FREE NOTES · NCERT + JEE/NEET LEVEL

Ray Optics & Optical Instruments

Mirror, refraction, total internal reflection, lens, lens maker's formula, power, prism, dispersion, microscope aur telescope. Sign convention ke saath, ray diagrams aur solved numericals.

01 Reflection & sign convention
02 Spherical mirrors
03 Refraction
04 Total internal reflection (TIR)
05 Curved surface pe refraction
06 Lens & lens maker's formula
07 Power & combination of lenses
08 Prism
09 Dispersion & scattering
10 Simple & compound microscope
11 Telescope
12 JEE Extra + Tricks
13 Solved numericals
14 Common mistakes
15 Formula sheet
16 Practice questions
17 Quick revision: exam se pehle 5 minute

01 Reflection & sign convention

Laws: (1) angle of incidence = angle of reflection. (2) Incident ray, reflected ray aur normal ek hi plane me.

NEW CARTESIAN SIGN CONVENTION

- Saari doori **pole/optical centre** se naapo.
- Light jis taraf ja rahi (aam taur pe left se right), us taraf +, ulta −.
- Principal axis ke upar +, neeche −.
- Object aam taur pe left me ⇒ u hamesha **negative**.

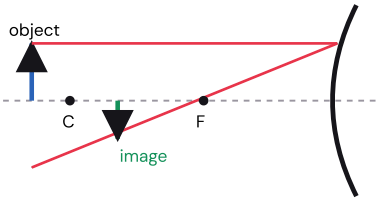
Plane mirror: image utni hi peeche jitna object aage, virtual, seedha, same size, left-right ulta. Mirror θ ghumao toh reflected ray 2θ ghoomti.

02 Spherical mirrors

$$1/v + 1/u = 1/f,\ f = R/2$$

$$\text{Magnification } m = h'/h = -v/u$$

Concave: f negative. Convex: f positive. m negative ⇒ real, ulti image. m positive ⇒ virtual, seedhi.



Concave mirror: real, ulti image

Concave mirror me object	Image
Infinity	F pe, bahut chhoti, real
C se bahar	F aur C ke beech, chhoti, real ulti
C pe	C pe, same size, real ulti
F aur C ke beech	C se bahar, badi, real ulti
F pe	Infinity pe
F aur P ke beech	Mirror ke peeche, badi, virtual seedhi (shaving mirror)

Convex mirror: hamesha virtual, seedhi, chhoti image. Bada area dikhaata ⇒ gaadi ka rear-view mirror.

03 Refraction

$$\text{Snell's law: } n_1 \sin i = n_2 \sin r$$

$n = c/v$ (refractive index), $n_{21} = n_2/n_1$

Patle se ghane medium me (air → glass) ray normal ki taraf mudti. Frequency same, speed aur λ badalte.

APPARENT DEPTH

Paani me sikka upar dikhta: apparent depth = real depth/n. Shift = d(1 − 1/n).

GLASS SLAB

Nikalti ray incident ke parallel, sirf **side me khiski** (lateral shift). Slab moti ya i zyada ⇒ shift zyada.

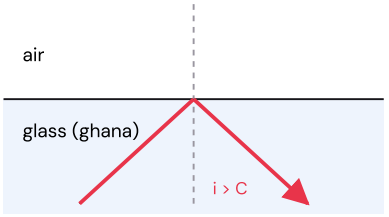
Sun asal me ufuq (horizon) ke neeche ho tab bhi dikhta (atmospheric refraction) ⇒ din ≈ 4 minute lamba. Taare isi wajah se timtimaate.

04 Total internal reflection (TIR)

Ghane se patle medium me jaati light: angle badhao, ek angle pe refracted ray surface ke along. Usse zyada angle pe light **poori wapas** reflect.

$$\sin C = 1/n \; (n_{21} = n_{\text{dense}}/n_{\text{rare}})$$

Do sharten: (1) ghane se patle me, (2) i > C. Glass C ≈ 42°, paani ≈ 49°, diamond ≈ 24°.



Poori light andar hi wapas

Examples: diamond ki chamak (C chhota), optical fibre (light andar baar-baar TIR), mirage (registaan me garam hawa), totally reflecting prism (periscope, binoculars).

05 Curved surface pe refraction

$$n_2/v - n_1/u = (n_2 - n_1)/R$$

n_1 = jahan se light aa rahi, n_2 = jahan ja rahi. Sign convention wahi. Isi se lens formula nikalta.

06 Lens & lens maker's formula

LENS MAKER'S FORMULA

$$1/f = (n - 1)(1/R_1 - 1/R_2)$$

Medium me rakho: n ki jagah n_{lens}/n_{medium}. Agar $n_{lens} = n_{medium}$ ⇒ lens gayab (f = ∞). Kam n wale medium me convex lens concave jaisa (jaise paani ke andar hawa ka bulbula).

THIN LENS FORMULA

$$1/v - 1/u = 1/f$$

$$m = v/u$$

Convex (converging): f +. Concave (diverging): f -.

MIRROR VS LENS

Mirror: 1/v + 1/u, m = -v/u. Lens: 1/v − 1/u, m = +v/u. Ye galti sabse common hai.

Convex lens ka image table bhi concave mirror jaisa (2F aur F ke saath). Object F ke andar ⇒ virtual, badi image (magnifying glass). Concave lens: hamesha virtual, seedhi, chhoti.

07 Power & combination of lenses

$$P = 1/f \text{ (f metre me)}$$

Unit dioptre (D). Convex +, concave −. Chashme ka number yahi hai.

PAAS-PAAS RAKHE LENSES

$P = P_1 + P_2$, $1/f = 1/f_1 + 1/f_2$

Doori d pe: $1/f = 1/f_1 + 1/f_2 - d/(f_1 f_2)$

Total magnification $m = m_1 \times m_2$

Lens ka aadha hissa dhak do: image poori banti, bas dhundli (intensity aadhi). **Biconvex lens ko kaatna:** principal axis ke along do hisson me kaato toh har tukde ka f same; lens ke plane ke parallel beech se kaato (do plano-convex) toh har tukde ka f 2 guna.

08 Prism

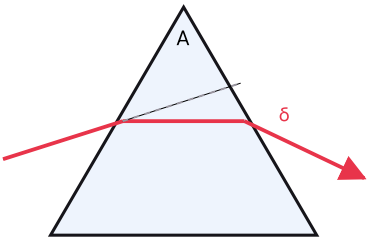
$A = r_1 + r_2$

Deviation $\delta = i + e - A$

Minimum deviation pe: i = e, $r_1 = r_2 = A/2$, ray base ke parallel.

$$n = \sin((A + \delta_m)/2) \,/\, \sin(A/2)$$

Patla prism (A chhota): $\delta = (n - 1)A$.



Ray base ki taraf mudti

09 Dispersion & scattering

Safed light prism se 7 rangon me bantati (VIBGYOR). Wajah: alag rang ka alag n. **Violet ka n sabse zyada ⇒ sabse zyada mudta; laal sabse kam.**

$$\text{Angular dispersion} = \delta_v - \delta_r = (n_v - n_r)A$$

$$\text{Dispersive power } \omega = (n_v - n_r)/(n - 1)$$

Phenomenon	Wajah
Rainbow (indradhanush)	Boondon me refraction + internal reflection + dispersion; Sun peeche hona chahiye
Aasmaan neela	Scattering $\propto 1/\lambda^4$ (Rayleigh): neela zyada bikharta
Sunrise/sunset laal	Light lamba raasta, neela bikhar ke nikal gaya, laal bacha
Badal safed	Bade droplets saare rang barabar scatter karte
Danger signal laal	Laal sabse kam scatter, door tak dikhta

10 Simple & compound microscope

AANKH

Least distance of distinct vision D = 25 cm (normal aankh). Near point 25 cm, far point infinity.

SIMPLE MICROSCOPE (CONVEX LENS)

Image D pe: $m = 1 + D/f$

Image infinity pe: $m = D/f$

COMPOUND MICROSCOPE

$$m = m_o \times m_e$$

Infinity pe: $m \approx (L/f_o)(D/f_e)$

Objective aur eyepiece dono ka f chhota. L = tube length.

11 Telescope

REFRACTING (ASTRONOMICAL) TELESCOPE

Normal adjustment (image infinity pe): $m = f_o/f_e$, tube length $L = f_o + f_e$

Image D pe: $m = (f_o/f_e)(1 + f_e/D)$

Objective ka f bada aur aperture bada (zyada light, zyada resolving power), eyepiece ka f chhota.

	Microscope	Telescope
Objective	Chhota f, chhota aperture	Bada f, bada aperture
Kya dekhte	Paas ki chhoti cheez	Door ki cheez

REFLECTING TELESCOPE (CASSEGRAIN)

Objective ki jagah concave mirror. Fayde: chromatic aberration nahi, bada mirror banana aur sambhaalna aasaan (lens bhaari aur toot-ta), spherical aberration parabolic mirror se khatam.

12 JEE Extra + Tricks

JEE LEVEL

- Prism: $n = \sin((A + \delta_m)/2)/\sin(A/2)$; patla prism $\delta = (n - 1)A$.
- Apparent depth = real depth / n (seedha dekhne pe); shift = $t(1 - 1/n)$.
- Lens combination: $P = P_1 + P_2$ (sate hue); d doori pe: $P = P_1 + P_2 - dP_1P_2$.
- Silvered lens mirror jaisa: $P_{eq} = 2P_{lens} + P_{mirror}$.
- Lens axis ke saath kaato: f same, intensity aadhi; axis ke perpendicular kaato: har aadhe ka 2f.
- Microscope $M \approx (L/f_o)(D/f_e)$; telescope $M = f_o/f_e$, lambai $f_o + f_e$ (normal adjustment).

13 Solved numericals

Q1. Concave mirror f = 15 cm, object 30 cm pe. Image kahan, kaisi?
$1/v = 1/f - 1/u = -1/15 + 1/30 = -1/30 \Rightarrow v = -30$ cm. $m = -1$. **Ans: 30 cm saamne, real, ulti, same size**

Q2. Convex lens f = 10 cm, object 15 cm pe. Image?
$1/v = 1/f + 1/u = 1/10 - 1/15 = 1/30 \Rightarrow v = +30$ cm. $m = v/u = -2$. **Ans: 30 cm, real, ulti, 2 guna**

Q3. Glass n = 1.5. Critical angle?
$\sin C = 1/1.5 = 0.667 \Rightarrow C \approx 41.8°$. **Ans: ≈ 42°**

Q4. Biconvex lens $R_1 = R_2 = 20$ cm, n = 1.5. f aur power?
$1/f = 0.5(1/20 + 1/20) = 1/20 \Rightarrow f = 20$ cm, $P = +5$ D. **Ans: 20 cm, +5 D**

Q5. +4 D aur −2 D lenses saath. f?
$P = +2$ D $\Rightarrow f = 50$ cm (convex). **Ans: 50 cm**

Q6. Prism A = 60°, $\delta_m = 30°$. n?
$n = \sin 45°/\sin 30° = 0.707/0.5 \approx 1.414$. **Ans: √2**

Q7. Telescope $f_o = 100$ cm, $f_e = 5$ cm. Normal adjustment me m aur tube length?
$m = 20$, $L = 105$ cm. **Ans: 20, 105 cm**

14 Common mistakes

- Mirror aur lens formula ka sign mix (+ aur −).
- u ko positive daal dena (object left me ⇒ u negative).
- Power nikaalte waqt f ko cm me rakhna (metre lo).
- TIR ki shart bhoolna: light ghane se patle medium me jaani chahiye.
- Violet ko kam mudne wala maan lena (violet sabse zyada mudta).
- Lens ka aadha dhakne pe aadhi image maan lena.

15 Formula sheet

Mirror	$1/v + 1/u = 1/f,\ f = R/2,\ m = -v/u$
Snell	$n_1 \sin i = n_2 \sin r$
Apparent depth	real/n
Critical angle	$\sin C = 1/n$
Spherical surface	$n_2/v - n_1/u = (n_2 - n_1)/R$
Lens maker	$1/f = (n-1)(1/R_1 - 1/R_2)$
Lens	$1/v - 1/u = 1/f,\ m = v/u$
Power	$P = 1/f,\ P = P_1 + P_2$
Prism	$n = \sin((A + \delta_m)/2)/\sin(A/2),\ \delta = (n-1)A$
Simple microscope	$m = 1 + D/f$
Compound microscope	$(L/f_o)(D/f_e)$
Telescope	$f_o/f_e,\ L = f_o + f_e$

16 Practice questions

1. Convex mirror f = 20 cm, object 20 cm pe. Image?
2. Paani (n = 4/3) me 2 m gehra taalaab kitna gehra dikhega?
3. Convex lens (n = 1.5, f = 20 cm) ko paani (4/3) me daala. Naya f?
4. Magnifying glass f = 5 cm. Max magnification?

ANSWERS

1) v = +10 cm, virtual, m = 0.5 · 2) 1.5 m · 3) (1.5 − 1)/(1.125 − 1) = 4 guna ⇒ 80 cm · 4) 1 + 25/5 = 6

17 Quick revision: exam se pehle 5 minute

MIRROR & LENS

- Mirror $1/v + 1/u$; lens $1/v - 1/u$.
- Concave mirror, convex lens: f; u hamesha −.
- P = 1/f (m), dioptre.

REFRACTION

- $n_1 \sin i = n_2 \sin r$.
- $\sin C = 1/n$; ghane → patla.
- Diamond, fibre, mirage = TIR.

PRISM

- δ_m: i = e.
- Violet sabse zyada mudta.
- Neela aasmaan: $1/\lambda^4$.

INSTRUMENTS

- Simple: 1 + D/f.
- Telescope: f_o/f_e.
- Reflecting: no chromatic aberration.

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