# PARMAR SSC

# REFLECTION AND REFRACTION

## Lecture - 5



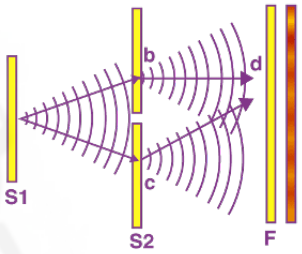
BY PARMAR SIR

# Light

- Light is defined as a form of electromagnetic radiation, specifically the part of the electromagnetic spectrum that is visible to the human eye.
- Light has dual nature (Light exhibits both wave-like and particle-like characteristics).
- Light can also be described as a stream of particles called photons, which carry energy.
- Light travels at a constant speed in a vacuum, approx. $3 \times 10^8$ m/s.
- Light is a form of transverse wave that travels in vacuum.
- Light can be polarized.

## Young's Double-Slit Experiment

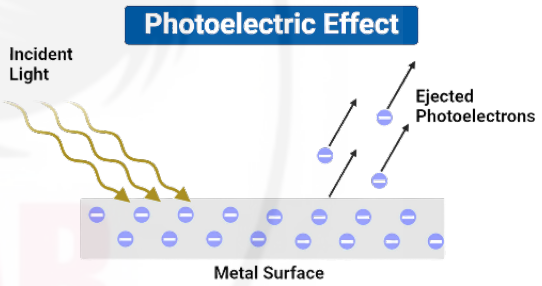
- It was performed in 1801 by Thomas Young, demonstrates the wave-like nature of light, showing that light can interfere with itself, creating an interference pattern of bright and dark fringes.



Young's Double Slits Experiment

## Photoelectric Effect

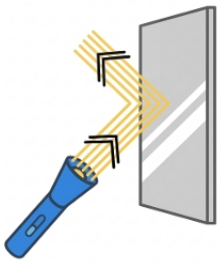
- The photoelectric effect is a phenomenon where electrons are emitted from the metal surface when light of sufficient frequency is incident upon it.
- This effect led to the conclusion that light is made up of packets or quantum of energy.
- Heinrich Rudolf Hertz was the first to observe the photoelectric effect in 1887.




- In 1905, Albert Einstein proposed the existence of photons, discrete packets of energy, to explain the photoelectric effect and other light-related phenomena (received Nobel Prize in 1921).

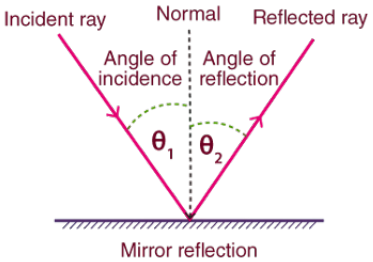
## Reflection of Light

- Reflection occurs when light rays strike a surface and change direction, returning to the same medium instead of passing through or being absorbed.



### Laws of Reflection

1. The angle of incidence (i) is equal to the angle of reflection (r).
2. The incident ray, reflected ray, and the normal all lie in the same plane.



# SPHERICAL MIRRORS

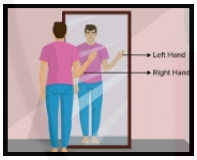
- There are different types of mirrors and they are broadly classified as




Plane Mirrors | Concave Mirrors | Convex Mirror

| Type | Description | Image Nature |
|---|---|---|
| Plane Mirror | Flat mirror | Virtual, erect, laterally inverted |
| Concave Mirror | Reflecting surface curves inward | Real / Inverted or Virtual / Erect depending on object position |
| Convex Mirror | Reflecting surface curves outward | Always Virtual, erect, and diminished |

**Plane Mirrors**



**Concave Mirrors**



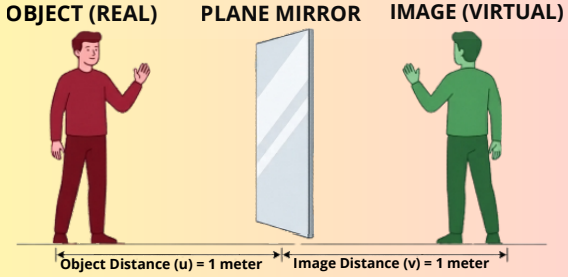
**Convex Mirrors**



Images are classified as either real or virtual, based on whether light rays actually converge to form the image, or only appear to diverge from a point.

## Image Formation in Plane Mirror

**PROPERTY: SAME SIZE (HEIGHT)**




**VIRTUAL IMAGE:** Forms behind the mirror; light rays do not pass through it.

**ERECT ORIENTATION:** Always upright, not inverted.

**SAME SIZE:** Image height is equal to the object height.

**LATERAL INVERSION:** Left and Right are reversed. Object: Left hand raised → Image: Right hand raised

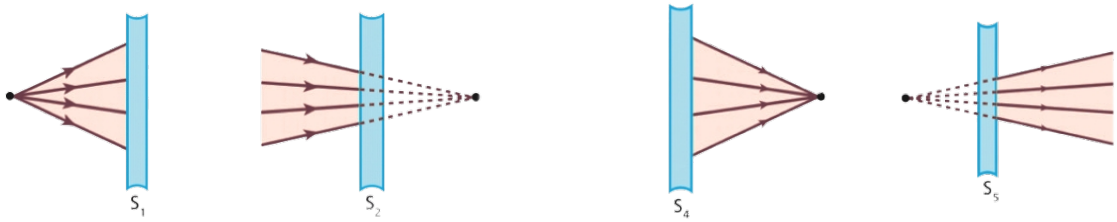
**Virtual Image** — The image cannot be projected on a screen and is formed behind the mirror.

**Erect Image** — The image is upright (not inverted), i.e., it has the same orientation as the object.

**Lateral Inversion** — The left and right sides of the object appear interchanged in the image.

**Same Size** — The image and object have the same size.

**Equal Distances** — The distance between the object and the mirror is equal to the distance between the image and the mirror.

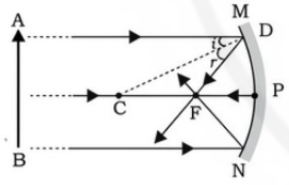



**Real objects are points from which light diverges. Virtual objects are points towards which light converges.**

## TYPES OF IMAGE

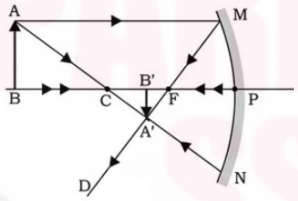
| Real Image | Virtual Image |
|---|---|
| Can be projected on a screen | Cannot be projected on a screen |
| Formed when light rays actually converge and intersect after reflection or refraction | Formed when light rays appear to diverge from a point, but do not actually intersect |
| Always inverted (upside down) | Always upright (right side up) |
| Formed by concave mirrors and convex lenses | Formed by convex mirrors, concave lenses, and plane mirrors |

## Image Formation by Concave Mirror



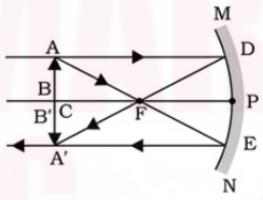
Real, inverted, highly diminished image at focus

**(a) When the object is situated at ∞**



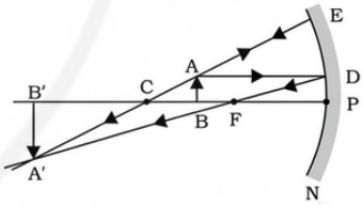
Real, inverted, diminished between C and F

**(b) Object beyond C**



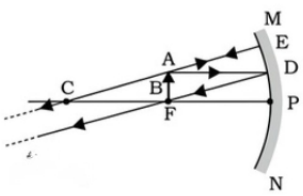
Real, inverted image of the same size as object at C

**(c) Object at C**



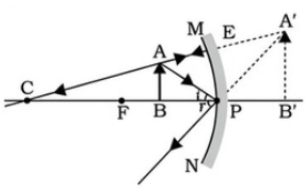
Real, inverted, enlarged beyond C

**(d) Object between C and F**



Real, inverted, highly enlarged image at infinity

**(e) Object at F**



Virtual, erect, enlarged image behind the mirror

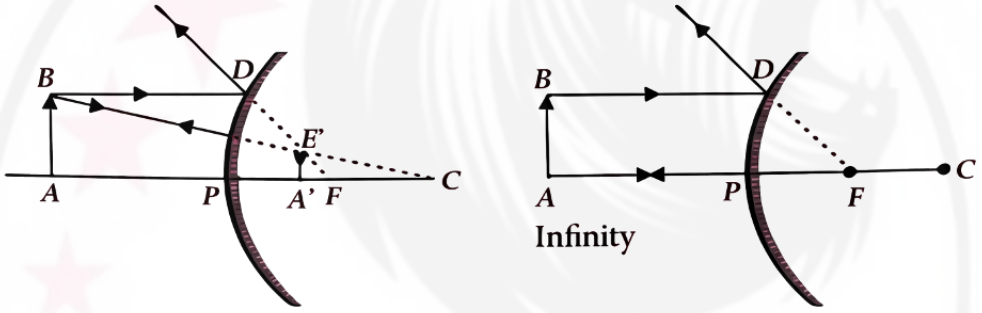
**(f) Object between F and P**

- *C: Curvature*
- *F: Focus*
- *P: Pole*

- A concave mirror can form both real and virtual images.

| Object Position | Image Position | Nature | Image Size |
|---|---|---|---|
| At infinity | At focus | Real, inverted | Highly diminished |
| Beyond C | Between C & F | Real, inverted | Diminished |
| At C | At C | Real, inverted | Same size |
| Between C & F | Beyond C | Real, inverted | Enlarged |
| At F | At infinity | Real, inverted | Highly enlarged |
| Between F & P | Behind mirror | Virtual, erect | Enlarged |

## Image Formation by Convex Mirror (Diverging in Nature)




*(A) At infinity* *(B) Between infinity and P*

- A convex mirror forms an image that is always virtual, erect, and diminished (regardless of the object's position) and appears behind the mirror.

| Object Position | Image Position | Nature | Image Size |
|---|---|---|---|
| At infinity | At F, behind the mirror | Virtual, erect | Highly diminished, point-sized |
| Between infinity and P of the mirror | Between P and F behind the mirror | Virtual, erect | Diminished |

### Sign Convention in Spherical Mirror

- All distances are measured from the pole of the mirror.
- Distances to the right of the pole are considered positive.
- Distances to the left of the pole are considered negative.
- Distances above the principal axis are considered positive.
- Distances below the principal axis are considered negative.

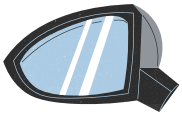
# Uses of Spherical Mirrors



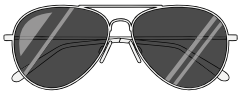

## Concave Mirror




Shaving and dentist mirrors, car headlights, telescopes, solar furnace, etc.

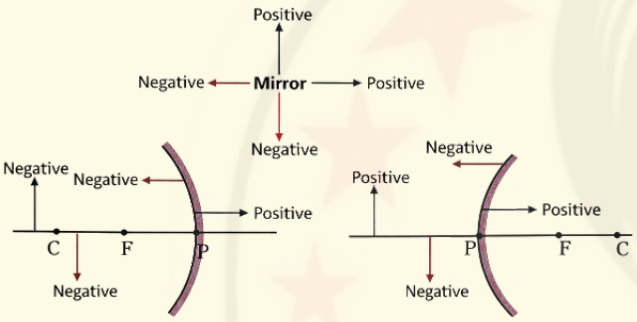


## Convex Mirror



Rear view mirrors in vehicles, security monitors in ATMs and stores, surveillance mirrors, sunglasses, etc.

## In Spherical Mirrors




**Object Distance (u)**

- Always negative (since the object is placed in front of the mirror).

**Image Distance (v)**

- **Concave mirror:** Real image (v is negative) and virtual image (v is positive).
- **Convex Mirror:** Image is always virtual and v is positive.

**Focal Length (f)**

- Concave mirror (f is negative) and convex mirror (f is positive)

**Radius of Curvature (R)**

- Same sign as focal length (R = 2f)

## Mirror Formula

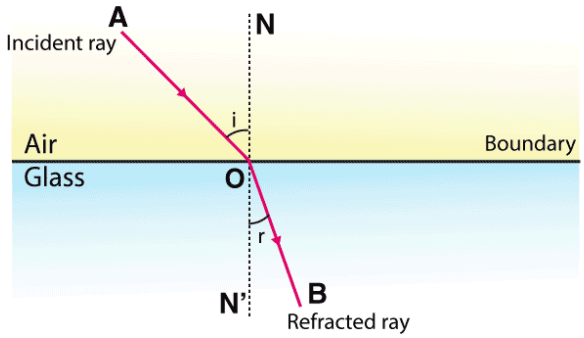
$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$

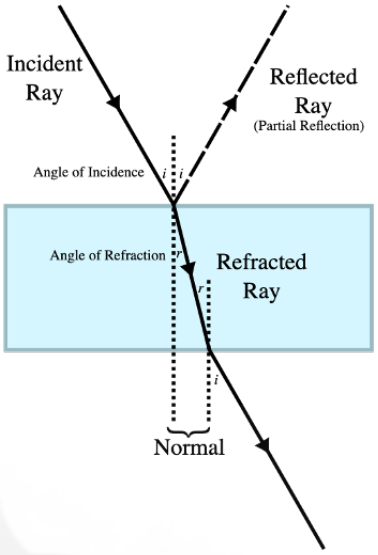
$$\text{Magnification of Mirrors} = \frac{hi}{ho} = \frac{-v}{u}$$

$M = 2$ (*image size is twice the size of an object*)
$M = -2$ (*image is real and inverted*)
$M = 0.2$ (*image size is smaller than the object*)

# Refraction of Light

- The refraction of light is the bending of light rays as they pass from one medium to another, thereby causing a change in its speed and direction.
- Refraction occurs due to a change in the speed of the light ray or wave.
- While the speed and wavelength of light changes as it moves into a different medium, the frequency, which is determined by the light source, remains constant.
- This bending by refraction makes it possible for us to have lenses, magnifying glasses, prisms and rainbows.




## Laws of Refraction

1. The incident ray, the refracted ray and the normal at the point of incidence. All lie in the same plane.
2. The ratio of the sine of the angle of incidence (i) and sine of the angle of refraction (r) is constant for the same pair of medium and for the same wavelength. (also known as Snell's Law).

$$\frac{Sin\ i\ (Angle\ of\ Incidence)}{Sin\ r\ (Angle\ of\ Refraction)} = Constant = \mu$$

***where μ (mu) is the refractive index of the second medium with respect to the first.**

### Refractive Index (μ)

$$\mu = \frac{Speed\ of\ light\ in\ vacuum}{Speed\ of\ light\ in\ medium}$$

**Absolute Refractive Index**

- It is the refractive index of a medium with respect to vacuum.

$$\mu = \frac{C}{V}$$

**Relative Refractive Index**

- It is the refractive index of one medium with respect to another medium.

$$\mu_{12} = \frac{V_2}{V_1}$$

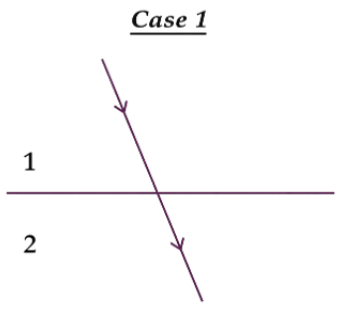
## Types of Medium

- **Rare Medium**: Light bends away from the normal when moving from a denser to a rarer medium.
- **Denser Medium**: Light bends toward the normal when moving from a rarer to a denser medium.

| Material medium | Refractive index |
|---|---|
| Air | 1.0003 |
| Ice | 1.31 |
| Water | 1.33 |
| Alcohol | 1.36 |
| Kerosene | 1.44 |
| Flint glass | 1.6 |
| Quartz | 1.46 |
| Turpentine oil | 1.47 |
| Diamond | 2.42 |
| Crown Glass | 1.52 |
| Canada Balsam | 1.53 |
| Musk | 1.54 |
| Rock salt | 1.54 |
| Carbon disulphide | 1.63 |
| Dense Flint Glass | 1.65 |
| Ruby | 1.71 |
| Sapphire | 1.77 |
| Cinnabar | 2.65 |

## Case A: Same Medium (No Refraction)

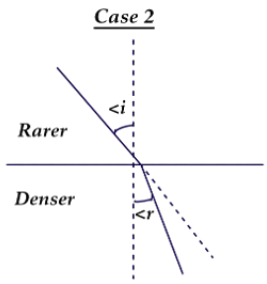
- When light travels through two mediums with the same optical density (E.g., air to air or water to water), it continues in a straight line without bending.
- This is because the speed of light remains constant, and there's no change in the direction of the light ray




*Same medium (No Refraction) with same density*

## Case B: From Rarer to Denser Medium

- When light travels from a rarer medium to a denser medium (E.g., air to glass or water), it bends towards the normal (the line perpendicular to the surface at the point of incidence).
- i is greater than r.
- The speed of light decreases in the denser medium.

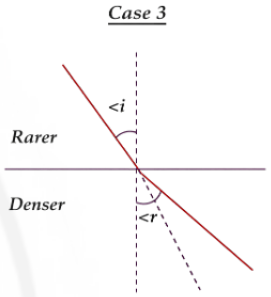



From Rarer to Denser Medium

<i > <r

## Case C: From Denser to Rarer Medium

- When light travels from a denser medium to a rarer medium (e.g., glass to air), it bends away from the normal.
- i is less than r.
- The speed of light increases in the rarer medium.



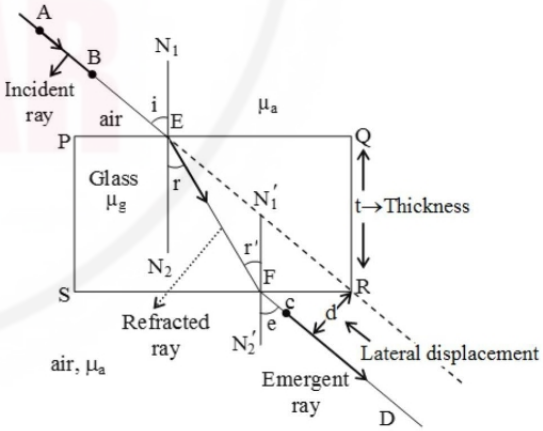

From Denser to Rarer Medium

<i < <r

## Refraction Through Glass Slab

**When light passes through a glass slab:**

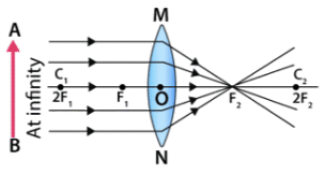
- It bends towards the normal on entering (air → glass, denser medium).
- It bends away from the normal on exiting (glass → air, rarer medium).
- The emergent ray is parallel to the incident ray but slightly shifted sideways - this is called lateral displacement.



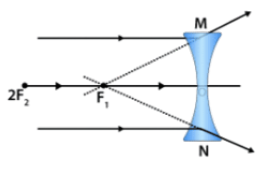

## SPHERICAL LENSES

- Spherical lenses are optical devices with curved, spherical surfaces that refract (bend) light, either converging or diverging it.
- They are classified into two main types: Convex (converging) and Concave (diverging) lens.




Convex Lens



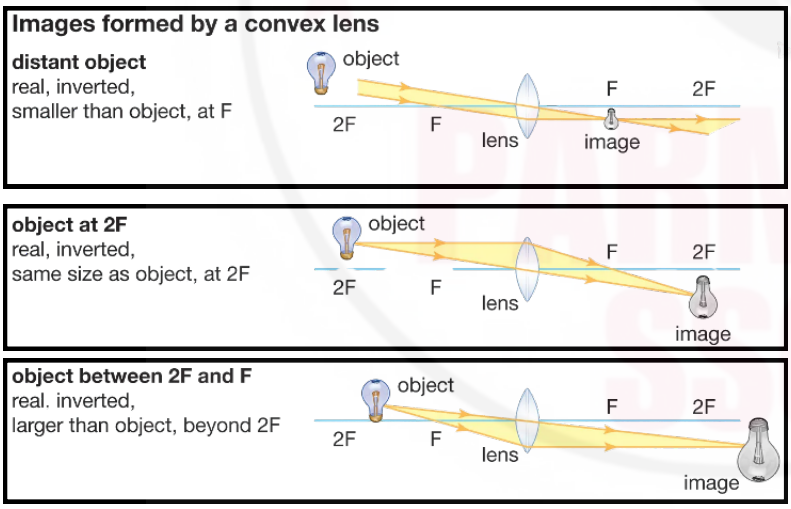

Concave Lens

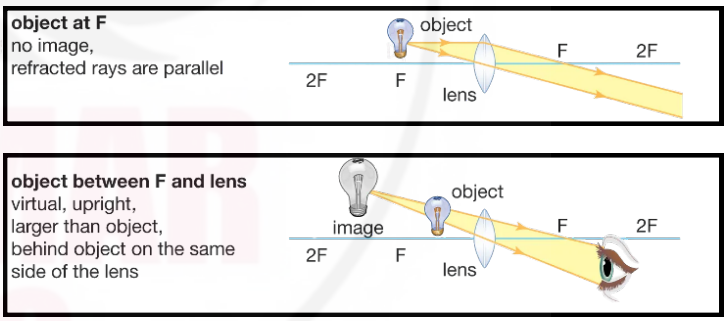
- Convex Lens: Centre bulged, ends narrow
- Concave Lens: Centre narrow, ends wider
- Convex Lens = Concave Mirror
- Concave Lens = Convex Mirror

## Image Formation by Convex Lens

- A convex lens (also called a converging lens) can form real or virtual images depending on the object's position.

| Object Position | Image Position | Nature | Image Size |
|---|---|---|---|
| At infinity | At focus (F) | Real, inverted | Highly diminished |
| Beyond 2F | Between F and 2F | Real, inverted | Diminished |
| At 2F | At 2F | Real, inverted | Same size |
| Between F and 2F | Beyond 2F | Real, inverted | Enlarged |
| At focus (F) | At infinity | Real, inverted | Highly enlarged |
| Between F and O | On same side of the lens | Virtual, erect | Enlarged |



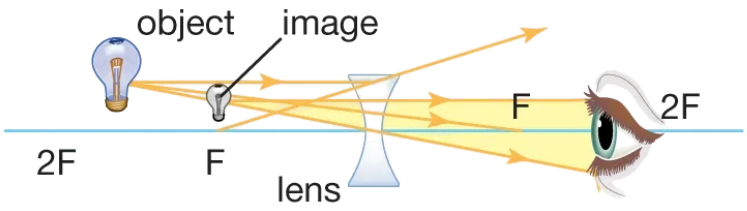

## Image Formation by Concave Lens

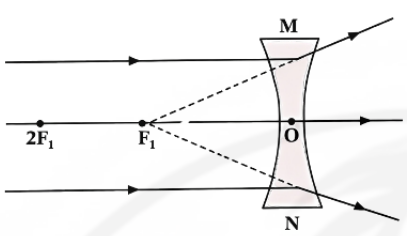
- A concave lens always forms a virtual, erect, and diminished image, regardless of the object's position.

| Object Position | Image Position | Nature | Image Size |
|---|---|---|---|
| At infinity | At F | Virtual, erect | Highly diminished |
| Between infinity and O (center) | Between F and O | Virtual, erect | Diminished |

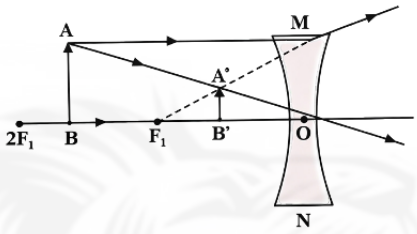
## Images formed by a concave lens

**characteristics of image regardless of object position**
virtual, upright,
smaller than object, between object and the lens




*(A) At infinity*




*(B) Between infinity and O*

$$\text{Lens Formula} = \frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

*f* = Focal length of lens
*v* = Image distance from the lens
*u* = Object distance from the lens

$$\text{Magnification } (M) = \frac{v}{u}$$

*M* = 1 (Image size = Object size)
*M* > 1 (Image is larger than object)
*M* < 1 (Image is smaller than object)

## Uses of Lenses




**Convex lens**




Used in eyeglasses to correct hypermetropia (farsightedness), magnifying glasses, microscopes, cameras, telescopes.



**Concave lens**

Used in eyeglasses to correct myopia (nearsightedness)

# Power of Lens

- Power of a lens is the reciprocal of its focal length (in meters).

$$Power\,(P) = \frac{1}{f}$$

## S.I. Unit of Power

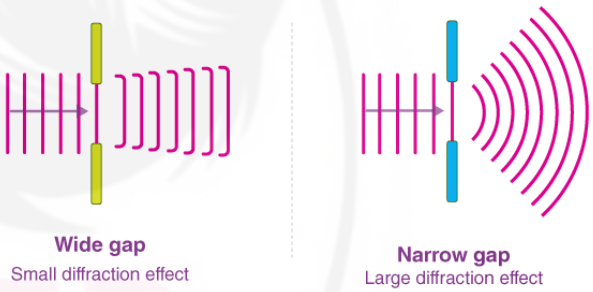
The SI unit of power is the dioptre (D) → 1 D = 1 $m^{-1}$.

## Sign Convention

- Convex lens (converging) → Positive power.
- Concave lens (diverging) → Negative power

# Diffraction

- Diffraction is the bending or spreading of light (or any wave) around the edges of an obstacle or through a small opening.

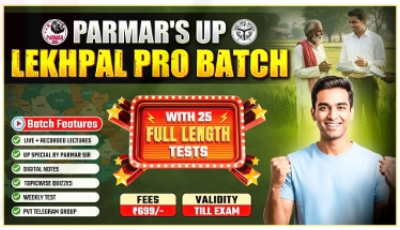





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