FREE NOTES · NCERT + JEE/NEET LEVEL

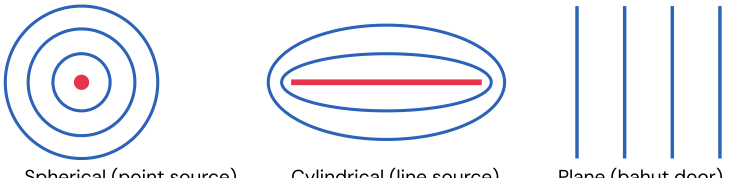
Wave Optics

Wavefront, Huygens principle, coherent sources, interference, Young's double slit, diffraction, resolving power aur polarisation (Malus aur Brewster). Diagrams aur solved numericals ke saath.

01 Wavefront
02 Huygens principle
03 Coherent sources
04 Interference
05 Young's double slit experiment (YDSE)
06 Diffraction (single slit)
07 Resolving power
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01 Wavefront

Aisi surface jis pe saare points **same phase** me hon. Light ki ray hamesha wavefront ke ⊥.



Teen tarah ke wavefront

02 Huygens principle

- Wavefront ka har point ek naya source (secondary source) ban jaata, jisse chhoti waves (wavelets) light ki speed se chaaron taraf.
- Thodi der baad in wavelets ko chhoone wali surface (envelope) = naya wavefront.

ISSE KYA PROVE HOTA

Reflection ke laws (i = r) aur Snell's law dono. Refraction me $\sin i/\sin r = v_1/v_2 = n_2/n_1$, yaani light ghane medium me **dheemi** chalti (Newton ki corpuscular theory ulta kehti thi, galat thi).

03 Coherent sources

Do sources jinke beech **phase difference constant** rahe (aur same frequency). Tabhi stable interference pattern dikhta.

DO ALAG BULB COHERENT KYUN NAHI?

Bulb me lakhon atoms random tareeke se light chhodte, phase har 10^{-10} s me badalta. Isliye ek hi source ko do hisson me baant ke coherent sources banaate hain (Young ke do slits, Lloyd's mirror) ya laser use karte.

04 Interference

Do coherent waves milein toh kahin tez (constructive), kahin kamzor (destructive).

$$I = I_1 + I_2 + 2\sqrt{(I_1 I_2)}\cos\varphi$$

Phase difference $\varphi = (2\pi/\lambda) \times$ path difference

	Constructive (bright)	Destructive (dark)
Path difference	$n\lambda$	$(2n-1)\lambda/2$
Phase difference	$2n\pi$	$(2n-1)\pi$
Intensity	$(\sqrt{I_1}+\sqrt{I_2})^2$	$(\sqrt{I_1}-\sqrt{I_2})^2$

Barabar intensity I_0: max $4I_0$, min 0. Energy khatam nahi hoti, sirf jagah badalti (redistribution).

05 Young's double slit experiment (YDSE)

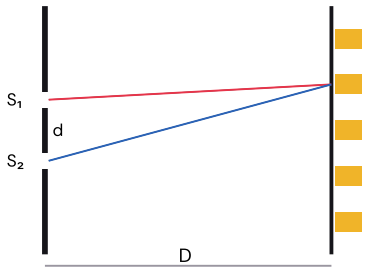
Path difference $= d \sin\theta \approx yd/D$

Bright fringe: $y_n = n\lambda D/d$

Dark fringe: $y_n = (2n-1)\lambda D/(2d)$

$$\text{Fringe width } \beta = \lambda D/d$$

d = slits ki doori, D = slit se screen. Angular width = λ/d.



Screen pe barabar doori ki bright-dark patti

Badlav	Fringe width β
Red ki jagah blue light	Kam (λ chhota)
Slits door (d badha)	Kam
Screen door (D badha)	Zyada
Poora setup paani (n) me	β/n
Safed light	Beech ki fringe safed, baaki rangeen

Ek slit ke aage t motai ki patli sheet (n): pattern us taraf khisakta, shift = $(n-1)tD/d$. Fringe width nahi badalti.

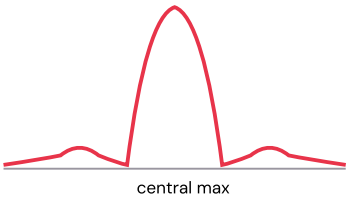
06 Diffraction (single slit)

Light ka kisi rukaavat ya chhote chhed ke kinaare se mudna. Tab dikhta jab chhed ka size λ ke kareeb ho.

Minima: $a \sin\theta = n\lambda$

Central maximum ki width $= 2\lambda D/a$

a = slit width. Central bright sabse chauda aur sabse tez; baaki ki intensity tezi se kam. Slit patli ⇒ pattern chauda.



Intensity: beech me sabse zyada

Interference	Diffraction
Do alag coherent sources	Ek hi wavefront ke alag hisse
Saari fringes barabar chaudi	Central chauda, baaki patle
Bright fringes ki intensity barabar	Intensity tezi se ghatti

Fresnel distance $z_F = a^2/\lambda$: isse kam doori pe ray optics chalta, zyada pe diffraction dikhta.

07 Resolving power

Do paas ki cheezon ko alag-alag dekh paane ki kshamata. Diffraction ki wajah se har instrument ki limit hai.

Telescope: minimum angle $\Delta\theta = 1.22\,\lambda/D$

Microscope: $d_{min} = 1.22\,\lambda/(2n \sin\beta)$

Telescope ka lens/mirror bada (D) ⇒ behtar resolution. Microscope me chhoti λ (electron microscope!) ⇒ behtar.

08 Polarisation

Normal light me electric field har direction me hilta (unpolarised). Polaroid se guzarne ke baad sirf ek direction me: **plane polarised**. Ye prove karta ki light **transverse** wave hai (sound polarise nahi hota).

MALUS'S LAW

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

Unpolarised light pehle polaroid se ⇒ $I_0/2$. θ = do polaroids ke axes ke beech angle. θ = 90° (crossed) ⇒ 0.

BREWSTER'S LAW

$$\tan i_B = n$$

Is angle pe reflected light poori polarised, aur reflected aur refracted ray ke beech 90°. Glass (1.5): $i_B \approx 56°$.

Uses: sunglasses (glare kam), 3D movie glasses, LCD screens, camera filters.

09 JEE Extra + Tricks

JEE LEVEL

- YDSE: $\beta = \lambda D/d$; medium me β/n; ek raaste me t moti slab se pattern $(n-1)tD/d$ khisakta (slab ki taraf).
- Intensity $I = 4I_o\cos^2(\varphi/2)$; alag intensities me $I_{max}/I_{min} = ((\sqrt{I_1} + \sqrt{I_2})/(\sqrt{I_1} - \sqrt{I_2}))^2$.
- Single slit: minima a $\sin\theta = n\lambda$ pe; central maximum ki chaudai $2\lambda D/a$ (baakiyon ki double).
- Malus law $I = I_o\cos^2\theta$; unpolarised roshni polaroid se: $I_o/2$.
- Brewster law $\tan i_p = n$; reflected aur refracted rays perpendicular.
- Resolving power: microscope $\propto 1/\lambda$; telescope $\propto D/\lambda$.

10 Solved numericals

Q1. YDSE: d = 0.5 mm, D = 1 m, λ = 600 nm. Fringe width?
$\beta = 600 \times 10^{-9} \times 1/(5 \times 10^{-4}) = 1.2 \times 10^{-3}$ m. **Ans: 1.2 mm**

Q2. Upar wale setup me 3rd bright fringe centre se kitni door?
$y_3 = 3\beta = 3.6$ mm. **Ans: 3.6 mm**

Q3. Do waves ki intensities 9 : 1. $I_{max} : I_{min}$?
$(3 + 1)^2 : (3 - 1)^2 = 16 : 4 = 4 : 1$. **Ans: 4 : 1**

Q4. Single slit a = 0.2 mm, λ = 500 nm, D = 2 m. Central maximum ki width?
$2\lambda D/a = 2 \times 5 \times 10^{-7} \times 2/(2 \times 10^{-4}) = 10^{-2}$ m. **Ans: 1 cm**

Q5. Unpolarised light (I_o) do polaroids se, axes ke beech 60°. Final intensity?
Pehle ke baad $I_o/2$, phir × $\cos^2 60° = ¼ \Rightarrow I_o/8$. **Ans: $I_o/8$**

Q6. Brewster angle 60°. Refractive index?
$n = \tan 60° = \sqrt{3} \approx 1.73$. **Ans: √3**

11 Common mistakes

- Malus me unpolarised light ke liye seedha $\cos^2$ laga dena (pehle aadha karo).
- Diffraction ka central width λD/a likhna (2λD/a hai).
- Paani me YDSE pe fringe width badhti maan lena (n se ghatti).
- Interference me energy "nasht" hoti maan lena (redistribute hoti).
- mm aur nm ko m me na badalna.

12 Formula sheet

Phase vs path	$\varphi = (2\pi/\lambda)\,\Delta x$
Resultant intensity	$I = I_1 + I_2 + 2\sqrt{(I_1 I_2)}\cos\varphi$
Fringe width	$\beta = \lambda D/d$
Bright / dark	$n\lambda D/d$ / $(2n-1)\lambda D/2d$
Sheet shift	$(n-1)tD/d$
Single slit minima	$a\sin\theta = n\lambda$
Central max width	$2\lambda D/a$
Resolving limit	$1.22\lambda/D$
Malus	$I = I_0\cos^2\theta$
Brewster	$\tan i_B = n$

13 Practice questions

1. YDSE me d aadhi aur D 2 guna. β?
2. Do crossed polaroids ke beech teesra 45° pe daalo. Intensity (unpolarised I_o se)?
3. Barabar intensity I_o ki do waves, phase difference 60°. Resultant?
4. Single slit chaudi karo. Central maximum?

ANSWERS

1) 4 guna · 2) $I_o/2 \times ½ \times ½ = I_o/8$ · 3) $2I_o(1 + \cos 60°) = 3I_o$ · 4) Patla ho jaata

14 Quick revision: exam se pehle 5 minute

HUYGENS

- Har point = secondary source.
- Ghane medium me light dheemi.
- Coherent: constant phase difference.

INTERFERENCE

- Bright nλ, dark (2n − 1)λ/2.
- β = λD/d; paani me β/n.
- $I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$.

DIFFRACTION

- a sin θ = nλ (minima).
- Central width 2λD/a.
- Resolving 1.22λ/D.

POLARISATION

- Light transverse hai.
- $I = I_o \cos^2\theta$; unpolarised ⇒ $I_o/2$.
- tan i_B = n; r + i = 90°.

Doubt hai? padhaiadda.netlify.app pe AI Doubt Solver se poocho, ya is chapter ka mock test do.