For a parallel-sided slab the emergent ray is parallel to the incident ray (no deviation, only lateral shift); apparent depth = real depth / refractive index for near-normal viewing (NCERT §9.3, p. 229).
- Total internal reflection (TIR) happens when light goes from denser to rarer medium and the angle of incidence exceeds the critical angle `ic`, where `sin ic = n21` (n21 < 1) or `n12 = 1/sin ic`; no transmission occurs (NCERT §9.4, p. 229–230).
- Table 9.1 lists critical angles with respect to air: water 48.75°, crown glass 41.14°, dense flint glass 37.31°, diamond 24.41° — the small `ic` of diamond explains its sparkle (NCERT §9.4, Table 9.1, p. 230).
- TIR applications include 90°/180° totally reflecting prisms, optical fibres (core has higher refractive index than cladding; >95% transmission over 1 km in silica), endoscopy "light pipes" (NCERT §9.4.1, p. 231–232).
- Refraction at a single spherical surface: `n2/v − n1/u = (n2 − n1)/R`, derived from Snell's law in small-angle approximation (NCERT §9.5.1, p. 233).
- Lens maker's formula (lens of refractive index n in air): `1/f = (n − 1)(1/R1 − 1/R2)`, with R1 positive and R2 negative for a double-convex lens; f turns out negative for a concave lens (NCERT §9.5.2, p. 234).
- Thin lens formula: `1/v − 1/u = 1/f`, valid for both convex and concave lenses, real and virtual images; lens magnification `m = h′/h = v/u` (NCERT §9.5.2, p. 235).
- Power of a lens `P = 1/f` (f in metres); SI unit dioptre (D), `1 D = 1 m^-1`; positive for converging, negative for diverging (NCERT §9.5.3, p. 236).
- For thin lenses in contact `1/f = 1/f1 + 1/f2 + …` so `P = P1 + P2 + …` (algebraic sum); total magnification of the combination is `m = m1 m2 m3 …` (NCERT §9.5.4, p. 237–238).
- Prism geometry: `r1 + r2 = A` and `d = i + e − A`; the deviation curve has a minimum where `i = e`, giving `r1 = r2 = A/2` and `i = (A + Dm)/2`; the prism formula is `n21 = sin[(A + Dm)/2] / sin(A/2)` (NCERT §9.6, p. 239–240).

- For a thin prism (small A), `Dm ≈ (n21 − 1)A` — thin prisms deviate light only slightly (NCERT §9.6, p. 240).
- Simple microscope (magnifier): a short focal-length convex lens; magnification with image at near point `m = 1 + D/f`, with image at infinity `m = D/f`; D = 25 cm is the least distance of distinct vision (NCERT §9.7.1, p. 240–242).
- Compound microscope uses an objective forming a real, inverted, magnified intermediate image at/near the focal plane of the eyepiece; `mo = L/fo` (L = tube length between second focal point of objective and first focal point of eyepiece); total magnification `m = (L/fo)(1 + D/fe)` for image at near point, `m = (L/fo)(D/fe)` for image at infinity (NCERT §9.7.1, p. 243–244).
- Refracting telescope: objective has large focal length and aperture, eyepiece short focal length; in normal adjustment `m = fo/fe`, tube length `fo + fe`; terrestrial telescopes add inverting lenses for an erect image (NCERT §9.7.2, p. 244–245).
- Reflecting (Cassegrain) telescope uses a concave primary mirror with a convex secondary mirror that sends light back through a hole in the primary; mirrors have no chromatic aberration, are lighter, and can be supported across the back; world's largest pair is the Keck telescopes (10 m mirrors) in Hawaii; largest in India is the 2.34 m Cassegrain at Kavalur (NCERT §9.7.2, p. 245–246).

2.2 Definitions to memorise

Term	Definition	Page
Principal axis	Line joining the pole of a spherical mirror to its centre of curvature (or, for a lens, the optical centre to the principal focus)	222
Cartesian sign convention	Distances measured from pole/optical centre; same direction as incident light is positive, opposite is negative; heights above axis positive, below negative	222–223
Focal length f (mirror)	Distance between focus F and pole P; `f = R/2` for a spherical mirror	223
Mirror equation	`1/v + 1/u = 1/f`	225
Linear magnification (mirror)	`m = h′/h = −v/u`	225–226
Refractive index n21	Ratio `sin i / sin r` for light going from medium 1 to medium 2; characteristic of the pair (and wavelength)	228
Critical angle ic	Angle of incidence in denser medium for which angle of refraction in rarer medium is 90°; `sin ic = n21` (rarer w.r.t. denser)	229–230
Total internal reflection	When `i > ic` for light going denser → rarer, no refracted ray; light is totally reflected	229–230
	`n2/v − n1/u = (n2 − n1)/R`	233

Term	Definition	Page
Refraction at spherical surface		
Lens maker's formula	`1/f = (n − 1)(1/R1 − 1/R2)` for a thin lens in air	234
Thin lens formula	`1/v − 1/u = 1/f`	235
Lens magnification	`m = h′/h = v/u`	235
Power of a lens P	`P = 1/f` with f in metres; SI unit dioptre, `1 D = 1 m^-1`	236
Combination of thin lenses	`1/f = 1/f1 + 1/f2 + …`, equivalently `P = P1 + P2 + …`	237
Angle of deviation (prism)	`d = i + e − A`, with `r1 + r2 = A`	239
Prism formula	`n21 = sin[(A + Dm)/2] / sin(A/2)` at minimum deviation	240
Simple microscope magnification	`m = 1 + D/f` (image at near point); `m = D/f` (image at infinity)	241–242
Compound microscope magnification	`m = (L/fo)(1 + D/fe)` (near point); `m = (L/fo)(D/fe)` (infinity)	243–244
Telescope magnifying power (normal adjustment)	`m = fo/fe`; tube length `fo + fe`	244

2.3 Diagrams / processes to remember

- Fig. 9.1 — laws of reflection at a curved surface (p. 222).
- Fig. 9.2 — Cartesian sign convention diagram (p. 222).
- Fig. 9.3 — focus of concave and convex mirrors with parallel paraxial rays (p. 223).
- Fig. 9.4 — geometry used to prove `f = R/2` (p. 223–224).
- Fig. 9.5 / 9.6 — ray diagrams for image formation by concave and convex mirrors (p. 224–226).
- Fig. 9.8 — Snell's law refraction; Fig. 9.9 — lateral shift through a parallel slab; Fig. 9.10 — apparent depth (p. 228–229).
- Fig. 9.11 — refraction and TIR from a denser medium; Fig. 9.12 — laser-beam demonstration of TIR in a beaker (p. 230–231).
- Fig. 9.13 — 90°/180° prisms and inverting prisms using TIR (p. 231).
- Fig. 9.14 — multiple TIR inside an optical fibre (p. 232).
- Fig. 9.15 — refraction at a single spherical surface (p. 232–233).
- Fig. 9.16 / 9.17 — image formation by a double-convex/concave lens and standard ray diagrams (p. 234–235).

- Fig. 9.18 — power of a lens defined via deviation of a parallel ray at unit height (p. 236).
- Fig. 9.19 — image formation by two thin lenses in contact (p. 237).
- Fig. 9.21 / 9.22 — prism geometry and the d-vs-i plot (p. 239–240).
- Fig. 9.23 — simple microscope, image at near point and at infinity (p. 241).
- Fig. 9.24 — compound microscope ray diagram (p. 243).
- Fig. 9.25 — refracting telescope; Fig. 9.26 — Cassegrain reflecting telescope (p. 245–246).

2.4 Common confusions / NTA trap points

- "Optical density" is about speed of light in the medium (refractive index), not mass per unit volume — turpentine is mass-lighter than water but optically denser (p. 229).
- Mirror equation is `1/v + 1/u = 1/f`, but the lens formula is `1/v − 1/u = 1/f` — the signs of the u-term differ. NTA distractors swap the two.
- For a concave mirror, f is negative; for a convex mirror, f is positive — students often invert this because "concave" sounds positive (Summary §4, p. 247).
- `sin ic = n21` here uses `n21` = rarer w.r.t. denser (so `n21 < 1`); the more common written form is `sin ic = 1/n` where n is denser w.r.t. rarer (p. 230). Watch which n is in the question.
- In the prism formula the angle at minimum deviation is `i = (A + Dm)/2`, NOT `(A + Dm)`; and at minimum deviation `r1 = r2 = A/2` (p. 240).
- Simple-microscope magnification has two forms: `1 + D/f` (image at near point) vs `D/f` (image at infinity). They differ by 1; pick the one matching the question's stated condition (p. 241–242).
- For combination of lenses, `P = P1 + P2 …` is algebraic — convex contributes positive, concave negative; sign errors are the most common trap (p. 238).
- Cassegrain uses a CONVEX secondary mirror (not concave) to send light back through a hole in the primary (p. 246).

🎯 Practice MCQs

📊 PYQ Alignment

> Ray Optics is one of the highest-yield Class XII Physics units in CUET (UG) — typically 4–6 direct MCQs per paper across the 2023–25 cycles, with another 2–3 case/assertion items. Patterns favour direct substitution into the mirror equation, lens formula, lens

maker's formula, the prism formula `n = sin[(A + Dm)/2]/sin(A/2)`, and microscope/telescope magnification. Conceptual questions usually probe critical-angle ranking from Table 9.1, the difference between mirror and lens sign conventions, the cause of TIR in optical fibres and diamond, and the Cassegrain layout (concave primary + convex secondary).

CUET 2025 — Actual PYQs from this chapter

Q.33 (CUET 2025) Which of the following statements are correct? (A) All mirrors follow the laws of reflection (B) Angle between incident ray and mirror surface equals angle between reflected ray and mirror surface (C) Rays parallel to principal axis reflect through focus in curved mirror (D) Rays through pole reflect symmetrically about axis Choose the correct answer:

- A) (A), (B), (C) B) (A), (C), (D) C) (A), (B), (D) D) (A), (D) **Tests:** Laws of reflection — mirrors, parallel rays through focus **Answer:** Not in extracted key

Q.34 (CUET 2025) Which statements about power of a lens are correct? (A) Power is ability of lens to converge or diverge rays (B) SI unit is dioptre if focal length in cm (C) For large focal length, power is smaller (D) Power of combination of lenses is not algebraic sum Choose correct option:

- A) (A) and (C) only B) (B) and (D) only C) (A) and (B) only D) (A) only **Tests:** Power of a lens — definition, sign convention, SI unit (dioptre) **Answer:** Not in extracted key

Q.35 (CUET 2025) In an experiment with a convex lens, image length = 1 cm, object length = 5 cm, object distance = 40 cm. The focal length of the lens is:

- A) 6.67 cm B) 3.35 cm C) 5.6 cm D) 3.6 cm **Tests:** Thin lens — focal length from magnification and object distance **Answer:** Not in extracted key

Q.37 (CUET 2025) The critical angle for light passing from denser to rarer medium is the angle for which:

- A) Angle of reflection = 90° B) Angle of refraction = 90° C) Angle of reflection = 0° D) Angle of refraction = 0° **Tests:** Critical angle — angle of refraction = 90° **Answer:** Not in extracted key

Q.39 (CUET 2025) Which statements about total internal reflection are correct? (A) Occurs when light travels from rarer to denser medium (B) Angle of incidence equals angle of reflection (C) In denser medium there is no refracted ray Choose correct option:

- A) (A) and (B) B) (A) and (C) C) (B) and (C) D) (C) only **Tests:** Total internal reflection — denser-to-rarer, no refracted ray beyond θ_c **Answer:** Not in extracted key

Q.40 (CUET 2025) If focal length of a concave lens is 50 cm, the power of lens is:

- A) +5 D B) −5 D C) +2 D D) −2 D **Tests:** Power of a concave lens — P = 1/f (in metres) **Answer:** Not in extracted key

CUET 2024 — Actual PYQs from this chapter

Q.19 (CUET 2024) Curved surface separating air and medium (μ=4/3). Object at 20 cm. Image distance from P:

- A) 16 cm left in air B) 16 cm right in water C) 20 cm right in water D) 20 cm left in air **Tests:** Refraction at a single spherical surface — image distance **Answer:** Not in extracted key

Q.20 (CUET 2024) Power of lens for fixed radii of curvature:

- A) $\propto (\mu - 1)$ B) $\propto \mu^2$ C) $\propto 1/\mu$ D) $\propto \mu^{-2}$ **Tests:** Lens-maker's equation — power $\propto (\mu - 1)$ **Answer:** Not in extracted key

Q.21 (CUET 2024) Correct graph of v vs u for convex lens.

- (options not in extracted source — see official paper) **Tests:** v vs u graph for a convex lens **Answer:** Not in extracted key

Q.32 (CUET 2024) The refractive index of an equilateral prism is $\sqrt{2}$. The angle of minimum deviation is:

- A) 60° B) 75° C) 30° D) 90° **Tests:** Prism — minimum deviation from refractive index **Answer:** Not in extracted key

Q.45 (CUET 2024) Lower half of a convex lens is made opaque. The image formed will:

- A) No change in image B) Only half image formed C) Image intensity reduces Options: 1. A only 2. B only 3. C only 4. B and C only **Tests:** Half-blocked convex lens — image is full but reduced intensity **Answer:** Not in extracted key

Q.47 (CUET 2024) Astronomical telescope: Objective focal length = 10 m Eyepiece focal length = 10 cm Tube length and magnification respectively:

- A) 20 cm, 1 B) 1000 cm, 1 C) 1010 cm, 1 D) 1010 cm, 100 **Tests:** Astronomical telescope — magnification and tube length **Answer:** Not in extracted key

CUET 2023 — Actual PYQs from this chapter

Q.26 (CUET 2023) Light travelling from one medium to another will show total internal reflection in which pair?

- A) Air → water B) Air → glass C) Water → glass D) Glass → water **Tests:** Total internal reflection — denser-to-rarer medium pair **Answer:** Not in extracted key

Q.29 (CUET 2023) An astronomical telescope has objective focal length 50 cm and eyepiece focal length 2 cm. Angular diameter of the Moon is (1/2^\circ). The angular size of image formed is:

- A) 27° B) 13.5° C) 1° D) 11.2° **Tests:** Astronomical telescope — magnification m = f_o/f_e **Answer:** Not in extracted key

Q.30 (CUET 2023) A spherical air lens of radii (R_1 = R_2 = 10) cm is in glass ((\mu = 1.5)). If the focal length in air is (f_1), when liquid fills the space the focal length becomes (f_2). Correct pair is:

- A) (f_1 = 15) cm, (f_2 = 30) cm B) (f_1 = -15) cm, (f_2 = -30) cm C) (f_1 = -15) cm, (f_2 = 15) cm D) (f_1 = -30) cm, (f_2 = -15) cm **Tests:** Lens-maker's equation for a spherical air-cavity in glass **Answer:** Not in extracted key

Q.31 (CUET 2023) Linear magnification produced by a mirror m = −1.5. Which case corresponds?

- A) Convex mirror with object between F and 2F B) Concave mirror with object between F and pole C) Convex mirror with object at infinity D) Concave mirror with object anywhere **Tests:** Mirror formula and linear magnification sign conventions **Answer:** Not in extracted key

Q.49 (CUET 2023) From the graph between magnification (m) and image distance (v) for a thin lens, the focal length is:

- A) (\frac{b^2}{ac}) B) (\frac{b^2 c}{a}) C) (\frac{a}{c}) D) (\frac{b}{c}) **Tests:** Thin-lens formula — magnification vs image-distance graph, focal length **Answer:** Not in extracted key