

Collegedunia NCERT Formula Sheet

The Ultimate Formula Reference for Class 12 Physics

Chapter 9: Ray Optics and Optical Instruments

Constant / Convention	Value / Note
Speed of light, c	3×10^8 m/s
Refractive index (air)	≈ 1.0003 (≈ 1)
Refractive index (water)	1.33
Refractive index (glass, typical)	1.5
Refractive index (diamond)	2.42
Sign convention	Cartesian; distances measured from pole

1 Reflection by Spherical Mirrors

A spherical mirror obeys two laws of reflection at every point. The mirror formula relates object distance, image distance, and focal length (NCERT 9.2–9.3).

Cartesian sign convention

All distances are measured from the **pole** of the mirror (or optical centre of the lens). Distances along the incident light direction are positive; against it, negative. Heights above the principal axis are positive; below, negative. **Concave mirror:** $f < 0$. **Convex mirror:** $f > 0$.

Mirror formula

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

$$\text{Focal length: } f = \frac{R}{2}$$

where u = object distance; v = image distance; R = radius of curvature.

Apply sign convention strictly. Real images have $v < 0$ for a concave mirror with object in front; virtual images have $v > 0$.

Magnification

$$m = \frac{h_i}{h_o} = -\frac{v}{u}$$

$|m| > 1$: magnified. $m < 0$: inverted (real). $m > 0$: erect (virtual). The minus sign comes directly from the sign convention.

2 Refraction at Plane Surfaces

When light crosses an interface between two media, it bends according to Snell's law. Total internal reflection happens above a critical angle (NCERT 9.4–9.5).

Snell's law

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$\frac{\sin \theta_1}{\sin \theta_2} = \frac{n_2}{n_1} = n_{12}$$

θ_1 = angle of incidence; θ_2 = angle of refraction (both measured from normal). Light bends **towards** the normal entering a denser medium.

Refractive index

$$n = \frac{c}{v}$$

$$n = \frac{\lambda_{\text{vac}}}{\lambda_{\text{med}}}$$

Speed and wavelength both decrease in a denser medium; **frequency stays the same**. n depends on wavelength (dispersion).

Apparent depth

$$d_{\text{apparent}} = \frac{d_{\text{real}}}{n}$$

$$\text{Shift: } \Delta d = d \left(1 - \frac{1}{n} \right)$$

Object viewed in a denser medium from above appears **closer to the surface**. The classic "broken pencil in a glass of water" effect.

Total internal reflection & critical angle

$$\sin C = \frac{n_2}{n_1} \quad (n_1 > n_2)$$

For glass-air: $\sin C = 1/n$

TIR occurs when $\theta_1 > C$ at a denser-to-rarer boundary. Used in **optical fibres**, prismatic binoculars, and the sparkle of diamond.

3 Refraction at Spherical Surfaces & Lenses

A spherical refracting surface has its own formula; combining two such surfaces gives a thin lens (NCERT 9.6–9.7).

Refraction at a single spherical surface

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

where light goes from medium n_1 to n_2 ; R = radius of curvature of surface (with sign).

Building block for the lens-maker's equation. Sign of R follows Cartesian convention: $R > 0$ if centre of curvature is on the side light goes into.

Lens-maker's equation

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

where n = lens material's refractive index relative to surroundings; R_1, R_2 = radii of the two surfaces.

Convex lens (converging): $f > 0$. Concave lens (diverging): $f < 0$. Lens placed in a medium with same n becomes invisible: $f = \infty$.

Lens formula

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

$$\text{Magnification: } m = \frac{v}{u}$$

Note the **minus sign** in lens formula vs the plus in mirror formula — comes from the different sign conventions for u in each.

Power of a lens

$$P = \frac{1}{f \text{ (in metres)}} \quad (\text{diopre, D})$$

Convex (converging): $P > 0$. Concave (diverging): $P < 0$. A 1 D lens has $f = 1$ m. Higher power = stronger lens = shorter focal length.

Lenses in contact

$$\frac{1}{f_{\text{eq}}} = \frac{1}{f_1} + \frac{1}{f_2} + \dots$$

$$P_{\text{eq}} = P_1 + P_2 + \dots$$

Powers **add directly**. Two convex lenses combine to a stronger converger; a convex + concave can compensate or cancel.

4 Prism & Dispersion

A prism deviates and disperses light because its refractive index depends on wavelength (NCERT 9.8).

Prism deviation

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

where A = prism angle; i, e = angles of incidence and emergence.

Total deviation is the sum of the deviations at both surfaces, less the prism angle.

Minimum deviation & refractive index

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

$\delta = \delta_m$ when the ray passes **symmetrically** through the prism ($i = e$). The standard method of measuring n in a school lab.

Dispersion

Different wavelengths see slightly different n , so different colours bend by different amounts. White light splits into VIBGYOR. **Violet bends most, red bends least**. Cause of rainbows, the spread of light through a glass prism, and chromatic aberration in lenses.

5 Optical Instruments

Magnifiers, microscopes, and telescopes use combinations of lenses to extend what the eye can see (NCERT 9.9).

Simple microscope (magnifier)

Image at D (least distance of distinct vision): $m = 1 + \frac{D}{f}$

Image at infinity (relaxed eye): $m = \frac{D}{f}$

where $D = 25$ cm for normal eye.

Higher magnification with shorter f . The eye is more relaxed when viewing image at infinity.

Compound microscope

$$m = m_o \times m_e = \frac{L}{f_o} \left(1 + \frac{D}{f_e}\right)$$

(image at D); for relaxed eye: $m = \frac{LD}{f_o f_e}$

where L = tube length; f_o, f_e = objective, eyepiece focal lengths.

Both lenses have **small** focal lengths; objective forms a real, inverted, enlarged image inside the tube, which the eyepiece magnifies further.

Astronomical telescope

Normal adjustment (image at infinity):

$$m = -\frac{f_o}{f_e}$$

Length: $L = f_o + f_e$

Objective has **large** f (collects parallel rays from infinity); eyepiece has **small** f (magnifies the intermediate image). Image is inverted — not a problem for astronomy.

JEE/NEET Extension: Resolving power

Telescope (Rayleigh): $\theta_{\text{min}} \approx \frac{1.22\lambda}{D}$ where D = aperture.

Microscope: resolution $\approx \frac{\lambda}{2n \sin \theta}$ where $n \sin \theta$ = numerical aperture.

Larger aperture and shorter wavelength \Rightarrow better resolution.

Sign of f

Concave mirror: $f < 0$. **Convex mirror:** $f > 0$.

Convex lens (converging): $f > 0$. **Concave lens** (diverging): $f < 0$.

Mnemonic: in mirrors, "C" (concave) makes things real and **negative**; in lenses, the convex lens converges and is **positive**.

Frequency, not wavelength, is invariant

When light enters a denser medium, its **wavelength shrinks** by factor n , but **frequency stays the same**. Speed equals c/n . The colour of light — determined by frequency — is therefore unchanged.

Quick Reference — Ray Optics

Quantity / Configuration	Expression	Notes
Mirror formula	$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$	$f = R/2$
Mirror magnification	$-v/u$	Cartesian sign
Snell's law	$n_1 \sin \theta_1 = n_2 \sin \theta_2$	At plane interface
Apparent depth	d/n	Object in denser medium
Critical angle	$\sin^{-1}(n_2/n_1)$	TIR at denser-rarer
Spherical surface refraction	$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$	One surface
Lens-maker's	$(n - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$	Gives $1/f$
Lens formula	$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$	Note minus sign
Lens magnification	v/u	Cartesian
Power of lens	$1/f$ (m)	Dioptre
Lenses in contact	$\sum P_i$	Powers add
Prism deviation	$(i + e) - A$	At any angle
Prism min deviation n	$\frac{\sin[(A + \delta_m)/2]}{\sin(A/2)}$	Symmetric ray
Magnifier (relaxed)	D/f	$D = 25$ cm
Compound microscope	$\frac{LD}{f_o f_e}$	Both f small
Telescope (normal)	$-f_o/f_e$	$f_o \gg f_e$
Telescope length	$f_o + f_e$	Normal adjustment