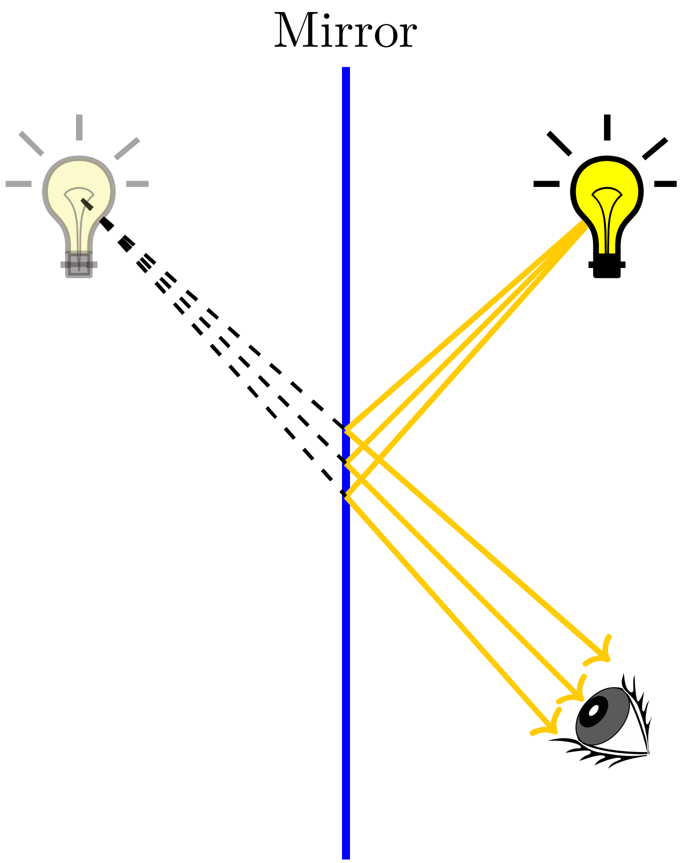
# Images from Spherical Mirrors

SP212 - General Physics II

United States Naval Academy
Annapolis

# Images




You are standing next to a light bulb and looking at a mirror. You will see the light bulb "in the mirror". Why?

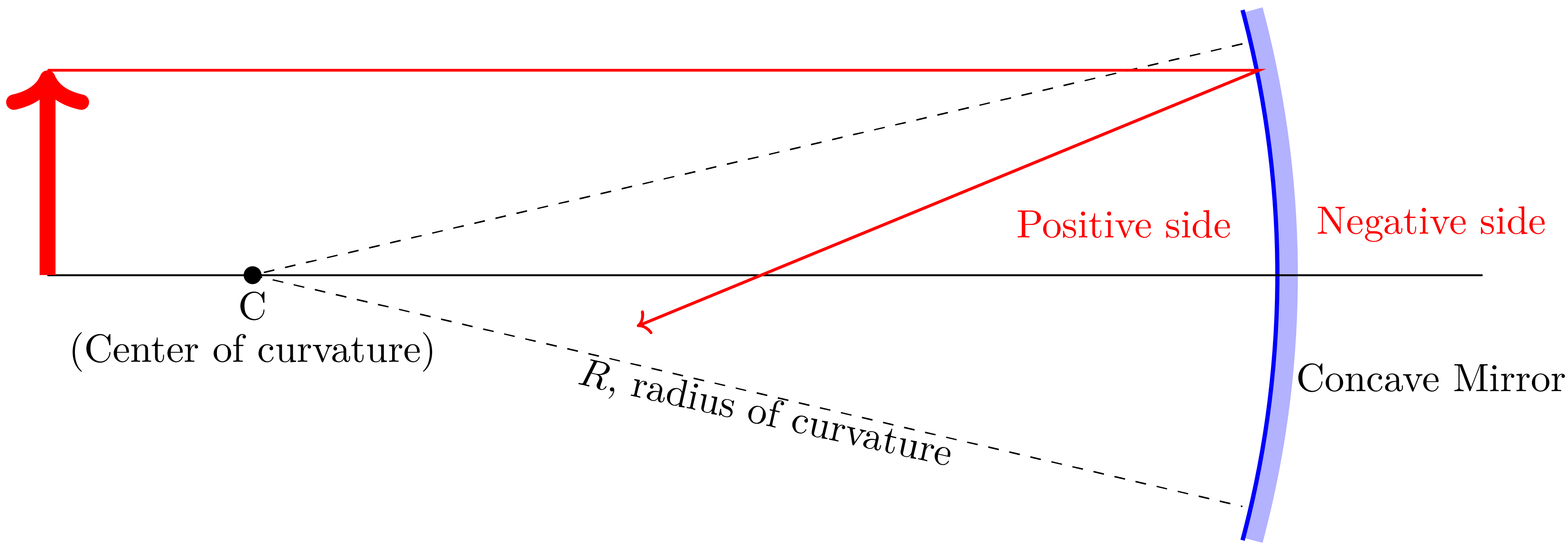
Light rays leave the bulb, moving in all directions. Some of them strike the mirror and reflect ($\theta_r = \theta_1$) and then pass into your eye.

Many rays of light traveling in slightly different directions pass into your eye. Your brain traces these rays back, and perceives an image at the place where the traced-back rays meet.

This leads to an image of the light bulb behind the mirror.

# Sign Convention: The positive side is where the light goes

A mirror reflects light, so the positive side is the same side of the mirror as where the object is. (The positive side is "in front of" the mirror.)




For a concave mirror, the center of curvature is on the side the light goes: $R$ is positive.

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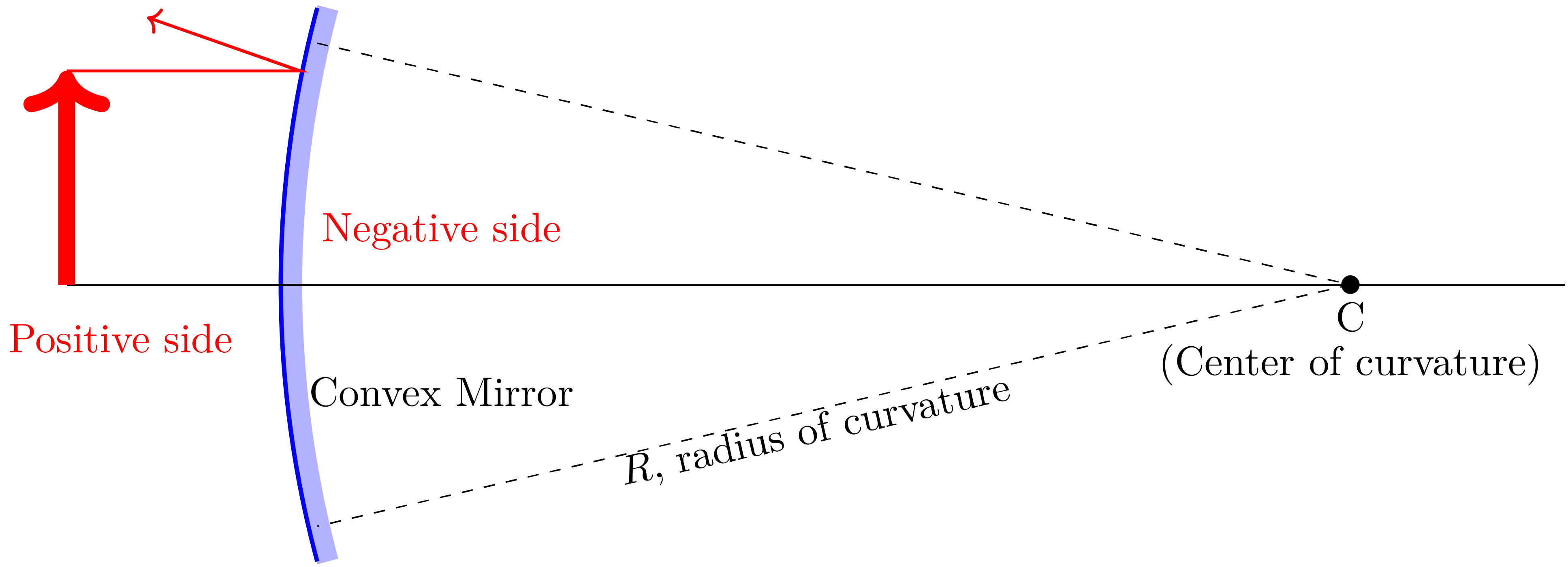
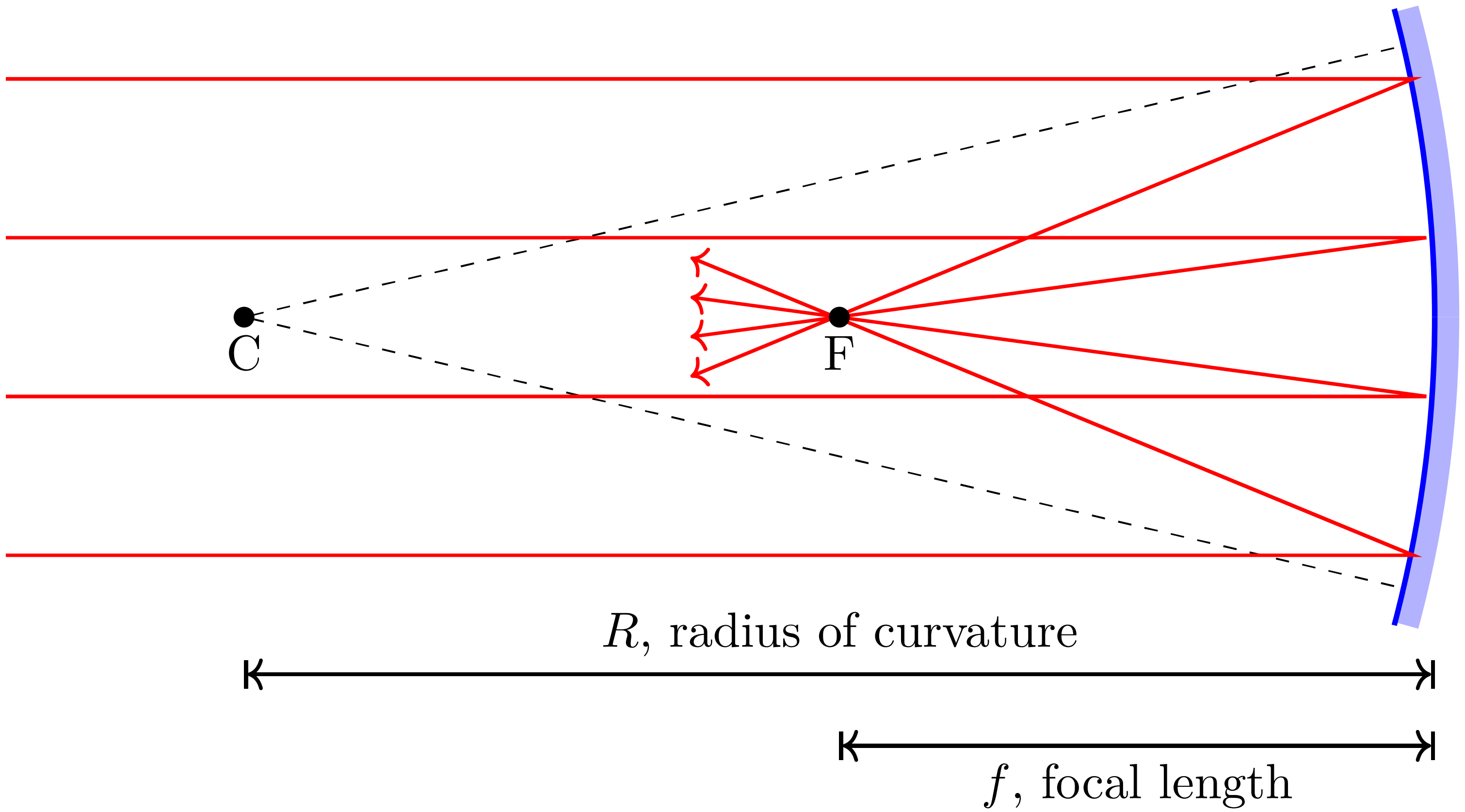


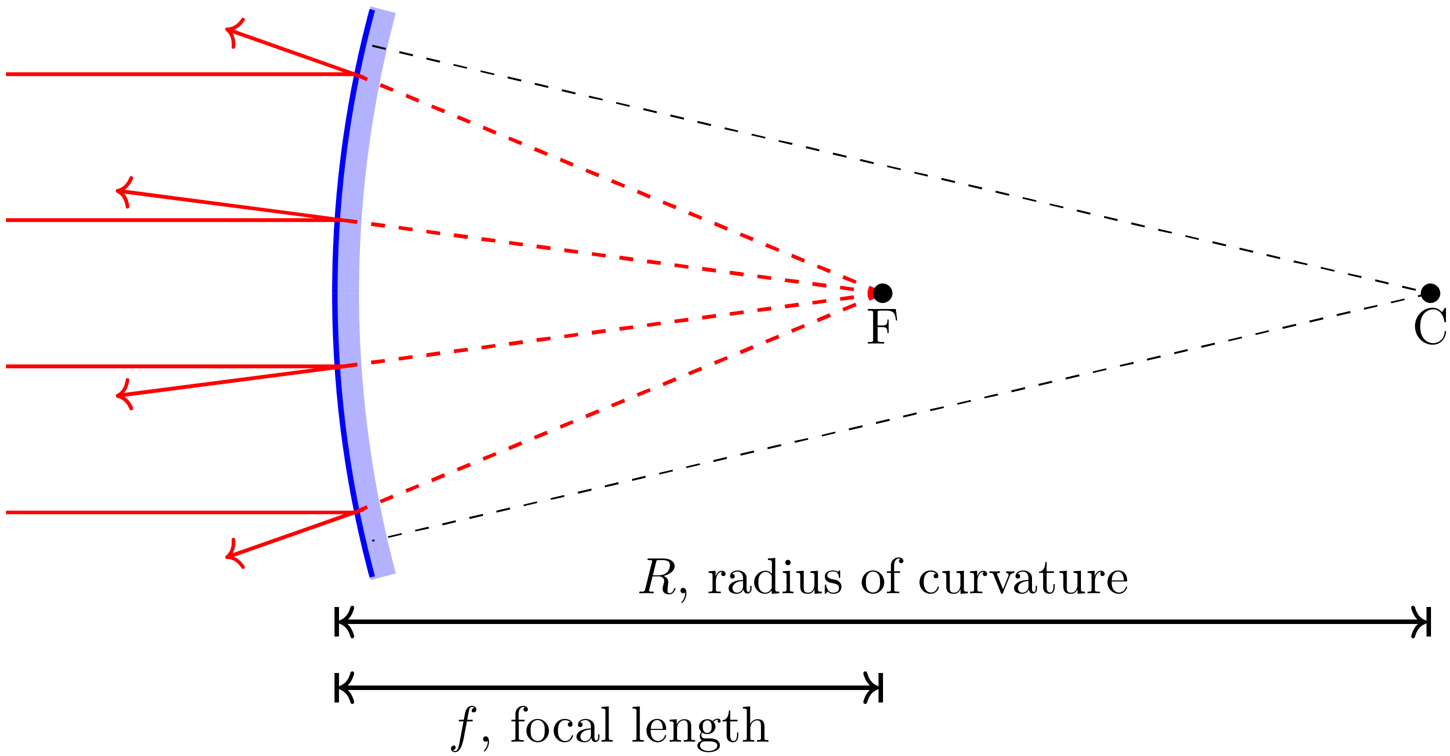

For a convex mirror, the center of curvature is on the side opposite where the light goes: therefore $R$ is negative.

Parallel rays of light striking a concave mirror reflect and converge at the focal point.




(This is strictly true only for rays of light that are pretty close to the optical axis: the paraxial approximation. For rays further away there is some aberration.)

Parallel rays of light striking a convex mirror reflect, but tracing the rays back leads to convergence at the focal point.




The focal point (F) and center of curvature (C) are both on the negative side of the mirror, so both $R$ and $f$ are negative.

The focal length of a spherical mirror is one-half its radius of curvature.

$$f = \frac{R}{2}$$ Focal length of a spherical mirror

- For a concave mirror, $R$ and $f$ are both positive.
- For a convex mirror, $R$ and $f$ are both negative.

# Ray Tracing

There are several special rays of light whose behavior is easy to predict.

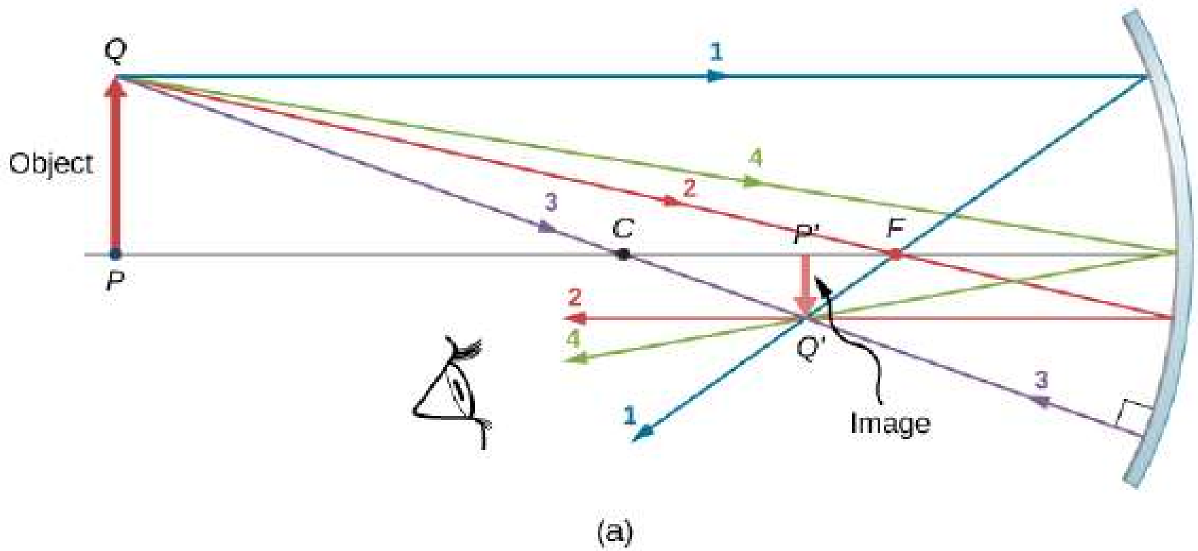



Fig. 2.9, *OpenStax University Physics Vol. 3*

1. A ray parallel to the optical axis reflects through the focal point.
2. A ray passing through the focal point reflects parallel to the optical axis.
3. A ray passing through the center of curvature reflects back upon itself.
4. A ray striking the mirror at the optical axis reflects making the same angle with the optical axis.

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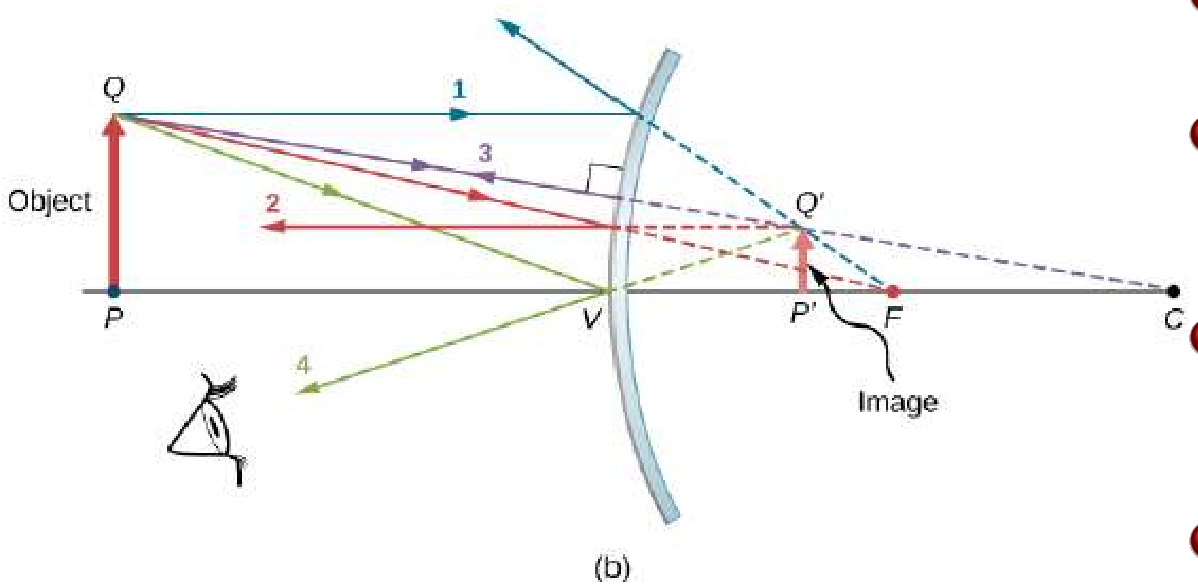


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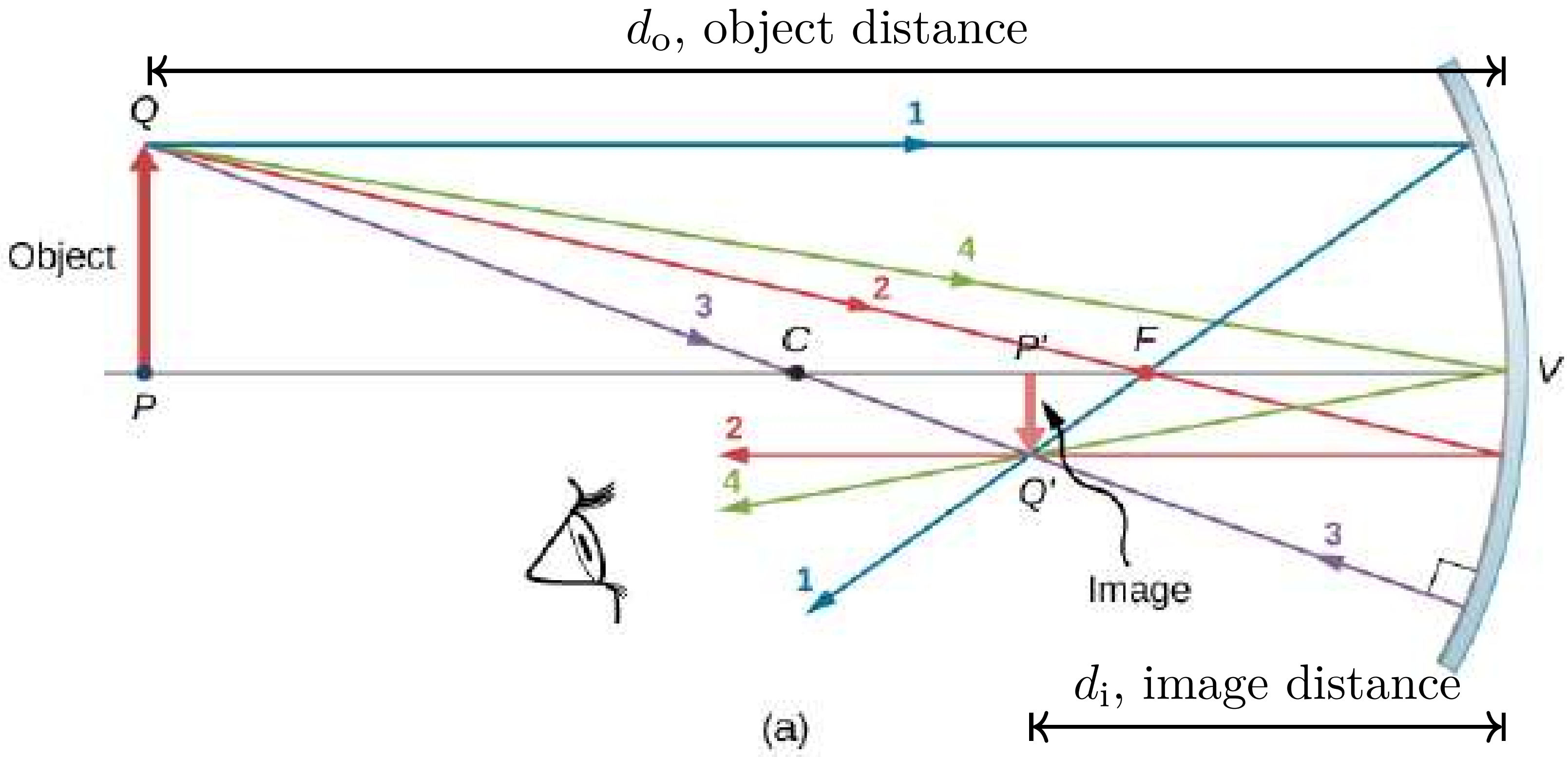
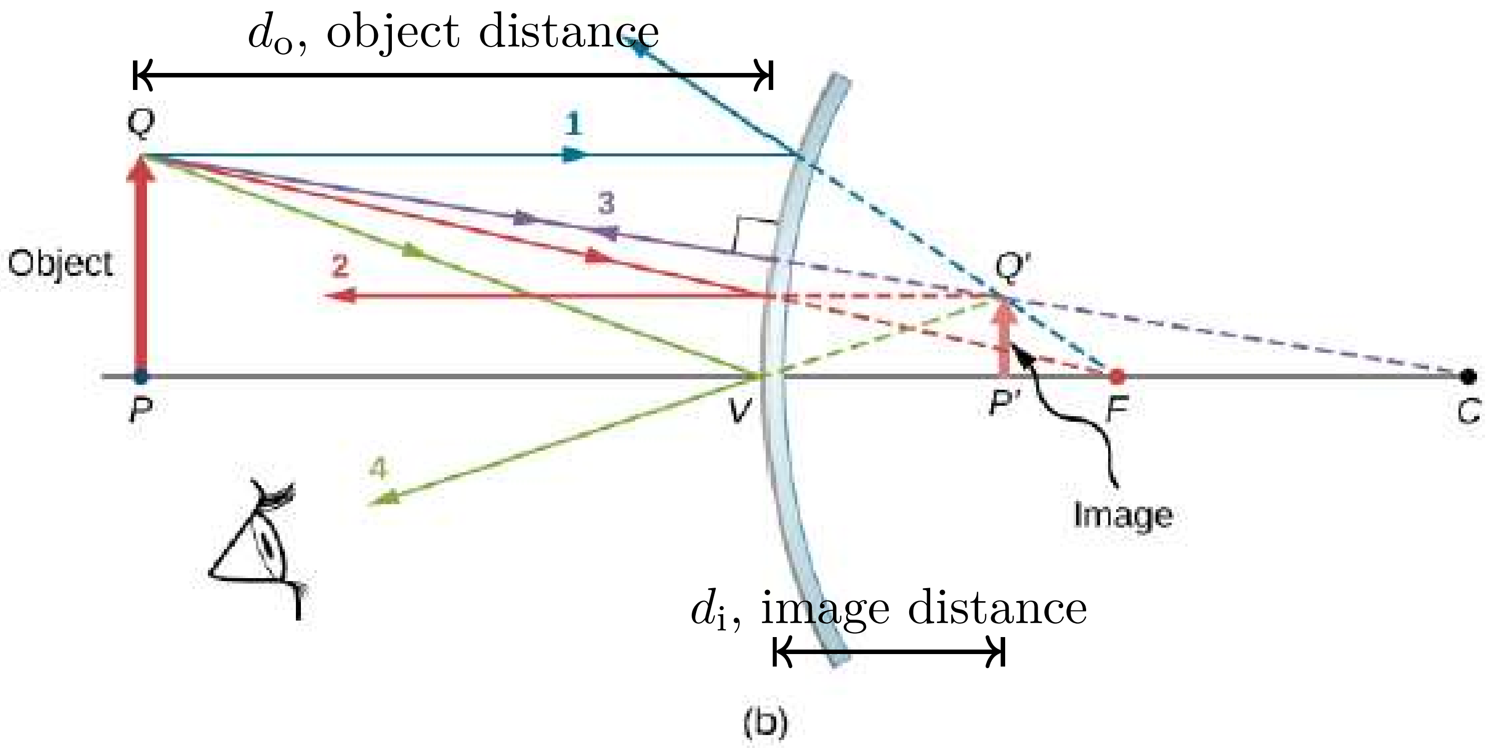
Your eye traces back the various rays of light to the image position.




A real image is formed when the rays of light actually converge at the image position. This image could be projected onto a screen of used to develop film.




A virtual image is formed when the rays of light don't actually converge at the image position; you need to trace the rays back "behind the mirror" to the convergence.

The image is behind the mirror, so $d_{\text{i}}$ is negative (the image is on the side of the mirror where light doesn't go).

## $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ — Mirror Equation

- $d_o$ is the object distance (distance between the object and the mirror)
  - For a single mirror this will always be positive.
- $d_i$ is the image distance (distance between the image and the mirror)
  - $d_i$ is positive for real images.
  - $d_i$ is negative for virtual images.
- $f$ is the focal length of the mirror
  - $f$ is positive for a concave mirror.
  - $f$ is negative for a convex.
- A real image has a positive image distance. Rays of light actually converge at the image.
  - A concave mirror creates a real image when $d_0 > f$.
- A virtual image has a negative image distance. Rays of light trace back to the image.
  - A concave mirror creates a virtual image when $d_0 < f$.
  - A single convex mirror can only create virtual images.

## $m = \frac{h_\text{i}}{h_\text{o}} = -\frac{d_\text{i}}{d_\text{o}}$ Magnification

- Magnification is the ratio between the image size and the object size: $m = \frac{h_\text{i}}{h_\text{o}}$
  - When $m > 0$ the image is upright.
  - When $m < 0$ the image is inverted (upside down).
  - When $|m| > 1$ the image is enlarged (bigger than the object).
  - When $|m| < 1$ the image is shrunken (smaller than the object).
- Magnification can be expressed as $m = -\frac{d_\text{i}}{d_\text{o}}$
- Real images have a positive $d_\text{i}$ and virtual images have a negative $d_\text{i}$
  - For a single mirror, real images are always inverted.
  - For a single mirror, virtual images are always upright.

**Example:**

A concave spherical mirror has a radius of curvature of 16 cm. How far away from the mirror should you place an object so that the magnification is -0.50?

## Example:

A concave spherical mirror has a radius of curvature of 16 cm. How far away from the mirror should you place an object so that the magnification is -0.50?

$$f = \frac{R}{2}, \text{ so } f = \frac{+16 \text{ cm}}{2} = +8.0 \text{ cm (concave mirrors have a positive } f\text{).}$$

$$m = -\frac{d_\mathrm{i}}{d_\mathrm{o}} = -0.50, \text{ so } d_\mathrm{i} = 0.50 \cdot d_\mathrm{o}$$

$$\frac{1}{d_\mathrm{o}} + \frac{1}{d_\mathrm{i}} = \frac{1}{f} \qquad \frac{1}{d_\mathrm{o}} + \frac{1}{0.50 \cdot d_\mathrm{o}} = \frac{1}{+8.0 \text{ cm}} \qquad \frac{1}{d_\mathrm{o}} + \frac{2}{d_\mathrm{o}} = \frac{1}{+8.0 \text{ cm}}$$

$$\frac{3}{d_\mathrm{o}} = \frac{1}{+8.0 \text{ cm}} \text{ Therefore } \boxed{d_\mathrm{o} = 24.0 \text{ cm}}$$

If the object is placed 24.0 cm in front of the mirror, then the resulting magnification will be $m = -0.50$.