9. RAY OPTICS AND OPTICAL INSTRUMENTS

Single Page Simple Synopsis

Ray Optics (Geometrical Optics) studies light by treating it as straight-line rays. This chapter explores how light reflects, refracts, and forms images through mirrors, lenses, and prisms, and explains how optical instruments like telescopes and microscopes work.

1. **Reflection of Light:** Reflection is the bouncing back of light when it strikes a polished surface.
   - **Laws of Reflection:** The angle of incidence equals the angle of reflection ($\angle i = \angle r$). The incident ray, reflected ray, and normal all lie in the same plane.
   - **Spherical Mirrors:** Concave and convex mirrors follow the **Mirror Formula:** $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$
     Here f = focal length, v = image distance, u = object distance
2. **Refraction of Light:** Refraction is the bending of light as it travels from one medium to another.
   - **Snell's Law:** $\mu = \frac{\sin i}{\sin r}$; μ is Refractive index of medium 2 with respect to medium 1.
   - **Total Internal Reflection (TIR):** When light travels from a denser to a rarer medium at an angle greater than the **critical angle**. It totally reflects back.
3. **Refraction by Lenses and Prisms:**
   - **Lens Maker's Formula:** $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$
     It relates the focal length of a lens to the radii of its curvature and refractive index.
   - **Prism:** Light passing through a prism undergoes deviation and dispersion (VIBGYOR).
4. **Optical Instruments:**
   - **The Human Eye:** Understand how our natural lens adjusts focus.
   - **Microscopes:** Simple and compound microscopes used to view tiny, nearby objects.
   - **Telescopes:** Refracting and reflecting telescopes used to view distant objects like planets and stars.

Real Life Examples

- **Regular mirrors**, dentist mirrors, spectacle glasses of various powers, real view vehicle mirrors, head lights and torches, Endoscopes with optical fibres (TIR), Optical fibres in Internet cables, microscopes, telescopes,...

IMP. IPE POINTS

1. Law of reflection: $\angle i = \angle r$

Angle of incidence (i) = Angle of reflection(r)

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2. Snell's law of refraction:

Refractive index $\mu = n_{21} = \frac{n_2}{n_1} = \frac{\sin i}{\sin r} = \text{constant}$

(or) $n_1 \sin i = n_2 \sin r$

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3. Refractive index in terms of velocities of light:

$$n_{21} = \frac{c_1}{c_2}$$

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4. Refractive index in terms of wavelengths :

$$n_{21} = \frac{\lambda_1}{\lambda_2}$$

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5. Refractive index in terms of refractive indices:

$$n_{21} = \frac{n_2}{n_1} \quad \text{(or)} \quad n_{12} = \frac{n_1}{n_2}$$

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6. When a light ray is passing from denser medium to rarer medium, the angle of incidence for which the angle of refraction is 90° is called **critical angle** i_C.

$$n_{21} = \frac{1}{\sin i_C} \text{ (or) } \sin i_C = \frac{1}{n_{21}}$$

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7. In the case of light ray passing from denser medium to rarer medium and if $i > i_C$, **total internal reflection** takes place.

Law of reflection, i = r holds good for this.

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8. Focal length (f) is the distance between the pole (P) of the mirror and its principal focus (F)

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9. Sign convention:

For concave mirror, f = –f

For convex mirror, f = +f

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10. Mirror formula: $\frac{1}{v} + \frac{1}{u} = \frac{1}{f} = \frac{2}{R}$

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11. Magnification for mirror: $m = \frac{h'}{h} = -\frac{v}{u}$

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12. Refraction at a spherical surface:

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

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13. Lens maker's formula:

$$\frac{1}{f} = (n_{21} - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

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14. Thin lens formula: $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

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15. Magnification for lens: $m = \frac{h'}{h} = \frac{v}{u}$

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16. A convex lens converges light rays.

A concave lens diverges light rays.

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17. Sign convention:

For convex lens, f = +f

For concave lens, f = –f

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18. Combined focal length (f) of thin lenses in contact: $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$

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19. Power (P) of a lens: $P = \frac{1}{f}$

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20. Combined power (P) of lenses in contact

$$P = P_1 + P_2$$

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21. Refractive index of material of the prism

$$n_{21} = \frac{\sin\left(\frac{A + D_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

For a thin prism, $D_m = (n_{21} - 1)\,A$

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22. Simple microscope – Magnification :

$$m = 1 + \frac{D}{f} \text{ (near point)}, \quad m = \frac{D}{f} \text{ (infinity)}$$

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23. Compound microscope:

Magnification $m = m_0 m_e$

$$m = \left(\frac{v_0}{u_0}\right)\left(1 + \frac{D}{f_e}\right) \text{ (or) } m = \frac{LD}{f_0 f_e}$$

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24. Telescope: Magnification, $m = \frac{f_0}{f_e}$

Length of telescope $L = f_0 + f_e$