Collegedunia NCERT Formula Sheet

The Ultimate Formula Reference for Class 12 Physics

Chapter 10: Wave Optics

Constant / Quantity	Value
Speed of light, c	3×10^8 m/s
Visible wavelength range	400–700 nm
Yellow sodium light	589 nm
1 nm	10^{-9} m
1 Å (Ångström)	10^{-10} m

1 Huygens' Principle

The wave theory of light treats every point on a wavefront as a secondary source — this picture explains reflection, refraction, and interference (NCERT 10.2–10.3).

Huygens' principle

Every point on a wavefront acts as a **source of secondary spherical wavelets**. The new wavefront at a later time is the **tangent envelope** of these wavelets. Direction of propagation is along the perpendicular to the wavefront.

Types of wavefront

Spherical: from a point source.
Plane: from a far source (parallel rays).
Cylindrical: from a line source.
A converging lens turns a plane wavefront into a converging spherical wavefront focused at f.

Reflection & refraction (Huygens)

Reflection: $\theta_i = \theta_r$
Refraction (Snell): $n_1 \sin\theta_1 = n_2 \sin\theta_2$
Both laws follow from constructing wavelet envelopes at the boundary — a deeper derivation than the ray picture, valid for waves of any kind.

2 Interference & Young's Double Slit

When two coherent waves overlap, they add as field amplitudes (not intensities) — producing bright and dark fringes (NCERT 10.4–10.5).

Coherent sources

Two sources are **coherent** if they emit waves of the same frequency with a constant phase difference. Sustained interference patterns require coherence — which is why two ordinary bulbs do **not** produce visible fringes (random phases).

Path difference & phase difference

$$\phi = \frac{2\pi}{\lambda}\Delta x$$

Constructive (bright): $\Delta x = n\lambda \quad (n = 0, 1, 2, \ldots)$

Destructive (dark): $\Delta x = \left(n + \frac{1}{2}\right)\lambda$

Path difference of one full wavelength means the waves are back in phase. Half-wavelength means they cancel.

Resultant intensity (two coherent sources)

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

Equal sources: $I = 4I_0 \cos^2\left(\frac{\phi}{2}\right)$

$I_{\text{max}} = 4I_0, \quad I_{\text{min}} = 0$

Bright fringes are **four times** as bright as a single source — not double. Energy is just redistributed; total stays the same.

Young's double-slit fringe positions

$$y_n = \frac{n\lambda D}{d} \quad \text{(bright fringes)}$$

$$y_n = \frac{(2n+1)\lambda D}{2d} \quad \text{(dark fringes)}$$

where D = slit-screen distance; d = slit separation.

Fringes are equally spaced and parallel to the slits. Order n counts from the central maximum.

Fringe width

$$\beta = \frac{\lambda D}{d}$$

Distance between consecutive bright (or dark) fringes. Larger λ or D widens fringes; smaller d does too. Often used in reverse to measure λ.

Effect of medium on fringe width

$$\beta_{\text{medium}} = \frac{\beta_{\text{air}}}{n}$$

Wavelength shrinks by n inside a medium, so fringes narrow. Useful in determining refractive index from fringe-width measurements.

3 Single-Slit Diffraction

Light passing through a single narrow slit spreads — producing a central bright maximum flanked by alternating dark and bright fringes (NCERT 10.6).

Diffraction vs interference

Both arise from wave superposition. **Interference**: waves from a few discrete sources (slits). **Diffraction**: waves from a continuous distribution (one slit treated as many infinitesimal sources). Single-slit pattern has **unequal** fringes; double-slit has equal ones.

Single-slit minima

$$a\sin\theta = n\lambda \quad (n = \pm 1, \pm 2, \ldots)$$

where a = slit width.

Note: dark fringes (not bright) at integer multiples of λ — opposite of double-slit. The central maximum sits between $n = -1$ and $n = +1$ minima.

Width of central maximum

$$y_{\text{first min}} = \frac{\lambda D}{a}$$

Total width: $W = \frac{2\lambda D}{a}$

Central maximum is **twice as wide** as the secondary fringes. Narrower slit (a small) gives wider central peak — the wave spreads more.

Angular spread (Fresnel distance)

$$Z_F = \frac{a^2}{\lambda}$$

Distance up to which ray-optics ($\theta \approx 0$) is valid. Beyond Z_F, diffraction effects dominate. For $a = 1$ mm and $\lambda = 500$ nm: $Z_F \approx 2$ m.

4 Polarisation

Light is a transverse wave: its $\vec{E}$ vibrates perpendicular to the direction of propagation. Polarisation restricts $\vec{E}$ to a single plane (NCERT 10.7).

Why polarisation matters

Sound waves cannot be polarised (they are longitudinal). Light, being transverse, can. **Unpolarised light**: $\vec{E}$ vibrates in all directions perpendicular to propagation. **Polarised light**: $\vec{E}$ confined to one plane.

Malus's law

$$I = I_0 \cos^2\theta$$

where θ = angle between the polariser's axis and the incoming polarisation; I_0 = intensity of polarised light incident on analyser.

$\theta = 0$: full transmission. $\theta = 90°$: complete blocking. Two crossed polarisers transmit nothing; insert a third at $45°$ between them and **some** light gets through.

Unpolarised through one polariser

$$I = \frac{I_0}{2}$$

An ideal polariser cuts unpolarised light's intensity in half (averaging $\cos^2$ over all angles gives $1/2$). The transmitted light is fully polarised.

Brewster's law

$$\tan\theta_B = n$$

where θ_B = Brewster's angle.

At θ_B, the reflected ray is **completely polarised** perpendicular to the plane of incidence. Reflected and refracted rays are perpendicular: $\theta_B + \theta_r = 90°$. Used in polaroid sunglasses, photography filters.

JEE/NEET Extension: Methods of polarisation

(i) **Reflection** (Brewster's angle),
(ii) **Selective absorption** (polaroid sheets),
(iii) **Refraction** (double refraction in calcite/quartz),
(iv) **Scattering** (sky light — partially polarised, especially $90°$ from the Sun).

Slits: bright vs dark

Double slit: bright fringes at $\Delta x = n\lambda$.
Single slit: **minima** (dark) at $a \sin\theta = n\lambda$.
The condition for a bright spot in one is the condition for a dark spot in the other — a common exam trap. The single-slit central maximum sits where double-slit would also have a bright fringe.

Path difference vs phase difference

Δx = path difference (length); ϕ = phase difference (angle). They are related by $\phi = (2\pi/\lambda)\Delta x$. Always check which one your formula uses — mixing them is the most common YDSE error.

Quick Reference — Wave Optics

Quantity / Concept	Expression	Notes
Path–phase relation	$\phi = (2\pi/\lambda)\Delta x$	Common conversion
YDSE bright fringe	$y_n = n\lambda D/d$	$n = 0, 1, 2, \ldots$
YDSE dark fringe	$y_n = (2n+1)\lambda D/2d$	Half-wavelength
Fringe width	$\lambda D/d$	Equal spacing
Resultant intensity	$4I_0 \cos^2(\phi/2)$	Equal sources
Single-slit min	$a \sin\theta = n\lambda$	Dark fringes
Central max width	$2\lambda D/a$	Twice secondaries
Fresnel distance	a^2/λ	Ray $\rightarrow$ wave transition
Malus's law	$I_0 \cos^2\theta$	Polarised light
Unpolarised $\rightarrow$ polariser	$I_0/2$	Half intensity
Brewster's law	$\tan\theta_B = n$	Reflected fully polarised
Brewster geometry	$\theta_B + \theta_r = 90°$	At Brewster's angle
Wavelength in medium	λ_{vac}/n	Frequency unchanged