Wave Optics

Class 12 · Physics · Quick Revision · **chapternotes.in**

NEET: 2-3 Qs (~8-12 marks) | Boards: 5-8 marks

Scan: practise free

Light as a wave: wavefronts (Huygens), how coherent waves interfere (Young), how a single slit and apertures diffract and limit resolution, and how transverse light polarises (Malus, Brewster).

1. Huygens' Principle & Wavefronts

A wavefront joins points of equal phase; each point reseeds the next wavefront.

$\lambda_{medium} = \lambda_{vacuum} / n$
wavelength shrinks in denser medium

$v = c / n$
speed falls in denser medium

$n_1 \sin\theta_1 = n_2 \sin\theta_2$
Snell's law from wave geometry

MUST KNOW Point source → spherical wavefront; line source → cylindrical; source at infinity / after a lens → plane.

MUST KNOW New wavefront = FORWARD (tangential) envelope of secondary wavelets; the backward envelope is discarded.

- Crossing a boundary: frequency f stays constant; speed and wavelength both change.

2. Superposition, Path Difference & Coherence

Coherent waves add to give a steady bright/dark pattern; energy is only redistributed.

$I = 4I_0\cos^2(\varphi/2)$
equal-amplitude resultant

$\varphi = (2\pi/\lambda)\,\Delta$
phase from path difference Δ

bright: $\Delta = n\lambda$; dark: $\Delta = (2n-1)\lambda/2$
constructive vs destructive

$I_{max} = (\sqrt{I_1}+\sqrt{I_2})^2$, $I_{min} = (\sqrt{I_1}-\sqrt{I_2})^2$
unequal sources

MUST KNOW Sources must be coherent: same frequency and a constant phase difference. Two independent bulbs are incoherent → no fringes, so one source is split into two.

MUST KNOW Interference conserves energy: the energy missing from dark fringes reappears in bright ones.

- I_{max}/I_{min} uses √(intensities), i.e. amplitude ratios — not the raw intensity ratio.

3. Young's Double-Slit Experiment (YDSE)

Two coherent slits give equally spaced, equally bright fringes of width β = λD/d.

path diff $\Delta = yd/D$
to a point y from centre

fringe width $\beta = \lambda D/d$
bright-to-bright spacing

bright: $y = n\lambda D/d$; dark: $y = (2n-1)\lambda D/2d$
fringe positions

angular width $\theta = \lambda/d$
independent of D

MUST KNOW Central fringe is BRIGHT (zero path difference, equidistant from both slits).

MUST KNOW β rises with λ and D, falls with d. Immersing the setup in a liquid of index n shrinks λ → β becomes β/n.

- White light: white central fringe flanked by coloured fringes, violet nearest the centre.

4. Diffraction at a Single Slit

A slit of width a spreads light into a wide central maximum with weak side maxima.

minima: $a \sin\theta = n\lambda$
n = 1,2,3 ... (DARK)

secondary maxima: $a \sin\theta = (2n+1)\lambda/2$
weak side peaks

central half-width $\theta = \lambda/a$
angular

central width $w = 2\lambda D/a$
linear, on screen at D

MUST KNOW In single slit, nλ gives a MINIMUM (dark) — the reverse of YDSE where nλ is a maximum.

MUST KNOW Central maximum is TWICE as wide as side maxima; side maxima fall off fast (first ≈ 4.5% of central).

- Narrower slit (smaller a) spreads light MORE: $w \propto 1/a$.

5. Resolving Power

Diffraction at an aperture sets the smallest angle two objects can be told apart.

$\theta = 1.22\lambda/D$
limit of resolution (circular aperture)

R.P. $= 1/\theta = D/1.22\lambda$
larger aperture → sharper

MUST KNOW Bigger objective diameter D or shorter wavelength λ → smaller θ → better resolution.

- Even a perfect lens blurs a star into a diffraction disc; that disc limits a telescope, not lens quality.

6. Polarisation, Malus's Law & Brewster's Angle

Only transverse waves polarise; intensity follows Malus, polarising angle follows Brewster.

unpolarised → polaroid: $I = I_0/2$
always half

Malus: $I = I_0\cos^2\theta$
θ between consecutive axes

Brewster: $\tan\theta_p = n$
reflected ray fully polarised

$\theta_p + r = 90°$
reflected ⊥ refracted ray

MUST KNOW Sound (longitudinal) CANNOT be polarised; all EM waves (transverse) can — a classic one-marker.

MUST KNOW Apply $I_0/2$ only to unpolarised light; apply Malus $I_0\cos^2\theta$ only to already-polarised light.

- Brewster uses tan (not sin); for glass (n ≈ 1.5), $\theta_p \approx 57°$. Crossed polaroids (θ = 90°) give zero.

Interference vs Diffraction

	Interference	Diffraction
Source	Two coherent slits	One slit / aperture
Fringe width	Equal (uniform β)	Central twice the rest
Brightness	All fringes equal	Falls off fast
nλ means	Bright (maximum)	Dark (minimum)
Cause	Two-wave superposition	Wavelets across one slit

YDSE Fringe Conditions

Fringe	Path diff Δ	Position y
Bright (nth)	nλ	nλD/d
Dark (nth)	(2n−1)λ/2	(2n−1)λD/2d
Central	0	0 (bright)

Mnemonic - a sinθ = nλ is a MINIMUM in single-slit diffraction but a MAXIMUM in YDSE interference
Single Slit, n-Lambda Sinks (dark); Double slit, n-Lambda Shines (bright)

Common traps

- a sinθ = nλ is a DARK minimum in single-slit diffraction, but the SAME nλ is a BRIGHT maximum in YDSE. Don't swap them.
- Slit WIDTH a (diffraction) is not slit SEPARATION d (YDSE) — different letters, different roles.
- $I_0/2$ is for unpolarised light hitting the first polaroid; Malus $I_0\cos^2\theta$ is only for already-polarised light. Never mix them.
- Huygens predicts light is SLOWER in a denser medium (v = c/n), the opposite of Newton — a favourite assertion-reason trap.
- In a liquid of index n the fringe width DECREASES (β → β/n) because λ shrinks; don't multiply by n.

Most asked in NEET » Fringe width β = λD/d (change d, D, λ) · Immersion in liquid → β/n · $I = 4I_0\cos^2(\varphi/2)$ intensity vs path diff · I_max/I_min from slit-width / amplitude ratio · Single-slit minima a sinθ = nλ & central width · Brewster angle $\tan\theta_p = n$ · Malus's law & three-polaroid stacks · Resolving power θ = 1.22λ/D