

Chapter 9 · Ray Optics and Optical Instruments

CBSE Class 12 Physics (042) · Unit VI Optics · Unit V + VI = 18 marks (the largest block) · Ultimate Revision Sheet

60-SECOND RECALL

Mirror formula	$1/v + 1/u = 1/f \cdot f = R/2 \cdot m = -v/u$
Lens formula	$1/v - 1/u = 1/f \cdot m = v/u$
Lens maker	$1/f = (\mu - 1)(1/R_1 - 1/R_2)$
Power	$P = 1/f$ (metres), diopetre · combination $P = P_1 + P_2$
Refraction at a surface	$\mu_2/v - \mu_1/u = (\mu_2 - \mu_1)/R$
Critical angle	$\mu = 1/\sin C$
Prism	$A + D = i + e \cdot \mu = \sin[(A + D_m)/2] / \sin(A/2)$
Telescope	$m = f_o/f_e$, length $f_o + f_e$

1. Sign Convention — get this right or lose everything

THE CARTESIAN CONVENTION

1. All distances are measured from the pole (mirror) or optical centre (lens).
 2. Distances measured in the direction of the incident light are POSITIVE; against it, negative.
 3. Heights above the principal axis are positive, below negative.
- Consequences: object distance u is always negative; concave mirror and convex lens have f negative and positive respectively; a real image has v positive for a lens and negative for a mirror.

2. Spherical Mirrors

FORMULAS

$$1/v + 1/u = 1/f \cdot f = R/2$$

$$\text{Magnification } m = h'/h = -v/u$$

m negative $\rightarrow$ real and inverted · m positive $\rightarrow$ virtual and erect.

Concave: converging, f negative. Convex: diverging, f positive, image always virtual, erect, diminished — which is why it is used as a rear-view mirror (wider field of view).

3. Refraction and Total Internal Reflection

FORMULAS

$$\text{Snell's law: } \mu = \sin i / \sin r = c/v = \lambda_{\text{vacuum}}/\lambda_{\text{medium}}$$

$$\text{Real depth / apparent depth} = \mu$$

Refraction at a spherical surface: $\mu_2/v - \mu_1/u = (\mu_2 - \mu_1)/R$

TOTAL INTERNAL REFLECTION — the two conditions 1. Light must travel from a *denser* to a *rarer* medium.

2. The angle of incidence must *exceed* the *critical angle C*, where $\mu = 1/\sin C$.

Applications: *optical fibres* (light stays trapped by repeated TIR), sparkle of diamond (C is only 24°), mirage, totally reflecting prisms in periscopes and binoculars.

4. Lenses

FORMULAS

$$1/v - 1/u = 1/f \cdot m = v/u = h'/h$$

$$\text{Lens maker's formula: } 1/f = (\mu - 1)(1/R_1 - 1/R_2)$$

$$\text{Power } P = 1/f \text{ (f in metres, unit diopetre)}$$

$$\text{Thin lenses in contact: } 1/F = 1/f_1 + 1/f_2 \rightarrow P = P_1 + P_2$$

TRAP A convex lens in *water* has a *longer focal length*, because $(\mu - 1)$ becomes smaller when the surrounding medium is denser. If $\mu_{\text{lens}} = \mu_{\text{medium}}$ the lens *disappears* — f becomes infinite.

Convex lens: f positive, P positive. Concave lens: f negative, P negative.

5. Prism

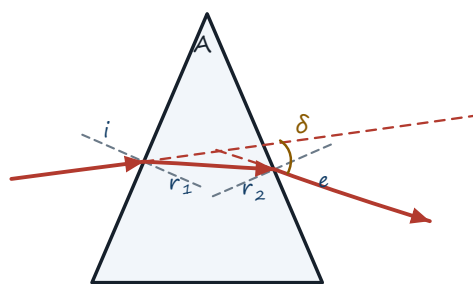
FORMULAS

$$A + D = i + e \cdot r_1 + r_2 = A$$

At minimum deviation: $i = e$, $r_1 = r_2$, and the ray passes symmetrically

$$\mu = \sin[(A + D_m)/2] / \sin(A/2)$$

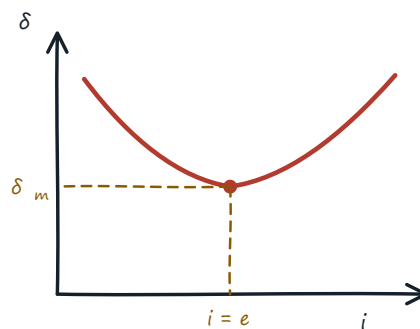
The graph of D against i falls to a single minimum and rises again — for any other deviation there are *two* possible angles of incidence.



$$r_1 + r_2 = A$$

$$\delta = i + e - A$$

The ray always bends TOWARDS the base.



Exactly ONE angle gives δ_m
every other δ is given by two.

At minimum deviation the ray inside runs parallel to the base and $i = e$, which is what makes $\mu = \sin[(A + \delta_m)/2] \div \sin(A/2)$ valid — that formula works at δ_m only.

6. Optical Instruments

COMPOUND MICROSCOPE

$$m = m_o \times m_e = (v_o/u_o)(1 + D/f_e) \text{ (image at near point)}$$

$$m \approx (L/f_o)(D/f_e) \text{ (image at infinity, } L = \text{tube length, } D = 25 \text{ cm)}$$

Both f_o and f_e are **SHORT**, and $f_o < f_e$. The objective forms a real, inverted, magnified image which the eyepiece then magnifies further.

ASTRONOMICAL TELESCOPE

$$m = f_o/f_e \text{ (normal adjustment) } \cdot \text{length} = f_o + f_e$$

$$m = (f_o/f_e)(1 + f_e/D) \text{ (image at near point)}$$

f_o is **LARGE** and f_e is **small** — the exact opposite of the microscope.

A large objective aperture gives greater light-gathering power and better resolution.

WHY REFLECTING TELESCOPES ARE PREFERRED

1. No **chromatic aberration** (mirrors do not disperse light). 2. Large mirrors are easier and cheaper to make than large lenses. 3. A mirror can be supported from behind, so it does not sag under its own weight. 4. Higher **resolving power** for the same cost.

WORKED EXAMPLE An object is **15 cm** in front of a **concave mirror** of focal length **10 cm**.

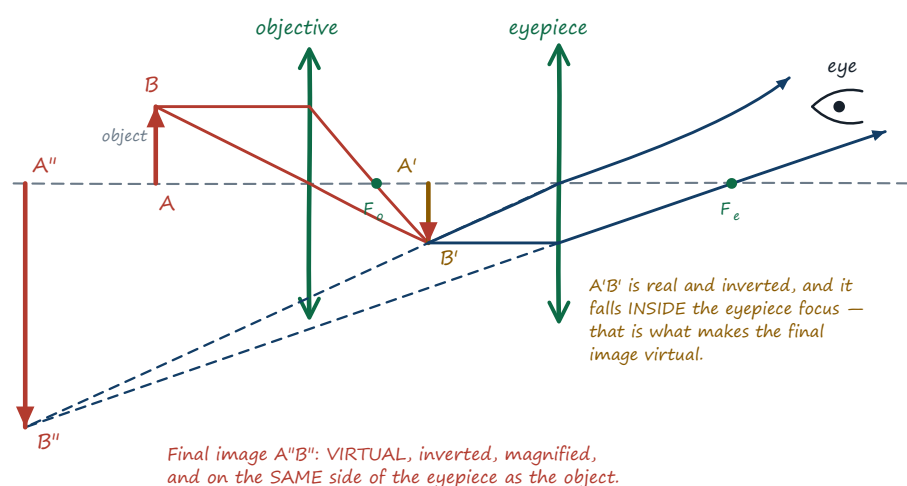
$$u = -15 \text{ cm, } f = -10 \text{ cm}$$

$$1/v = 1/f - 1/u = (-1/10) - (-1/15) = -1/10 + 1/15 = (-3 + 2)/30 = -1/30$$

$$v = -30 \text{ cm} \rightarrow \text{image is } 30 \text{ cm in front of the mirror, so it is real.}$$

$$m = -v/u = -(-30)/(-15) = -2 \rightarrow \text{inverted and twice the size.}$$

Compound microscope — ray diagram



$m = (v_o/u_o)(1 + D/f_e)$ with the image at the near point $D = 25$ cm, or $m = (L/f_o)(D/f_e)$ with it at infinity. A microscope wants a **short** f_o ; a telescope ($m = f_o/f_e$) wants a **long** one — mixing those up is the commonest slip in this chapter.

7. Question Triggers what the wording is really asking

If the question says...	Use
"rear-view mirror / wide field of view"	Convex mirror — virtual, erect, diminished
"light trapped inside a fibre"	Total internal reflection
"apparent depth of a coin in water"	$\mu = \text{real depth} / \text{apparent depth}$
"focal length of a lens in water"	Lens maker's formula with μ_{relative}
"angle of minimum deviation"	$\mu = \sin[(A + D_m)/2] / \sin(A/2)$
"two lenses in contact"	$P = P_1 + P_2$
"why reflecting telescope"	No chromatic aberration , cheaper large mirrors
"objective of a telescope vs microscope"	Telescope f_o large ; microscope f_o small

MOST-ASKED BOARD QUESTIONS

- [3M] Derive the **lens maker's formula**, or the relation for refraction at a single spherical surface.
- [3M] Draw a ray diagram of a **compound microscope** / **astronomical telescope** and derive its magnifying power.
- [3M] Derive $\mu = \sin[(A + D_m)/2] / \sin(A/2)$ for a prism.
- [2M] State the conditions for **total internal reflection** and give two applications.
- [2M] Numerical using the mirror or lens formula with magnification.
- [2M] Why is a **reflecting telescope** preferred over a refracting one?
- [1M] Define the **power** of a lens and give its unit. $\rightarrow P = 1/f$, **diopetre**

THE HABIT THAT SCORES — Write the sign of every quantity **before** substituting, in a single line: $u = -\dots$, $f = -\dots$

Most lost marks in this chapter are not conceptual at all — they are a dropped minus sign in the second line of working.