Refraction of Light

1. **Refraction :** The phenomenon, due to which a ray of light deviates from its original path, while travelling from one optical medium to another is called refraction.
2. **Rules for the change in the path of rays while travelling from one medium to another :**
   (i) When a ray of light travels obliquely from optically rarer medium to optically denser medium, it always bends towards the normal, at the point of incidence.
   (ii) When a ray of light travels obliquely from optically denser medium to optically rarer medium, it always bends away from the normal, at the point of incidence.
   (iii) When a ray of light strikes another optical medium at right angles, it does not suffer any refraction.
3. **Laws of refraction :**
   (a) Snell's Law : It states that, the ratio between all the values of sine of angle of incidence (in air) and the sine of angle of refraction in another optical medium is a constant quantity.
   (b) The incident ray, the refracted ray and the normal, lie in the same plane, at the point of incidence.

4. **Refractive index :** It is the ratio between the sine of angle of incidence (in air) and the sine of angle of refraction in another optical medium.

5. **Refractive index**

$$\mu = \frac{\sin i}{\sin r} = \frac{\text{Velocity of light in vacuum or air}}{\text{Velocity of light in given optical medium}}$$

6. **Lateral displacement :** It is the perpendicular shift in the path of incident ray, while emerging from an optical slab.

7. **Factors on which lateral displacement depends :**

   (i) Lateral displacement is directly proportional to angle of incidence.

   (ii) Lateral displacement is directly proportional to refractive index of the optical material.

   (iii) Lateral displacement is directly proportional to thickness of optical material.

   (iv) Lateral displacement is inversely proportional to wavelength of incident light.

8. $^{a}\mu_{b} = \frac{1}{^{b}\mu_{a}}$, where $^{a}\mu_{b}$ is the refractive index when a ray of light travels from air (a) to optical medium b, and $^{b}\mu_{a}$ is the refractive index when a ray of light travels from medium b to air (a).

9. **Real depth :** The actual depth at which an object is situated in a refracting material, is called real depth.

10. **Apparent depth :** The depth to which an object appears to rise in a refracting material, is called apparent depth.
11. **Refractive index**

    μ = Real depth ÷ Apparent depth.

12. **Prism :** It is a piece of glass or any other transparent material, bounded by two triangular and three rectangular surfaces.
13. **Refracting surfaces of prism :** The rectangular surfaces of prism are called refracting surfaces.
14. **Angle of prism :** The angle between two refracting surfaces is called angle of prism.
15. **Refracting edge of prism :** The line along which, two refracting surfaces of a prism meet is called refracting edge.
16. **Angle of deviation :** The angle between the incident ray and the emergent ray, when it passes through a glass prism is called angle of deviation.
17. **Angle of minimum deviation :** It is the least angle of deviation for a particular angle of incidence.

18. Factors which determine the angle of deviation.

(i) It depends upon angle of incidence.

(ii) It depends upon refractive index of material of prism.

(iii) It depends upon refractive angle of prism.

(iv) It depends upon wavelength of incident light, i.e., more the wavelength, lesser is the angle of deviation.

19. For all cases of refraction through glass prism :

Angle of incidence + Angle of emergence

= Refracting angle of prism + Angle of deviation

$$\angle i + \angle e = \angle A + \angle \delta$$

20. In the minimum deviation position :

(i) Angle of incidence = Angle of emergence.

(ii) Angle of refraction at first refracting surface = Angle of refraction at second refracting surface.

21. Total internal reflection : The phenomenon, due to which a ray of light, while travelling from denser medium to rarer medium is reflected into denser medium, at the surface of separation of two media is called total internal reflection.

22. Critical angle : The angle of incidence in the denser medium, for which angle of refraction in the rarer medium is 90°, is called the critical angle.

23. Conditions for total internal reflection :

(i) The rays of light must travel from the denser medium to the rarer medium.

(ii) The angle of incidence in the denser medium must be greater than the critical angle.

24. Totally reflecting prism : An isosceles glass prism having one angle as 90°, is called totally reflecting prism.

25. Uses of totally reflecting prisms :

(i) They are used in refracting periscope.

(ii) They are used in prism binoculars.

26. Advantages of refracting periscope over reflecting periscope :

(i) The final image is very clear as no rays of light are absorbed.

(ii) Any deposition of moisture or dust does not put periscope out of commission.

27. Differences between reflection and total internal reflection :

(i) Reflection takes place from polished surface, when rays travel from rarer medium to denser medium. The total internal reflection takes place only when rays of light travel from denser medium to rarer medium.

(ii) Reflection takes place at all angles of incidence. Total internal reflection takes place when angle of incidence in denser medium is greater than critical angle.

(iii) During reflection, rays of light are absorbed. During total internal reflection, no rays of light are absorbed.

28. $^{a}\mu_{g} = \frac{1}{\text{Sin c}}$, where $^{a}\mu_{g}$ is the refractive index and 'C' is the critical angle of a given optical medium.

29. Lens : It is a piece of transparent material, having one or two spherical surfaces.

30. Converging lens or convex lens : A piece of transparent material, having one or two spherical surfaces, such that, it is thicker in the middle and tapering at edges is called converging lens.

Converging lenses are of three kinds : (i) Double convex lens, (ii) Plano-convex lens, (iii) Concavo-convex lens.

31. Diverging lens or concave lens : A piece of a transparent material, having one or two spherical surfaces, such that, it is thicker at the edges and tapering in the middle, is called concave lens.

Concave lenses are of three kinds : (i) Double concave lens, (ii) Plano-concave lens, (iii) Convexo-concave lens.

32. Principal axis : An imaginary line, joining the centres of curvature of two spherical surfaces of lens is called principal axis.

33. Optical centre : A point within the lens, situated on the principal axis, such that any ray of light passing through it does not suffer any refraction, is called optical centre.

34. First principal focus (F_1) : It is the point on the principal axis of lens, such that, rays of light, starting from it (in case of convex lens) or appear to meet (in case of concave lens), after refraction, travel parallel to principal axis.

35. **Second principal focus** (F_2) : It is the point on the principal axis of lens, such that, rays of light, travelling parallel to principal axis, either actually meet at this point (in case of convex lens) or appear to come from this point (in case of concave lens).

36. **Focal plane :** The vertical plane passing through principal focus of lens is called focal plane.

37. **Focal length :** The distance between optical centre and principal focus is called focal length.

38. A convex lens always forms a real and inverted image for all positions of objects, **except when the object is between first principal focus and optical centre**, when it forms virtual, erect and magnified image.

39. A concave lens always forms virtual, erect and diminished image.

40. A convex lens can be put to the following uses :

(i) As a burning glass

(ii) As an objective lens for a telescope

(iii) As an objective lens for a photographic camera

(iv) As an objective lens for a cine camera

(v) As an erecting lens in a terrestrial telescope

(vi) As an objective lens in the search lights

(vii) As a magnifying glass.

41. A concave lens can be used as : (i) Eye lens for Galilean telescope

(ii) Correcting short-sightedness.

42. Characteristics of image formed in lens, when object travels from infinity to optical centre.

S.No.	*Nature of lens*	*Position of object*	Nature of Image	*Position of Image*
1.	Convex	At Infinity	Real, inverted, diminished to a point	At F_2, on the other side of lens
2.	Convex	In between ∞ and $2F_1$	Real, inverted, diminished	In between F_2 and $2F_2$, on the other side of lens.
3.	Convex	At $2F_1$	Real, inverted, and same size as object	At $2F_2$, on the other side of lens
4.	Convex	In between $2F_1$ and F_1	Real, inverted, magnified	In between $2F_2$ and ∞, on the other side of lens
5.	Convex	At F_1	Real, inverted, highly magnified	At ∞, on the other side of lens
6.	Convex	In between F_1 and O	Virtual, erect, magnified	At point of distinct vision, on the same side of lens
7.	Concave	At infinity	Virtual, erect, diminished to a point	At F_2, on the same side of lens
8.	Concave	In between ∞ and O	Virtual, erect, diminished	In between O and F_2, on the same side of lens.

43. Simple microscope : When an object is placed between optical centre and first principal focus of convex lens, it acts as simple microscope.

44. The magnification of simple microscope is given by the expression, $m = 1 + \frac{D}{f}$, where m is the magnification, D is the least distance of distinct vision and *f* the focal length of convex lens.

45. A simple microscope is used :

(i) to read fine print,

(ii) to observe weave patterns of a cloth,

(iii) to observe lines of hand by palmist,

(iv) to observe biological specimens,

(v) to read vernier scale on instruments like travelling microscope, spectrometer.