



# Lenses

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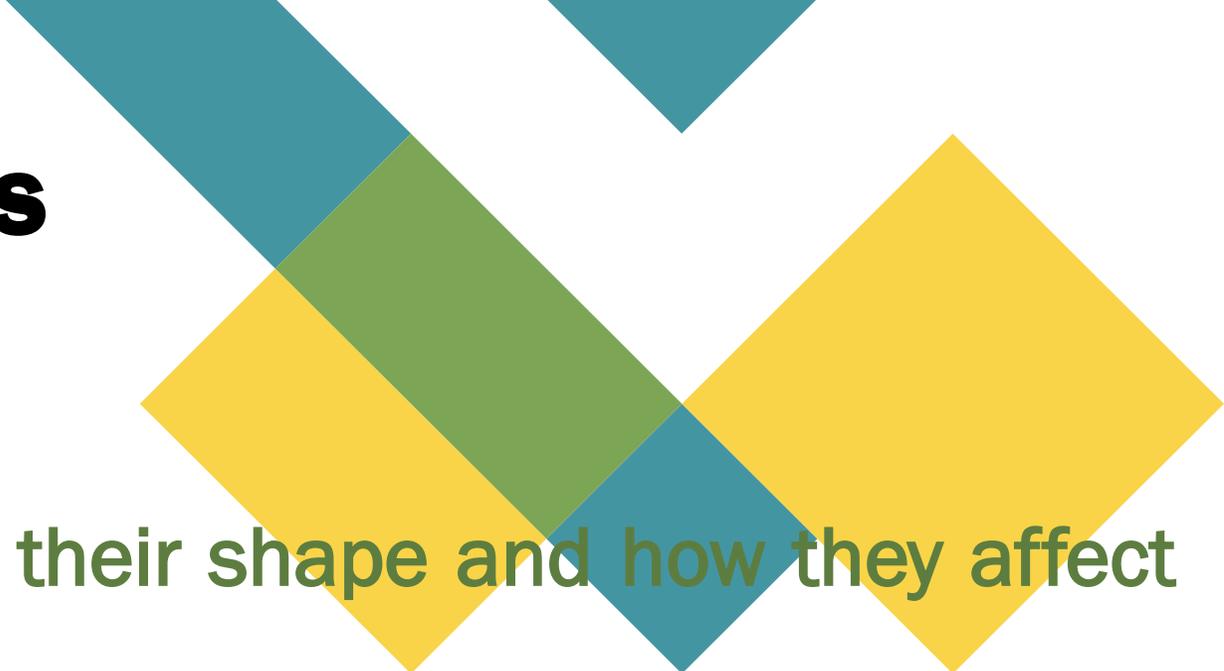
# What is a Lens?



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- **Definition:** A lens is a transparent material (like glass or plastic) bounded by at least one spherical surface.
- **Function:** Its primary job is to refract (bend) light rays to form images.
- **Refraction** is the change in the direction of light as it passes from one medium (air) to another (glass/lens).

# Classification of Lenses



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- Lenses are classified based on their shape and how they affect parallel light rays.
- Two Main Types:
  - **Convex Lens (Converging Lens):** Thicker in the middle, thinner at the edges.
  - **Concave Lens (Diverging Lens):** Thinner in the middle, thicker at the edges.

# The Convex Lens (Converging)



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- **Shape:** Bulges outwards, like a magnifying glass.
  - **Action on Light:** Takes parallel rays of light and bends them inwards, causing them to meet at a single point after refraction.
  - **Convergence:** Because it brings light rays together, it is called a Converging Lens.

# The Concave Lens (Diverging)



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- Shape: Curves inwards, like an hourglass shape.
  - Action on Light: Takes parallel rays of light and bends them outwards, causing them to spread apart after refraction.
  - Divergence: Because it spreads light rays apart, it is called a Diverging Lens.

# Key Optical Terminology (Part 1)



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- **Optical Centre (O):** The central point of the lens. Light rays passing through this point pass straight through without deviation (without bending).
  - **Principal Axis:** An imaginary straight line passing through the optical centre and perpendicular to the lens surfaces.

# Key Optical Terminology (Part 2)



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- **Aperture:** The effective diameter of the circular outline of the lens. It determines how much light the lens can gather.
- **Principal Focus (F):** The most important point! There are two principal foci, and , one on each side of the lens.

# Principal Focus of a Convex Lens



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- **Definition:** It is the point on the principal axis where light rays parallel to the principal axis actually converge (meet) after refraction by the lens.
  - **Nature:** This focal point is Real because the light rays actually intersect here.

# Principal Focus of a Concave Lens



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- **Definition:** It is the point on the principal axis from which light rays parallel to the principal axis appear to diverge (spread out) after refraction by the lens.
- **Nature:** This focal point is Virtual because the light rays only appear to come from this point.

# Focal Length ( $f$ )



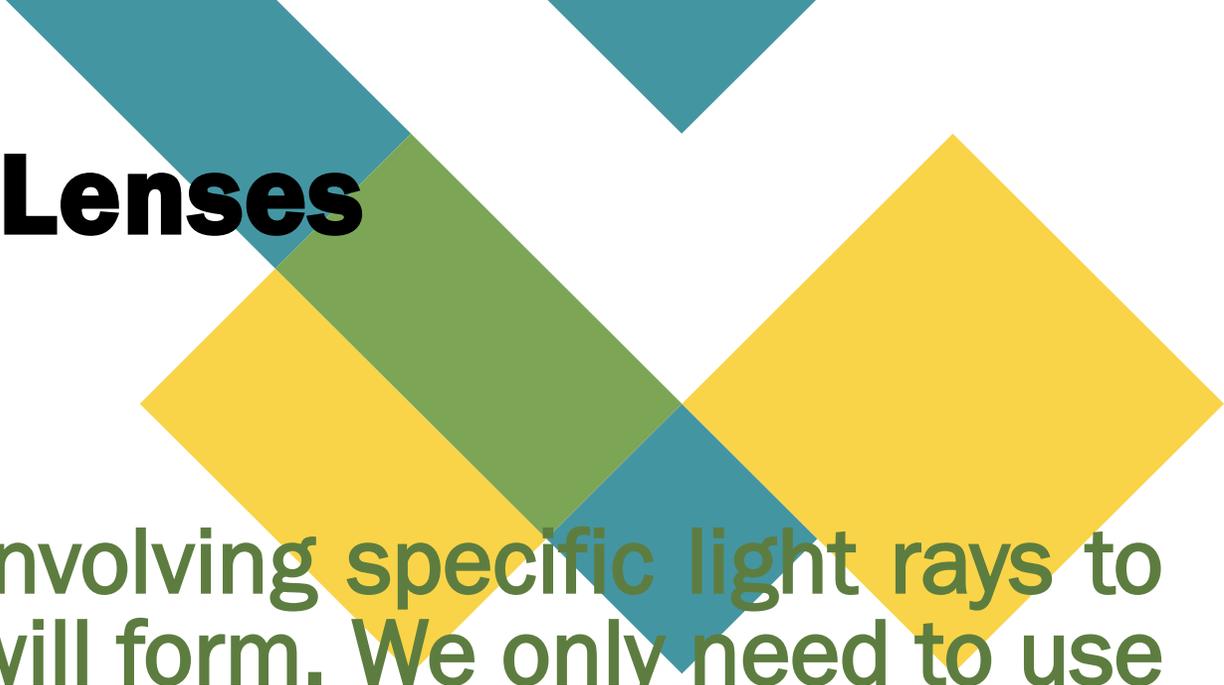
- Definition: The distance between the Optical Centre (O) and the Principal Focus (F).
- Relationship to Lens Type:
  - For a Convex Lens (Converging): Focal length ( $f$ ) is considered positive ( $+f$ ).
  - For a Concave Lens (Diverging): Focal length ( $f$ ) is considered negative ( $-f$ ).

# Relationship to Lens Type:



- 
- For a Convex Lens (Converging): Focal length ( $f$ ) is considered positive ( $+f$ ).
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# Ray Diagram Rules for Lenses



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- We use three simple rules involving specific light rays to determine where an image will form. We only need to use two of these rays.

# Rule 1: Parallel Ray



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- A ray of light parallel to the principal axis, after refraction:
  - **Convex Lens:** Passes through the **Principal Focus (F2)** on the other side.
  - **Concave Lens:** Appears to diverge from the **Principal Focus (F1)** on the same side.

## Rule 2: Focus Ray

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- A ray of light passing through the Principal Focus ( $F_1$ ) (for a convex lens) or directed towards  $F_2$  (for a concave lens), after refraction:
    - **Becomes parallel** to the principal axis.

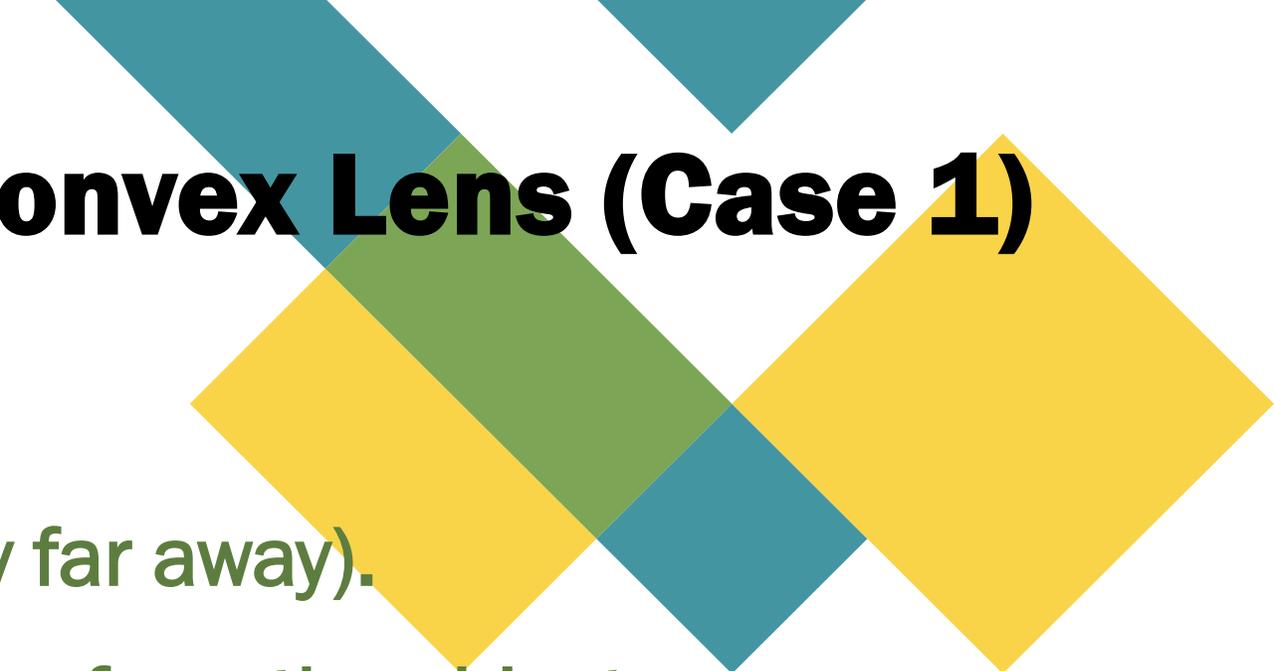
# Rule 3: Optical Centre Ray



- A ray of light passing through the **Optical Centre (O)** of the lens:
- Passes straight through** the lens without any deviation or change in direction.



# Image Formation by Convex Lens (Case 1)



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- **Object Position:** At Infinity (very far away).
  - **Ray Diagram:** Parallel rays come from the object.
  - **Image Properties:**
    - **Position:** At the Principal Focus (F<sub>2</sub>).
    - **Nature:** Real and Inverted.
    - **Size:** Highly diminished (point size).

# Image Formation by Convex Lens (Case 2)

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- Object Position: Beyond  $2F_1$  (Twice the focal length).
- Image Properties:
  - Position: Between  $F_2$  and  $2F_2$ .
  - Nature: Real and Inverted.
  - Size: Diminished (smaller than the object).

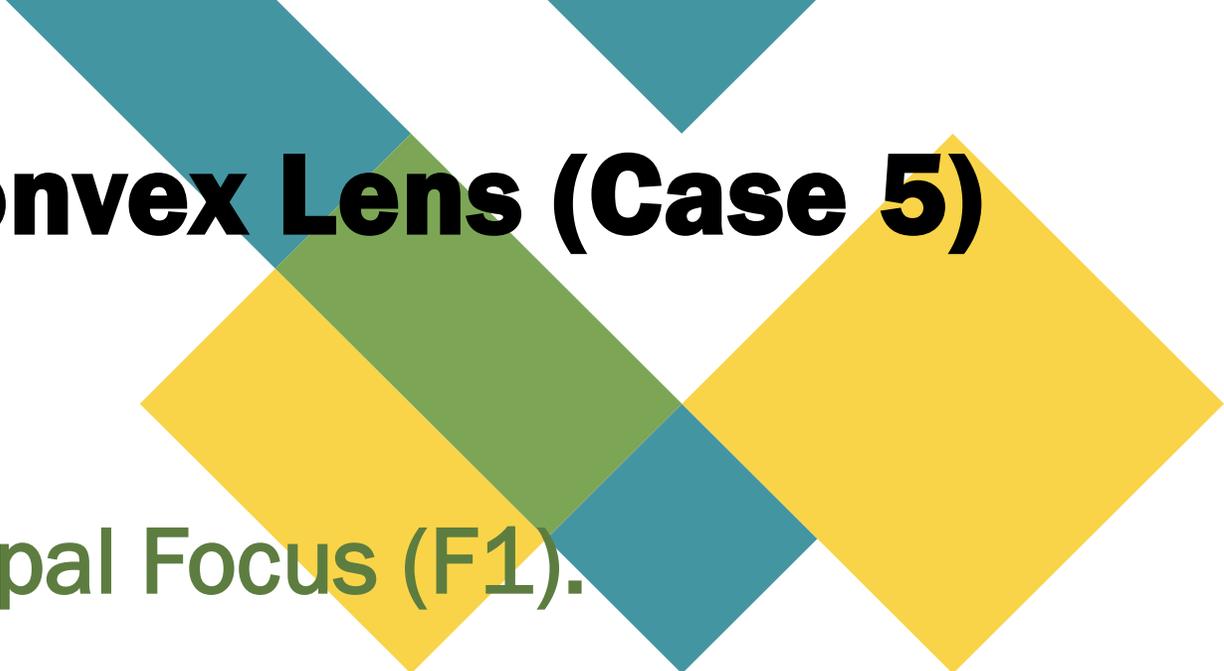
# Image Formation by Convex Lens (Case 3)

- Object Position: At  $2F_1$ .
- Image Properties:
  - Position: At  $2F_2$ .
  - Nature: Real and Inverted.
  - Size: Same size as the object.

# Image Formation by Convex Lens (Case 4)

- Object Position: Between  $F_1$  and  $2F_1$ .
- Image Properties:
  - Position: Beyond  $2F_2$ .
  - Nature: Real and Inverted.
  - Size: Enlarged (larger than the object).

# Image Formation by Convex Lens (Case 5)



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- **Object Position:** At the Principal Focus ( $F_1$ ).
  - **Image Properties:**
    - **Position:** At Infinity (rays become parallel).
    - **Nature:** Real and Inverted.
    - **Size:** Highly Enlarged.

# Image Formation by Convex Lens (Case 6: Magnifying Glass)

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- **Object Position:** Between the Optical Centre (O) and the Principal Focus (F1).
  - **Ray Diagram:** The refracted rays diverge.
  - **Image Properties:**
    - **Position:** On the **same side** as the object.
    - **Nature:** **Virtual** and **Erect** (Upright).
    - **Size:** Enlarged. *This is how a magnifying glass works.*

# Image Formation by Concave Lens (Case 1)



- 
- Object Position: At Infinity.
  - Ray Diagram: Parallel rays diverge but appear to come from  $F_1$ .
  - Image Properties:
    - Position: At the Principal Focus ( $F_1$ ).
    - Nature: Virtual and Erect.
    - Size: Highly diminished (point size).

# Image Formation by Concave Lens (Case 2)

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- Object Position: Between Infinity and the Optical Centre (O).
  - Ray Diagram: Regardless of the position, the rays always diverge.
  - Image Properties:
    - Position: Always between O and  $F_1$  .
    - Nature: **Virtual** and **Erect**.
    - Size: Diminished (smaller than the object).
  - *A concave lens always produces a virtual, erect, and diminished image.*

# Real vs. Virtual Images



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- **Real Image:** Formed when light rays actually meet after refraction.
  - Can be obtained on a screen (e.g., projector image). Always Inverted.
- **Virtual Image:** Formed when light rays only appear to meet when extended backward.
  - Cannot be obtained on a screen. Always Erect.

# The Cartesian Sign Convention



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- To use formulas correctly, we need a standard set of rules for measurement.
  - **Origin:** All distances are measured from the **Optical Centre (O)**.
  - **Direction of Incident Light:** All distances measured in the direction of the incident light are taken as **positive (+)**.
  - **Opposite Direction:** All distances measured against the direction of incident light are taken as **negative (-)**.

# Sign Convention for Heights



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- Height Upwards: Heights measured perpendicular to and above the principal axis are taken as positive (+h). (Object height is usually positive).
  - Height Downwards: Heights measured perpendicular to and below the principal axis are taken as negative (-h). (Inverted image height is negative).

# Applying Sign Convention to Lens Parameters

Parameter	Symbol	Convex Lens	Concave Lens
Object Distance	$u$	Negative (always)	Negative (always)
Image Distance	$v$	Positive (Real) / Negative (Virtual)	Negative (always Virtual)
Focal Length	$f$	Positive ( $+f$ )	Negative ( $-f$ )

# The Lens Formula



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- This formula relates the object distance ( $u$ ), image distance ( $v$ ), and the focal length ( $f$ ) of the lens.

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

- *Note: Always use the correct sign conventions for  $u$ ,  $v$ , and  $f$  when substituting values into this formula.*

# Magnification (M) Defined



- Definition: The ratio of the height of the image ( $h'$ ) to the height of the object ( $h$ ).

- $$M = \frac{\text{Height of Image}}{\text{Height of Object}} = \frac{h'}{h}$$

# Magnification in Terms of Distances

- Magnification can also be expressed in terms of image distance ( $v$ ) and object distance ( $u$ ).

- $$M = \frac{v}{u}$$

- *Unlike mirrors, the sign here is positive for lenses:  $M = \frac{v}{u}$ .*

# Interpreting the Magnification Value



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- If  $|M| > 1$ : The image is Enlarged (magnified).
- If  $|M| < 1$ : The image is Diminished (smaller).
- If  $|M| = 1$ : The image is the Same Size.

# Interpreting the Magnification Sign



- If  $M$  is Positive (+): The image is Virtual and Erect (Upright).
- If  $M$  is Negative (−): The image is Real and Inverted.

# Power of a Lens (P)



- **Definition:** The ability of a lens to converge or diverge light rays. It is the reciprocal of the focal length ( $f$ ).

- $$P = \frac{1}{f}$$

- **Crucial:** For this formula, the focal length ( $f$ ) must be in meters (m).

# Unit of Power: The Dioptr (D)



- Unit: The SI unit of power is the Dioptr (D).
- Definition: 1 Dioptr is the power of a lens whose focal length is 1 meter.

$$1 \text{ D} = 1 \text{ m}^{-1}$$

# Power and Lens Type

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- Convex Lens (Converging): Since  $f$  is positive, its power ( $P$ ) is positive ( $+D$ ).
- Concave Lens (Diverging): Since  $f$  is negative, its power ( $P$ ) is negative ( $-D$ ).
- *Optometrists prescribe corrective lenses in Dioptries.*

# Lenses in Combination

- When two or more thin lenses are placed in close contact, the combination acts as a single lens.
- **Total Power:** The total power ( $P_{\text{total}}$ ) of the combination is the algebraic sum of the individual powers ( $P_1, P_2$ , etc.).

$$P_{\text{total}} = P_1 + P_2 + P_3 + \dots$$

# Applications of Convex Lenses



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- Magnifying Glass: Used for reading small print (Object  $O$  between and  $F$  ).
- Camera Lenses: Focus light onto the sensor/film.
- Projectors: Enlarging small slides/images onto a large screen.
- Corrective Lenses: Used to correct the eye defect Hypermetropia (farsightedness).

# Applications of Concave Lenses



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- **Peepholes:** Used in doors to give a wide, diminished view of the outside.
- **Telescopes:** Used as eyepieces in certain designs.
- **Corrective Lenses:** Used to correct the eye defect Myopia (nearsightedness).



# Thank you

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