

Mirror Equation and Magnification

Quantifying Image Formation for Spherical Mirrors

The Mirror Equation

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

Relates object distance (u), image distance (v), and focal length (f) for spherical mirrors.

All distances are measured from the pole.

u : Object distance v : Image distance f : Focal length

Linear Magnification

$$m = \frac{h'}{h} = -\frac{v}{u}$$

Defined as the ratio of image height (h') to object height (h).

m : Magnification

Negative m : Real & Inverted image

Positive m : Virtual & Erect image

Common Traps & Errors

$$m = \frac{h'}{h} = -\frac{v}{u}$$

Defined as the ratio of image height (h') to object height (h).

m : Magnification

• **Negative m :** Real & Inverted image

• **Positive m :** Virtual & Erect image

Sign Convention Mistakes:

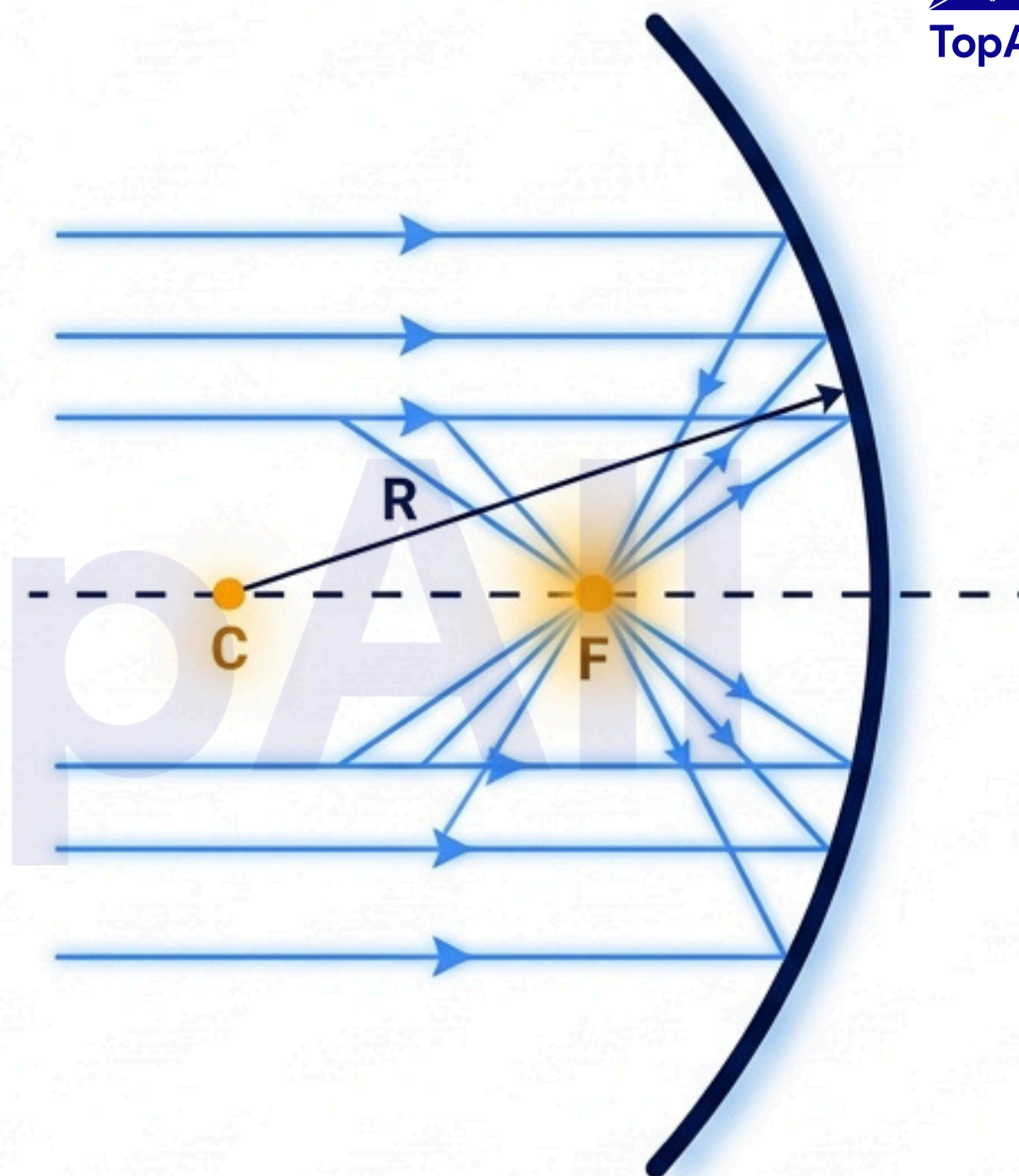
- Always measure from the pole.
- Incident light direction is positive.

Confusing concave ($f < 0$) and convex ($f > 0$) mirrors.

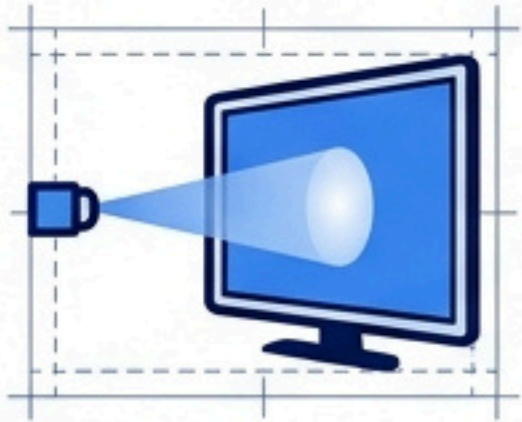
Verified Rules & Takeaways

Focal length for paraxial rays: $f = R/2$.

The mirror equation is valid only for paraxial rays.

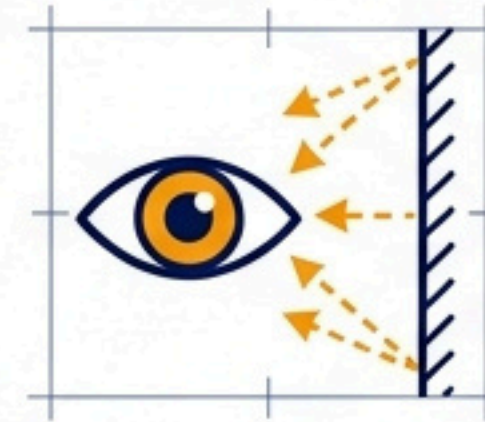


Core Concept: The Nature of Images



Real Image

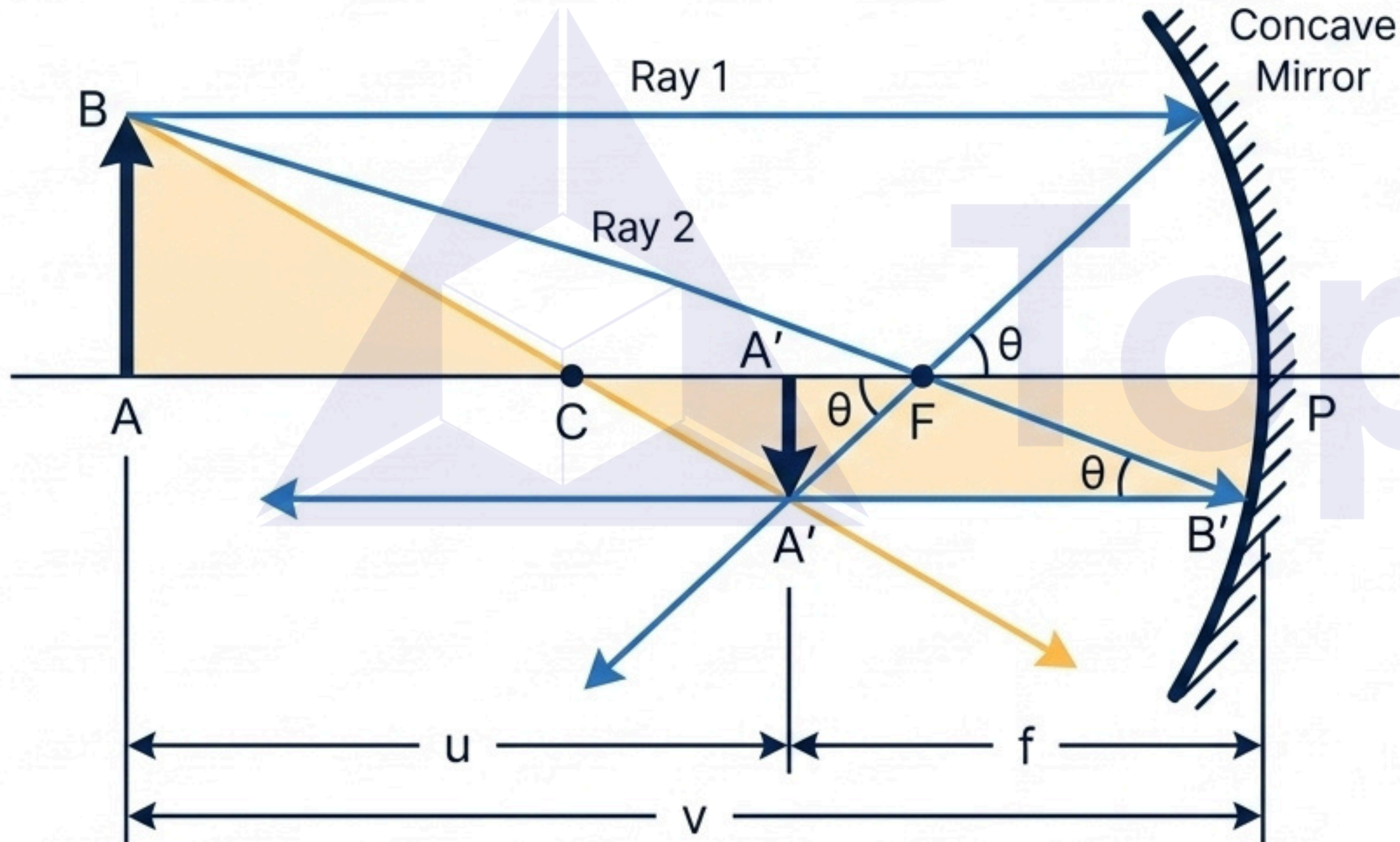
- **Definition:** Rays actually converge to a precise point after reflection.
- **Key Trait:** Can be physically captured on a screen.
- **Orientation:** Always inverted (for single mirrors).



Virtual Image

- **Definition:** Rays appear to diverge from a point behind the mirror.
- **Key Trait:** Cannot be captured on a screen (exists only in the observer's eye).
- **Orientation:** Always erect.

Concave Mirror Derivation: Similarity of Triangles ABP and A'B'P



Anatomy of the Derivation

- Triangles A'B'P and ABP are similar because angle of incidence = angle of reflection at Pole (P).
- Therefore, the ratio of heights ($\frac{A'B'}{AB}$) equals the ratio of distances ($\frac{B'P}{BP}$).



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Formula Bank: The Governing Equations

The Mirror Equation

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

v = image distance
 u = object distance
 f = focal length

Linear Magnification

$$m = \frac{h'}{h} = -\frac{v}{u}$$

h' = image height
 h = object height
 m = linear magnification

$$f = R/2$$



The Sign Convention Pitfall

Under exam pressure, students frequently **swap the signs of mirror formulas** with lens formulas.

$$\frac{1}{v} = \frac{1}{u} \quad m = \frac{v}{u}$$

The Blueprint Standard

For Spherical Mirrors:

- 1: **Mirror Equation** always has a **PLUS sign** ($1/v + 1/u$).
- 2: **Mirror Magnification** always has a **NEGATIVE sign** ($m = -v/u$).

Pro-Tip: Always apply the Cartesian sign convention to u , v , and f **BEFORE** plugging them into these formulas, not after.

Mini Problem: Crossing the Focal Point



Setup: Concave mirror with Radius $R = 15 \text{ cm} \rightarrow$ Focus $f = -7.5 \text{ cm}$

Object at $u = -10 \text{ cm}$
(Outside Focus)

$$\frac{1}{v} + \frac{1}{(-10)} = \frac{1}{(-7.5)} \rightarrow v = -30 \text{ cm}$$

$$m = \frac{-(-30)}{(-10)} \rightarrow m = -3$$

[Real, Inverted, Magnified]



Object at $u = -5 \text{ cm}$
(Inside Focus)

$$\frac{1}{v} + \frac{1}{(-5)} = \frac{1}{(-7.5)} \rightarrow v = +15 \text{ cm}$$

$$m = \frac{-(+15)}{(-5)} \rightarrow m = +3$$

[Virtual, Erect, Magnified]

Revision Card: Decoding the Signs

Sign of v (Image Location)	✓ Negative ($-$) $\rightarrow$ Real image, formed in front of mirror. ✓ Positive ($+$) $\rightarrow$ Virtual image, formed behind mirror.
Sign of m (Orientation)	✓ Negative ($-$) $\rightarrow$ Inverted image. ✓ Positive ($+$) $\rightarrow$ Erect image.
Magnitude of m (Size)	✓ $m > 1 \rightarrow$ Magnified Image. ✓ $m < 1 \rightarrow$ Diminished Image.

Variables h, h', u, v, f must adhere to Cartesian conventions.



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