Collegedunia NCERT Notes

The Ultimate NCERT Revision Guide for Class 12 Physics

Chapter 9: Ray Optics and Optical Instruments

Chapter Overview

Ray Optics treats light as travelling in straight lines (*rays*) and explains how mirrors, lenses, and prisms form images. Together with Wave Optics, it carries the highest weightage in Class 12 Physics ($\sim$10 marks) and is heavily tested in JEE Main and NEET. This chapter is dense with sign-convention pitfalls and ray-diagram conventions, but every numerical reduces to one of four formulas: mirror equation, Snell's law, lens equation, or prism formula.

1 Reflection of Light by Spherical Mirrors

A spherical mirror is a portion of a hollow sphere whose inner or outer surface is silvered. Two types: **concave** (silvered on the convex outer side, so the reflecting face is the concave inner one) and **convex** (silvered on the concave inner side, with the reflecting face on the convex outer one). Reflection at any point of the mirror obeys the same two laws as a plane mirror: the angle of incidence equals the angle of reflection, and the incident ray, reflected ray, and normal lie in the same plane.

1.1 Basic terms and pole-centre-focus geometry

For any spherical mirror we identify five reference quantities:

- **Pole (P)** — the geometric centre of the reflecting surface.
- **Centre of curvature (C)** — the centre of the sphere of which the mirror is a part.
- **Radius of curvature (R)** — the distance PC, equal to the radius of that sphere.
- **Principal axis** — the straight line through P and C.
- **Principal focus (F)** — the point on the principal axis where paraxial rays parallel to the axis meet (concave) or appear to diverge from (convex) after reflection.

Focal Length and Radius of Curvature

For a spherical mirror, the focal length f is half the radius of curvature:

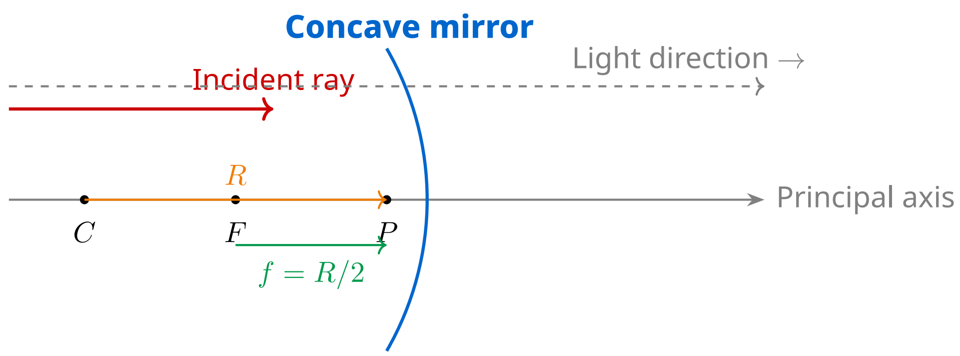
$$f = \frac{R}{2}$$

This relation holds for paraxial rays — rays close to and nearly parallel to the principal axis.

1.2 Cartesian sign convention

The New Cartesian sign convention is mandatory for every numerical in this chapter. Place the pole P at the origin and the principal axis along the x-axis with light travelling left to right. Then:

- Distances measured **in the direction of incident light** are positive; **against** the direction of incident light are negative.
- Heights measured **above** the principal axis are positive; **below** are negative.
- For a real object on the left of the mirror, the object distance u is negative.
- For a concave mirror, the focal length f is negative; for a convex mirror, f is positive.



Sign Convention Summary for Concave and Convex Mirrors

For a real object placed in front of a mirror (which is the standard setup):

- Concave mirror: $u < 0$, $f < 0$, $R < 0$. Real image gives $v < 0$; virtual image gives $v > 0$.
- Convex mirror: $u < 0$, $f > 0$, $R > 0$. Image is always virtual, so $v > 0$.

1.3 The mirror equation

The mirror equation links the object distance u, image distance v, and focal length f for a spherical mirror in the paraxial approximation. It is derived using similar triangles formed by the principal axis, the incident ray, and the reflected ray.

Mirror Equation and Magnification

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

Linear magnification (lateral magnification):

$$m = \frac{h'}{h} = -\frac{v}{u}$$

where h is object height (above axis is positive) and h' is image height.

- If $|m| > 1$ the image is enlarged; if $|m| < 1$, diminished.
- If m is negative, image is inverted (real image of a real object); if positive, image is erect (virtual image of a real object).

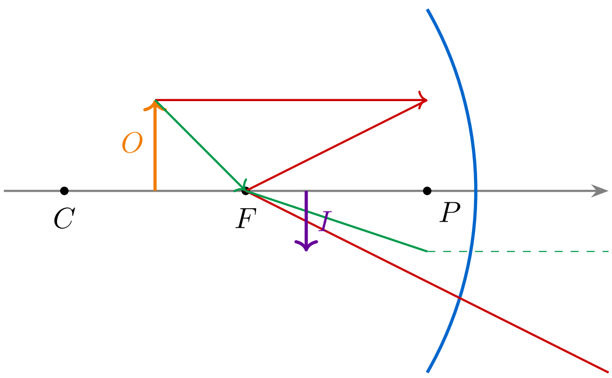
Quick Tip

For a concave mirror, the image type depends only on where the object is relative to C and F. Memorise: object beyond $C \rightarrow$ real, inverted, diminished image between C and F. Object at $C \rightarrow$ real, inverted, same-size image at C. Object between C and $F \rightarrow$ real, inverted, enlarged image beyond C. Object at $F \rightarrow$ image at infinity. Object between F and $P \rightarrow$ virtual, erect, enlarged image behind the mirror.

1.4 Image formation by ray tracing

To draw a ray diagram, use any two of these standard rays from the object:

1. A ray parallel to the principal axis, after reflection passes through (or appears to come from) F.
2. A ray through (or aimed at) F, after reflection becomes parallel to the principal axis.
3. A ray through (or aimed at) C, retraces its path because it strikes the mirror normally.
4. A ray to the pole P, reflects symmetrically about the principal axis.



Reading the diagram: An object placed beyond C (here at distance -4.5 units) gives an image between C and F (here at -2), real, inverted, and diminished. The orange arrow is the object; the purple arrow is the image; the red and green rays are two of the standard rays.

Common Mistake

The most frequent error in mirror numericals is forgetting the sign convention. Students plug $u = +20$ cm for a real object placed 20 cm in front of a concave mirror and get the wrong image distance. The object is on the left of the pole, so $u = -20$ cm. Memorise: **real object distance is always negative**, regardless of mirror type.

1.5 Image formation by concave and convex mirrors

CBSE often asks "describe the image formed when an object is placed at ...". The table below covers all positions in front of a concave mirror plus the convex case. Memorise it; it converts a 2-mark question into 30 seconds of recall.

Object position	Image position	Nature	Size
At infinity	At F	Real, inverted	Highly diminished
Beyond C	Between C and F	Real, inverted	Diminished
At C	At C	Real, inverted	Same size
Between C and F	Beyond C	Real, inverted	Enlarged
At F	At infinity	Real, inverted	Highly enlarged
Between F and P	Behind the mirror	Virtual, erect	Enlarged
Convex mirror (any object position)			
Anywhere in front	Behind the mirror, between P and F	Virtual, erect	Diminished

Why Convex Mirrors are Used as Rear-View Mirrors

A convex mirror always gives a virtual, erect, diminished image regardless of object position. The diminished size means a wider field of view fits within the mirror's frame, so a driver can see more of the road and surroundings. The erect orientation matches the real world (cars stay right-side up), preventing confusion. The trade-off is that distances appear greater than they really are, hence the warning "objects are closer than they appear".

2 Refraction of Light and Total Internal Reflection

When light travels from one transparent medium into another, it bends at the interface. This bending is called **refraction**, and it occurs because the speed of light is different in different media. The phenomenon is governed by Snell's law and characterised by the refractive index of each medium.

2.1 Laws of refraction (Snell's law)

Refraction at a plane boundary follows two laws:

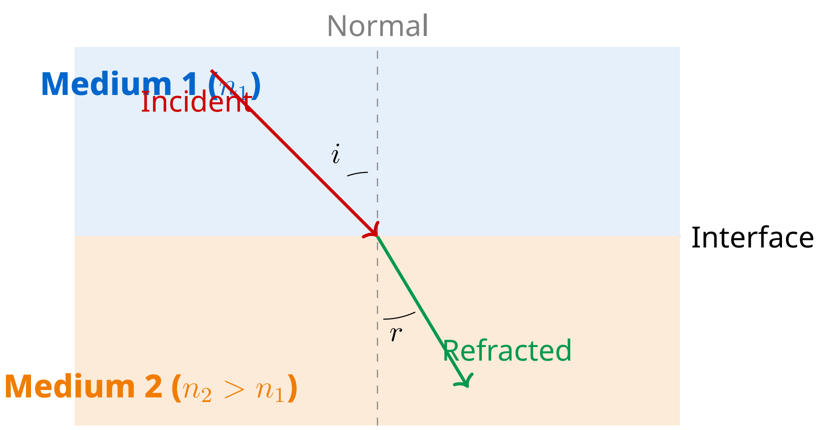
1. The incident ray, the refracted ray, and the normal to the surface at the point of incidence all lie in the same plane.
2. The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant for any two given media. This constant is the **relative refractive index**.

Snell's Law

$$n_{12} = \frac{\sin i}{\sin r} = \frac{n_2}{n_1} = \frac{v_1}{v_2}$$

where n_{12} is the refractive index of medium 2 with respect to medium 1, v_1 and v_2 are speeds of light in the two media, and n_1, n_2 are absolute refractive indices.

- **Absolute refractive index** of a medium: $n = c/v$, where c is the speed of light in vacuum and v is the speed in the medium.
- Light bends **towards** the normal when going from a rarer to a denser medium ($n_2 > n_1$, so $r < i$).
- Light bends **away from** the normal when going from a denser to a rarer medium ($n_2 < n_1$, so $r > i$).
- The frequency of light does not change on refraction; only the wavelength and speed change. Hence colour does not change.



Speed and Wavelength on Refraction

On entering a denser medium, the speed of light decreases ($v_2 < v_1$) and the wavelength shrinks ($\lambda_2 < \lambda_1$). Frequency ν stays constant: $\nu = v/\lambda$ holds in both media. So a yellow light remains yellow underwater, even though its wavelength is shorter there.

2.2 Apparent depth and real depth

When you look at an object underwater (a coin at the bottom of a pool, a fish in an aquarium), the object appears to be at a shallower depth than its real depth. This is a direct consequence of Snell's law applied at the water-air boundary.

Apparent vs Real Depth

$$\text{Apparent depth} = \frac{\text{Real depth}}{n} \quad \text{(for an object viewed normally)}$$

where n is the refractive index of the denser medium with respect to the rarer medium (typically water w.r.t. air, $n \approx 1.33$).

Example: A pool that is 4 m deep appears only $4/1.33 \approx 3.0$ m deep when viewed from above. Always compute apparent depth as smaller than real depth (the object appears raised). The shift in apparent position is Real − Apparent = Real$(1 - 1/n)$.

Real-World Application

This is why a pencil dipped halfway into a glass of water appears bent at the water surface, and why fish in an aquarium look closer to the glass than they are. Spear-fishers correct for it instinctively by aiming below where the fish appears.

2.3 Total Internal Reflection (TIR)

When light travels from a denser to a rarer medium and the angle of incidence exceeds a particular value called the **critical angle** i_c, the light is reflected entirely back into the denser medium. No light enters the rarer medium. This phenomenon is total internal reflection.

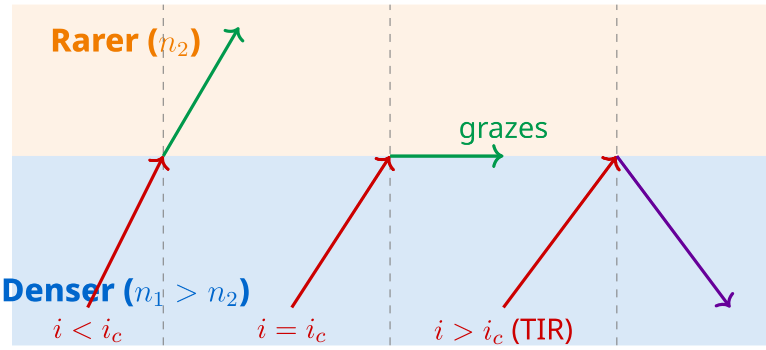
Critical Angle

$$\sin i_c = \frac{n_2}{n_1} = \frac{1}{n_{12}} \quad \text{(when light goes from denser to rarer)}$$

For light going from glass ($n = 1.5$) to air ($n = 1$): $\sin i_c = 1/1.5 = 0.667$, so $i_c \approx 41.8°$.

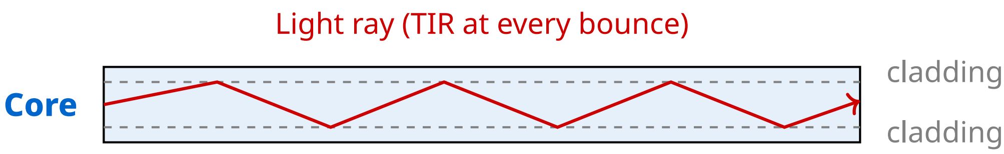
Two conditions for TIR:

- Light must travel from a denser medium to a rarer medium.
- Angle of incidence in the denser medium must exceed the critical angle: $i > i_c$.



2.4 Optical fibres

Optical fibres exploit TIR to guide light along a thin transparent core, even around bends. A fibre is a thin glass thread (core, $n_1 \approx 1.5$) coated with a slightly less dense cladding ($n_2 < n_1$). Light entering one end strikes the core-cladding boundary at an angle greater than the critical angle, undergoes TIR, and zigzags down the fibre with very little loss.



Real-World Application

Optical fibres carry the internet. The undersea cables linking continents are bundles of thin glass fibres each guiding laser-light pulses at near-100% transmission over thousands of kilometres. Optical fibres are also used in medical endoscopy (a flexible fibre lets a doctor see inside the body) and in fibre-optic decorative lamps.

Quick Tip

For TIR problems, first ask: **is the light going from denser to rarer?** If yes, compute $i_c = \sin^{-1}(n_2/n_1)$ and compare with the actual angle. If $i > i_c$, the answer is "totally internally reflected"; do not try to apply Snell's law to find a refracted ray (it does not exist).

3 Refraction at Spherical Surfaces and by Lenses

Most optical instruments use lenses, which work by refracting light at curved (spherical) surfaces. Before tackling lenses, we derive the refraction formula at a single spherical surface; combining two such surfaces gives the lens-maker's formula.

3.1 Refraction at a single spherical surface

Consider a spherical surface separating two media of refractive indices n_1 (object side) and n_2 (image side), with centre of curvature on the image side. Using sign conventions and applying Snell's law in the paraxial approximation, the relation between object distance u, image distance v, and radius of curvature R is:

Refraction at a Spherical Surface

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

Sign convention: distances measured in the direction of the incident light are positive; against, negative. R is positive if the centre of curvature is on the side of the outgoing light, negative otherwise.

3.2 Lens-maker's formula

A thin lens has two refracting surfaces with radii of curvature R_1 and R_2. Applying the spherical-surface refraction formula at each surface and combining gives the **lens-maker's formula**, which links the focal length f to the lens material and shape.

Lens-Maker's Formula

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

where n is the refractive index of the lens material relative to the surrounding medium, R_1 is the radius of curvature of the first surface (the one light hits first), and R_2 is the radius of the second surface.

Sign rule for R_1 and R_2: Apply the same convention as before. For a biconvex lens, $R_1 > 0$ and $R_2 < 0$, so the bracket is positive and $f > 0$ (converging). For a biconcave lens, $R_1 < 0$ and $R_2 > 0$, so $f < 0$ (diverging).

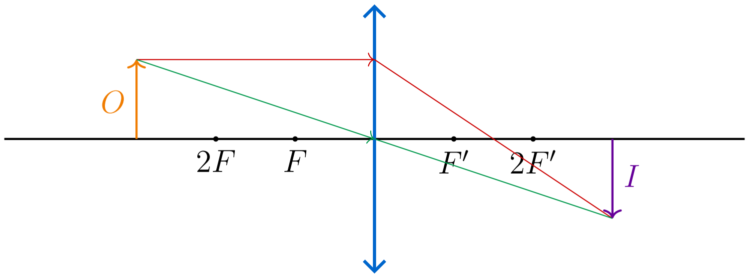
3.3 Thin lens formula and magnification

For a thin lens, the relation between object distance, image distance, and focal length is identical in form to the mirror formula but with a different sign on u:

Thin Lens Formula

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

Magnification: $m = h'/h = v/u$. A converging lens has $f > 0$; a diverging lens has $f < 0$.



Reading this diagram: An object placed beyond $2F$ on the left of a convex lens gives a real, inverted, diminished image between F' and $2F'$ on the right. Standard ray pairs used: a ray parallel to the axis passes through F' after refraction; a ray through the optical centre goes straight through undeviated.

Image formation by a convex lens at various object positions

Object position	Image position	Nature	Size
At infinity	At F'	Real, inverted	Highly diminished, point-sized
Beyond $2F$	Between F' and $2F'$	Real, inverted	Diminished
At $2F$	At $2F'$	Real, inverted	Same size
Between F and $2F$	Beyond $2F'$	Real, inverted	Enlarged
At F	At infinity	Real, inverted	Highly enlarged
Between F and the lens	On the same side as the object	Virtual, erect	Enlarged

Quick Tip

For a concave (diverging) lens, the image is **always** virtual, erect, and diminished, located between the lens and F on the same side as the object. So for any ”describe the image” question on a concave lens, the answer is fixed: virtual, erect, diminished.

Mirror vs Lens Formula: A Common Confusion

The mirror formula is $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ (*plus*). The lens formula is $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ (*minus*). The difference comes from the sign of u in the two cases. Memorise both forms exactly.

3.4 Power of a lens

The power of a lens measures how strongly it converges or diverges light. It is defined as the reciprocal of the focal length in metres.

Power of a Lens

$$P = \frac{1}{f \text{ (in metres)}} \quad \text{(Unit: dioptre, D = m}^{-1}\text{)}$$

Converging lens: $P > 0$. Diverging lens: $P < 0$. A lens of focal length 20 cm has $P = 1/0.20 = +5$ D.

3.5 Combination of thin lenses in contact

When two thin lenses of focal lengths f_1 and f_2 are placed in contact, the combination behaves as a single lens whose power is the algebraic sum of the individual powers.

Combination of Thin Lenses in Contact

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} \quad \text{or equivalently} \quad P = P_1 + P_2$$

The combined magnification is the product of individual magnifications: $m = m_1 \times m_2$.

Quick Tip

For a 2-lens combination, work in powers (dioptres), not focal lengths. Powers add directly: a $+10$ D and a -4 D lens in contact give $+6$ D combined, hence focal length $1/6$ m ≈ 16.7 cm. Try the same with focal lengths and you have to do reciprocals twice.

Common Mistake

The combination formula $1/F = 1/f_1 + 1/f_2$ assumes lenses are **in contact**. If they are separated by a distance d, the formula changes to $1/F = 1/f_1 + 1/f_2 - d/(f_1 f_2)$, which is in JEE Main scope (not boards). Check first whether the problem says "in contact"; if yes, use the simple sum; if a separation is given, use the corrected formula.

4 Refraction Through a Prism

A prism is a transparent solid with two flat refracting surfaces inclined at an angle A, called the angle of the prism (or refracting angle). When a ray of light passes through a prism, it refracts at the first surface, travels through the prism, and refracts again at the second surface, ultimately emerging deviated from its original path.

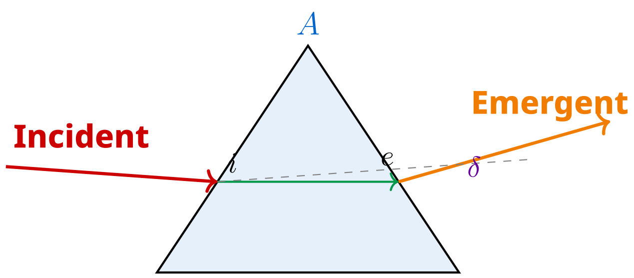
4.1 Geometry and angle of deviation

Let the angle of incidence at the first face be i, the angle of refraction inside the prism be r. At the second face, the angle of refraction inside is r', and the angle of emergence is e. The angle between the emergent ray and the incident ray (extended) is the **angle of deviation**, denoted δ.

Prism Geometry Relations

$$A = r + r' \qquad \text{and} \qquad \delta = (i + e) - A$$

where A is the prism angle, i and e are angles of incidence and emergence at the two faces, and r, r' are the angles of refraction inside the prism.



4.2 Minimum deviation and the prism formula

As we vary the angle of incidence i, the deviation δ first decreases, reaches a minimum, and then increases. At the minimum-deviation condition, the path of light through the prism is symmetric: the ray inside the prism is parallel to the base, and $i = e$ and $r = r'$.

Prism Formula at Minimum Deviation

$$n = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

where n is the refractive index of the prism material relative to the surrounding medium, A is the prism angle, and δ_m is the angle of minimum deviation.

For a small-angle prism (thin prism, $A < 10°$), the formula simplifies to $\delta = (n - 1)A$. This is the relation behind the prism in a spectroscope and the elementary derivation of dispersion.

Symmetry at Minimum Deviation

At minimum deviation, the ray passes through the prism symmetrically — equally inclined to both faces. This is also the condition under which the prism formula above is derived, and is why CBSE always specifies "at minimum deviation" when asking you to find n from A and δ_m.

4.3 Dispersion through a prism

When white light passes through a prism, it splits into its component colours because the refractive index of glass varies slightly with wavelength: n is larger for violet (shorter λ) than for red (longer λ). Hence violet bends more, red less, producing a spectrum from red to violet.

- **Order of colours** from least bent to most bent: red, orange, yellow, green, blue, indigo, violet (VIBGYOR reversed).
- The angular separation between extreme colours (red to violet) is called **angular dispersion**.
- This is the basic mechanism behind a prism spectroscope used to identify spectral lines of elements.

Memory Aid

VIBGYOR — **V**iolet, **I**ndigo, **B**lue, **G**reen, **Y**ellow, **O**range, **R**ed. This is the order from highest to lowest refractive index in glass, i.e., from most bent to least bent in a prism. Useful for any spectrum-related question.

5 Optical Instruments

The 2026-27 syllabus covers two instrument families: the **microscope** (simple and compound), used to view small nearby objects, and the **telescope** (refracting and reflecting), used to view distant objects. Both rely on combinations of lenses (or lenses and mirrors) to produce angular magnification.

5.1 Simple microscope (magnifying glass)

A simple microscope is a single converging lens of short focal length used to look at a small object placed inside its focal length. The lens forms a virtual, erect, magnified image at the least distance of distinct vision $D = 25$ cm.

Magnifying Power of a Simple Microscope

When the image is formed at D (eye accommodated): $$m = 1 + \frac{D}{f}$$

When the image is at infinity (eye relaxed): $m = \frac{D}{f}$

where f is the focal length of the lens and $D = 25$ cm is the least distance of distinct vision.

5.2 Compound microscope

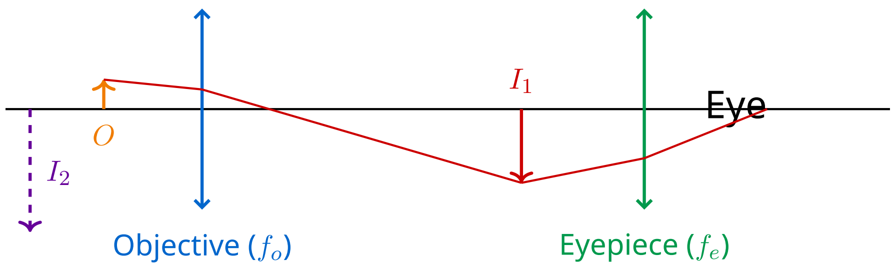
A compound microscope uses two converging lenses: an **objective** (small focal length f_o, placed near the object) and an **eyepiece** (slightly larger focal length f_e, placed near the eye). The objective forms a real, inverted, magnified image of the object inside the focal length of the eyepiece, which then magnifies this image further.

Magnifying Power of a Compound Microscope

$$m = m_o \times m_e = \frac{v_o}{|u_o|} \times \left(1 + \frac{D}{f_e}\right) \quad \text{(image at } D\text{)}$$

$$m = \frac{v_o}{|u_o|} \times \frac{D}{f_e} \quad \text{(image at infinity)}$$

For very high magnification, both f_o and f_e should be small.



5.3 Astronomical telescope (refracting)

An astronomical telescope is built for distant objects (stars, planets) where the object is at effectively infinity. It uses a long-focal-length objective and a short-focal-length eyepiece, both converging lenses. Parallel rays from the distant object form a real image at the focal plane of the objective; the eyepiece then magnifies this image.

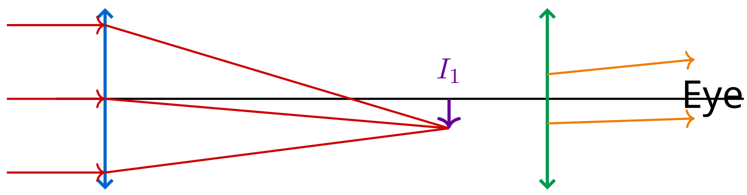
Magnifying Power of an Astronomical Telescope

For final image at infinity (normal adjustment): $m = \frac{f_o}{f_e}$.

For final image at the least distance of distinct vision: $m = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$.

Length of the tube in normal adjustment: $L = f_o + f_e$.

Design choice: For a high-magnification telescope, f_o should be *large* and f_e *small*. This is the opposite of a microscope (where both are small).



5.4 Reflecting telescope (Cassegrain)

A reflecting telescope replaces the objective lens with a concave parabolic mirror. Light entering the front of the tube reflects off the primary concave mirror, then off a smaller secondary convex mirror, and is finally focused into the eyepiece. Reflecting telescopes are favoured for astronomy because they can be built much larger than refractors (mirror weight is supported from the back; lenses must be supported only at the rim and sag under their own weight). They also avoid **chromatic aberration** since reflection does not depend on wavelength.

Why Reflecting Telescopes for Big Astronomy

Three reasons reflecting telescopes dominate professional astronomy: (1) Concave mirrors do not produce chromatic aberration, so all colours focus together. (2) Large mirrors can be physically supported across their back surface, allowing diameters of several metres; large lenses sag and distort under their own weight. (3) Reflecting design allows compact tube lengths via folding the light path, which is more practical to mount and aim.

Real-World Application

The Hubble Space Telescope (2.4 m primary mirror) and the James Webb Space Telescope (6.5 m primary, segmented) are both reflecting telescopes using the same Cassegrain-style design students learn in NCERT. Earth-based telescopes like the Very Large Telescope in Chile use 8.2 m mirrors built using exactly this principle.

Quick Tip

For ”compare microscope vs telescope” questions, lock these contrasts: (i) Microscope objects are nearby, telescope objects are at infinity. (ii) Both objectives and eyepieces are short-focus in microscopes; the objective is long-focus and the eyepiece short-focus in telescopes. (iii) Both produce inverted final images, which matters for a microscope (you flip the slide mentally) but not for stars (no ”up” in space).

5.5 Comparison of microscope and telescope

Property	**Compound Microscope**	**Astronomical Telescope**
Object distance	Small (just outside f_o)	Very large (effectively infinity)
Objective focal length f_o	Small	Large
Eyepiece focal length f_e	Small	Small
Magnifying power	$m_o \cdot m_e$ (large product)	f_o/f_e
Image type	Virtual, inverted, magnified	Virtual, inverted, magnified
Tube length	$L = v_o + u_e$	$L = f_o + f_e$
Use case	Cells, microorganisms, fine structure	Stars, planets, distant terrestrial

6 Numerical Strategy and Worked Approach

This chapter delivers most of its marks through numericals. Below is the standard 5-step approach that handles every CBSE board numerical from this chapter.

6.1 The 5-step approach for any optics numerical

1. **Identify the optical element.** Mirror? Lens? Prism? Combination? This decides which formula to start with.
2. **Set up the sign convention.** Place the origin at the pole or optical centre. Light travels left to right (positive direction). Write down the sign of every distance *before* substituting it into the formula.
3. **Plug in the relevant formula.** Mirror: $1/v + 1/u = 1/f$. Lens: $1/v - 1/u = 1/f$. Refraction at sphere: $n_2/v - n_1/u = (n_2 - n_1)/R$. Prism: $n = \sin((A + \delta_m)/2)/\sin(A/2)$.
4. **Solve algebraically, then substitute numbers.** Substituting numbers too early is the cause of most arithmetic errors. Carry the algebra symbolically until the last step.
5. **Check the sign of the answer for physical consistency.** A positive v for a concave-mirror real image is a sign error. Always sense-check: real images on the same side as the object (mirror) give negative v; real images on the opposite side (lens) give positive v.

6.2 Worked example: lens combination

Problem: A convex lens of focal length 20 cm is placed in contact with a concave lens of focal length 30 cm. Find the focal length and power of the combination.

Solution following the 5-step approach:

Step 1. Two thin lenses in contact. Use the combination formula.

Step 2. Sign convention: convex lens $f_1 > 0$, concave lens $f_2 < 0$. So $f_1 = +20$ cm, $f_2 = -30$ cm.

Step 3. Apply the combination formula:

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

Step 4. Substitute symbolically, then numerically:

$$\frac{1}{F} = \frac{1}{20} + \frac{1}{-30} = \frac{3-2}{60} = \frac{1}{60} \text{ cm}^{-1}$$

So $F = +60$ cm $= +0.60$ m. Power $P = 1/F = 1/0.60 \approx +1.67$ D.

Step 5. Sign check: F is positive, meaning the combination behaves as a converging system. This is consistent because the convex lens is "stronger" ($P_1 = 1/0.20 = +5$ D) than the concave ($P_2 = -1/0.30 \approx -3.33$ D), and $P_1 + P_2 = +1.67$ D matches our $1/F$ calculation.

Final answer: $F = +60$ cm, $P = +1.67$ D (converging combination).

Quick Tip

Whenever you see "thin lenses in contact", convert focal lengths to powers (in dioptres) and add them. Powers add directly; reciprocals do not. This trick saves both time and arithmetic errors and works for any number of lenses.

6.3 Common pitfalls in board numericals

- **Confusing focal length sign**: concave mirror is $-$, convex mirror is $+$. Convex lens is $+$, concave lens is $-$. Mirrors and lenses follow opposite sign rules for the same shape.
- **Dropping the negative sign on u**: real objects always give $u < 0$. Forgetting this yields image positions on the wrong side.
- **Mirror formula vs lens formula sign**: Mirror is $1/v + 1/u$; lens is $1/v - 1/u$. The two are different.
- **Forgetting to convert focal length to metres**: power P requires f in metres, not centimetres. A 20 cm focal length lens has power $P = 1/0.20 = 5$ D, not $1/20 = 0.05$ D.
- **Magnification sign**: m is negative for real, inverted images and positive for virtual, erect images. Don't lose the sign in the answer.

Common Mistake

A board favourite trick: "an object placed at the focus of a convex lens forms an image at ...". Many students answer "at $2F$". Wrong. The image is **at infinity** when the object is at F, because parallel rays emerge from the lens. Memorise this case as a special case before the exam.

7 Quick Reference Summary

This section condenses every formula and constant from the chapter into one place for last-minute revision.

7.1 All key formulas

Formula	Use
$f = R/2$	Mirror focal length from radius of curvature
$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$	Mirror equation
$m = -v/u$	Mirror magnification (lateral)
$n_{12} = \frac{\sin i}{\sin r} = \frac{n_2}{n_1} = \frac{v_1}{v_2}$	Snell's law
$\sin i_c = n_2/n_1$	Critical angle (denser to rarer)
$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$	Refraction at a spherical surface
$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$	Lens-maker's formula
$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$	Thin lens equation
$m = v/u$	Lens magnification (lateral)
$P = 1/f$ (in metres)	Power of a lens (in dioptres)
$1/F = 1/f_1 + 1/f_2$	Combination of thin lenses in contact
$A = r + r', \quad \delta = (i+e) - A$	Prism geometry relations
$n = \frac{\sin\big((A+\delta_m)/2\big)}{\sin(A/2)}$	Prism formula at minimum deviation
$m = 1 + D/f$ (image at D)	Simple microscope magnifying power
$m = D/f$ (image at infinity)	Simple microscope magnifying power
$m = (v_o/\lvert u_o\rvert)(1 + D/f_e)$	Compound microscope (image at D)
$m = f_o/f_e$	Telescope (image at infinity)
$L = f_o + f_e$	Telescope tube length (normal adjustment)

7.2 Sign convention quick check

- Origin: pole of mirror or optical centre of lens.
- Light travels left to right (positive direction).
- Real object on the left of the optical element: $u < 0$.
- Real image (formed by mirror): $v < 0$. Real image (formed by lens): $v > 0$.
- Concave mirror: $f < 0$. Convex mirror: $f > 0$.

- Convex (converging) lens: $f > 0$. Concave (diverging) lens: $f < 0$.
- Heights above the principal axis: positive. Below: negative.

7.3 Standard constants and useful values

Quantity	Standard value
Speed of light in vacuum, c	3×10^8 m/s
Refractive index of water	≈ 1.33
Refractive index of crown glass	≈ 1.5
Refractive index of diamond	≈ 2.42
Critical angle (glass to air)	$\approx 41.8°$
Critical angle (water to air)	$\approx 48.6°$
Critical angle (diamond to air)	$\approx 24.4°$
Least distance of distinct vision, D	25 cm

Final Tip for Boards

This chapter is famous for sign-convention errors. Before plugging in numbers, write down: (i) origin of coordinate system, (ii) sign of u, (iii) sign of f. With these three checked, the formula does the rest. CBSE typically asks two numericals (one mirror or lens, one optical instrument) plus one short-answer (TIR application or prism dispersion). Practising 8 to 10 numericals across these sub-types covers the entire chapter.