PHYS 262

George Mason University

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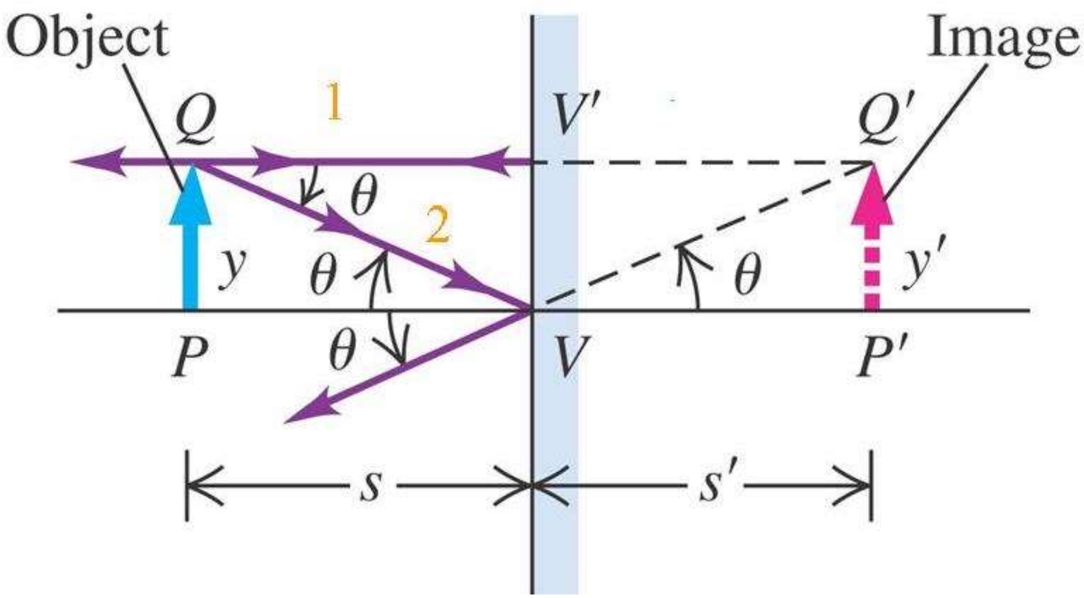
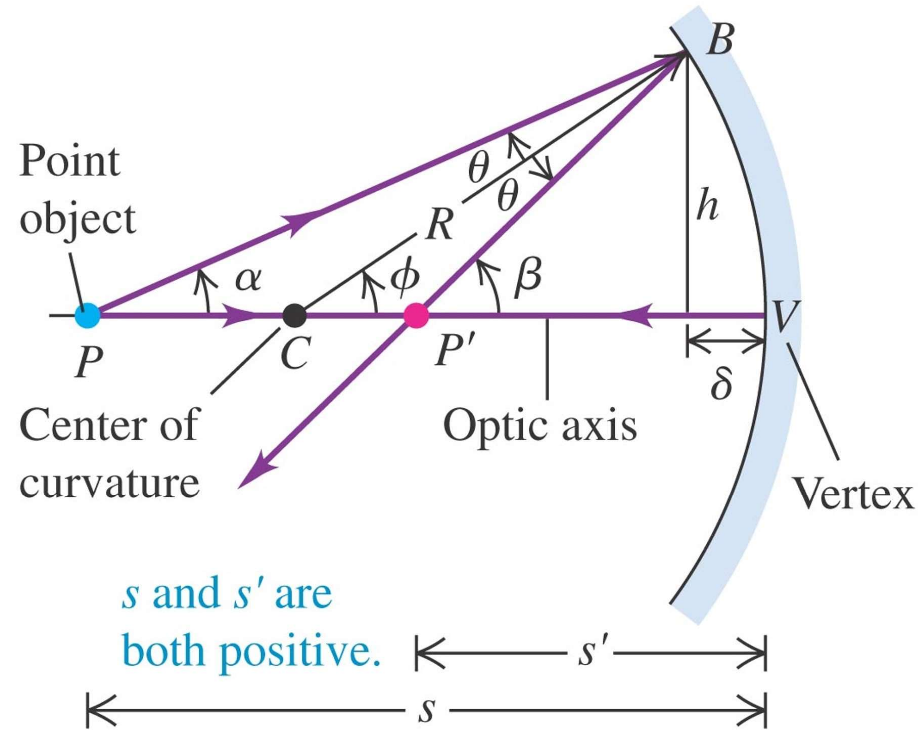
Chapter 34: Geometric Optics

- Reflection & Refraction at a Plane Surface
- Reflection & Refraction at a Spherical Surface
- Thin Lenses
- Optical Instruments

Images Formed by Flat/Spherical Mirrors





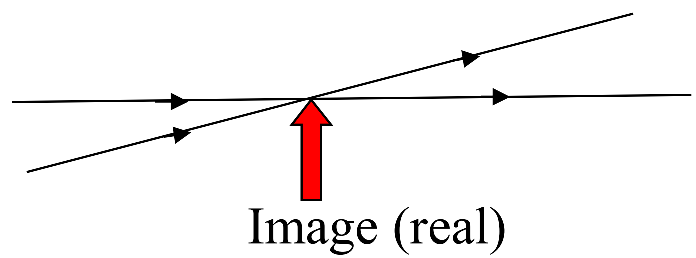
Definitions:

S → Object Distance
S' → Image Distance

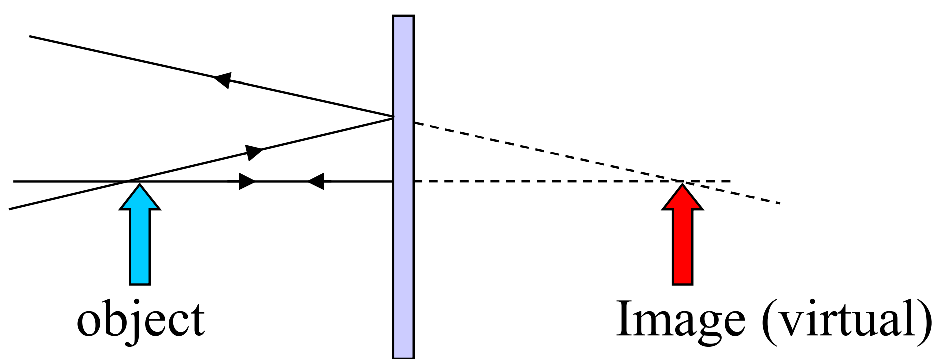
$$m = \frac{\text{image height}}{\text{object height}} = \frac{y'}{y}$$ → Lateral Magnification

Real and Virtual Images

- Image can be **real** or **virtual**
  - **Real Image**: rays actually first converge then diverge from the image point.



  - **Virtual Image**: rays do not actually pass thru the image point but they appear to be diverging from it.



Summary for Spherical Mirrors

The following are valid for both concave and convex spherical mirrors if we follow the proper sign conventions.

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$ (object-image relation, spherical mirror)

$$f = \frac{R}{2}$$ (focal length, spherical mirror)

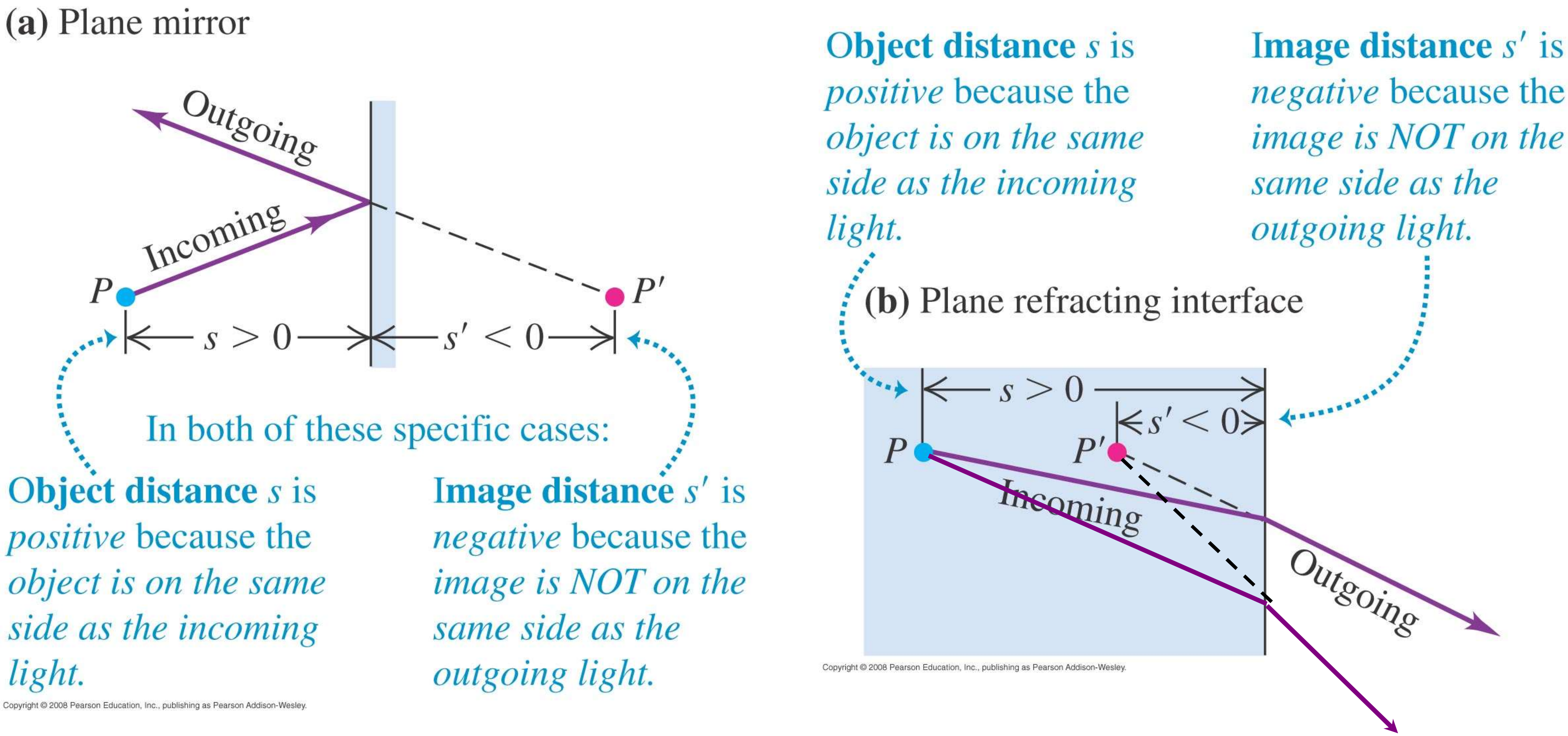
$$m = -\frac{s'}{s}$$ (lateral magnification, spherical mirror)

Note: these equations agree with results for a flat mirror if we take $R = \infty$.

Sign Rules for Spherical Mirrors

1. Object Distance:
   - *s* is + if the object is on the same side as the incoming light (for both reflecting and refracting surfaces) and *s* is – otherwise.
2. Image Distance:
   - *s'* is + if the image is on the same side as the outgoing light and is – otherwise.
3. Object/Image Height:
   - *y* (*y*') is + if the image (object) is erect or upright. It is – if it is inverted.
4. Radius of Curvature and Focal Length:
   - *R* and *f* is + when the center of curvature C is on the same side as the outgoing light and – otherwise.

Sign Rules (examples)

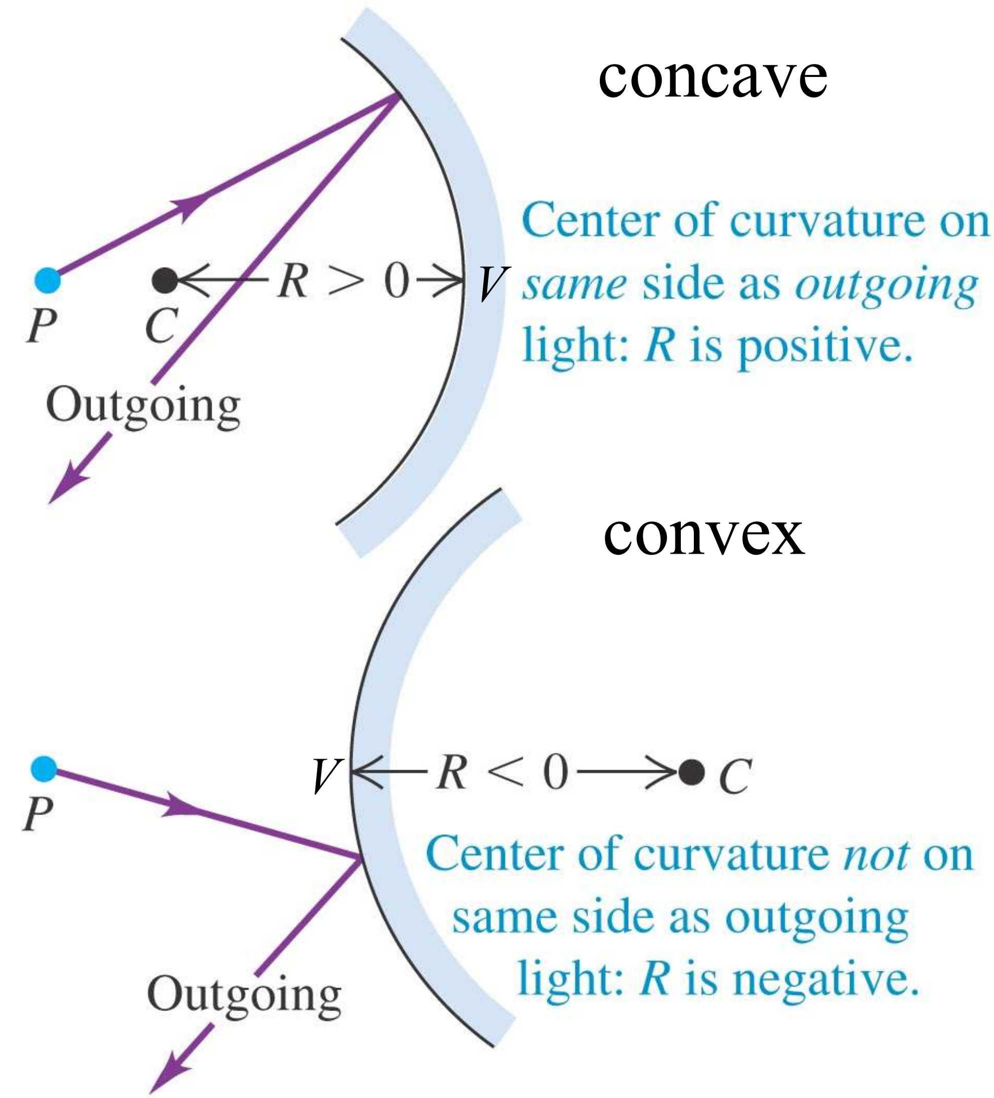


Reflection at a Spherical Surface

Sign Rule (#4) for the *radius of curvature* of a spherical surface:

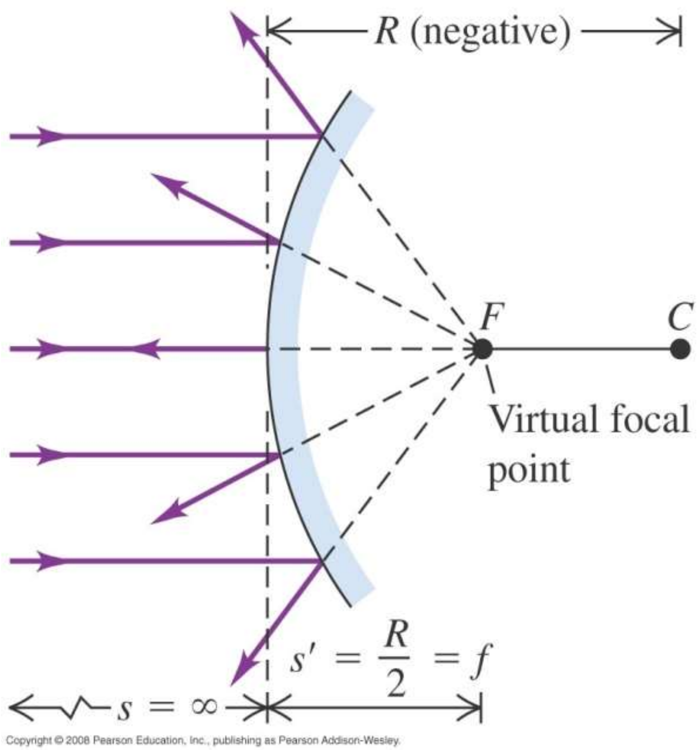
→The radius of curvature *R* is + when the center of curvature *C* is on the *same* side as the *outgoing* light (concave) and – otherwise.

(*CV* is called the optical axis.)

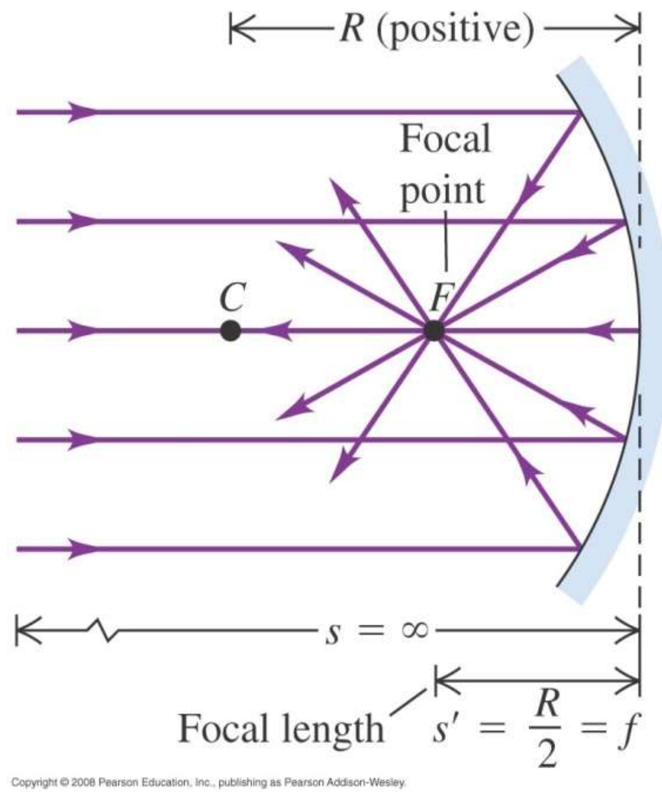


Focal Point of Spherical Mirrors

Convex Mirror
$f < 0$

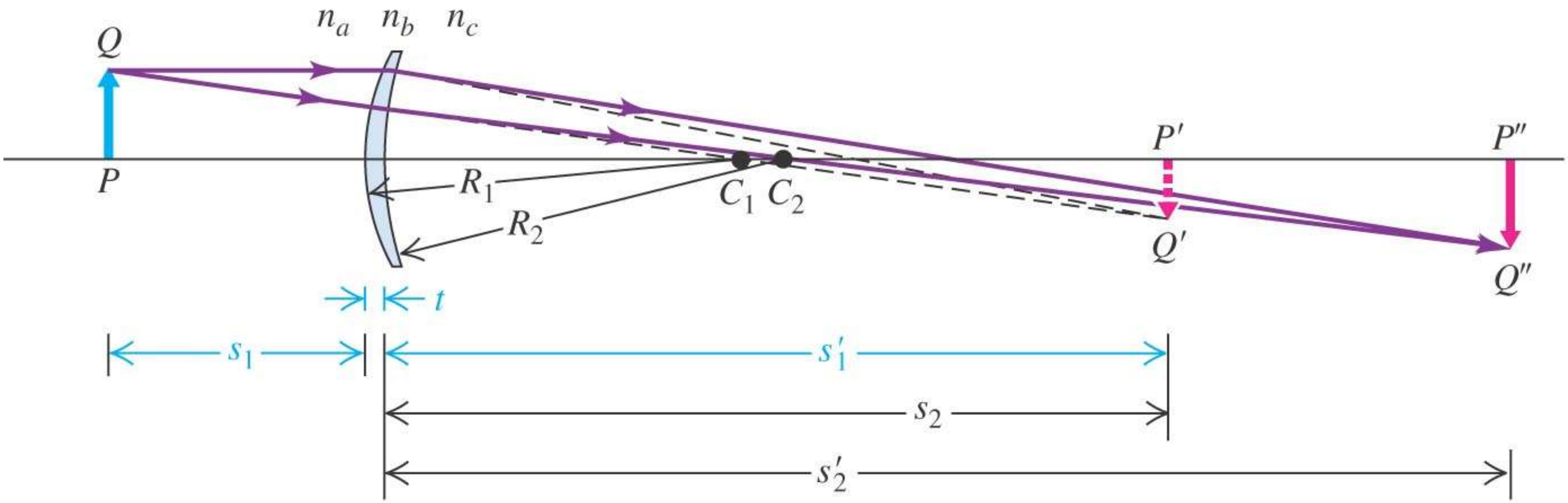


Concave Mirror
$f > 0$



Thin Lenses

Consider a *thin* lens as two closely spaced spherical surfaces.



Thin Lens

$$\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}$$ (object-image relation, thin lens)

where,

$$\frac{1}{f}=(n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$ (lensmaker's equation)

$$m=\frac{y'}{y}=\frac{-s'}{s}$$ (lateral magnification, thin lens)

Sign Rules for Mirrors & Lens

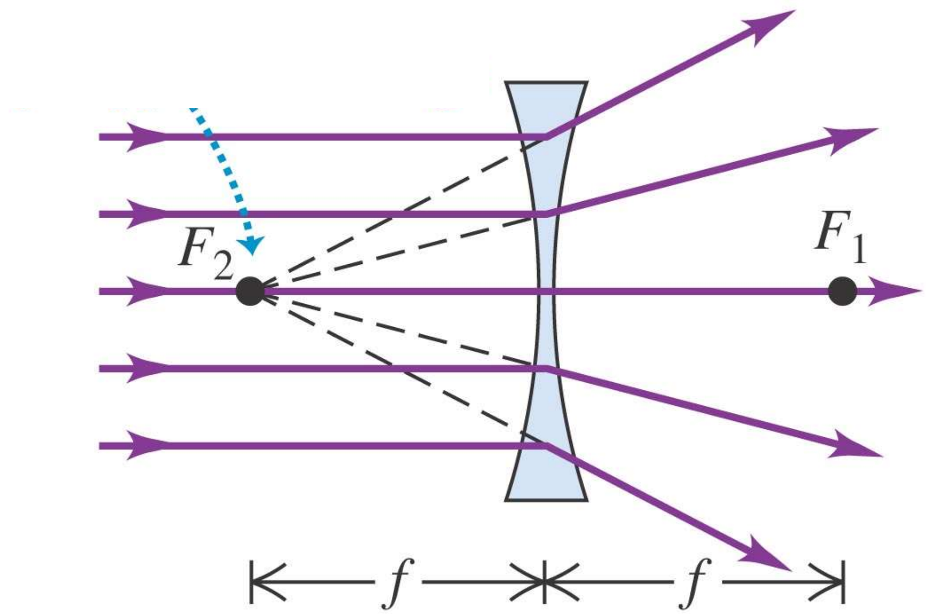
1. Object Distance:
   - *s* is + if the object is on the same side as the incoming light (for both reflecting and refracting surfaces) and *s* is – otherwise.
2. Image Distance:
   - *s'* is + if the image is on the same side as the outgoing light and is – otherwise.
3. Object/Image Height:
   - *y* (*y*') is + if the image (object) is erect or upright. It is – if it is inverted.
4. Radius of Curvature:
   - *R* is + when the center of curvature C is on the same side as the outgoing light and – otherwise.
5. Focus Length: (+ concave, - convex)

   (+ converging, - diverging)

Focal Points of Lens

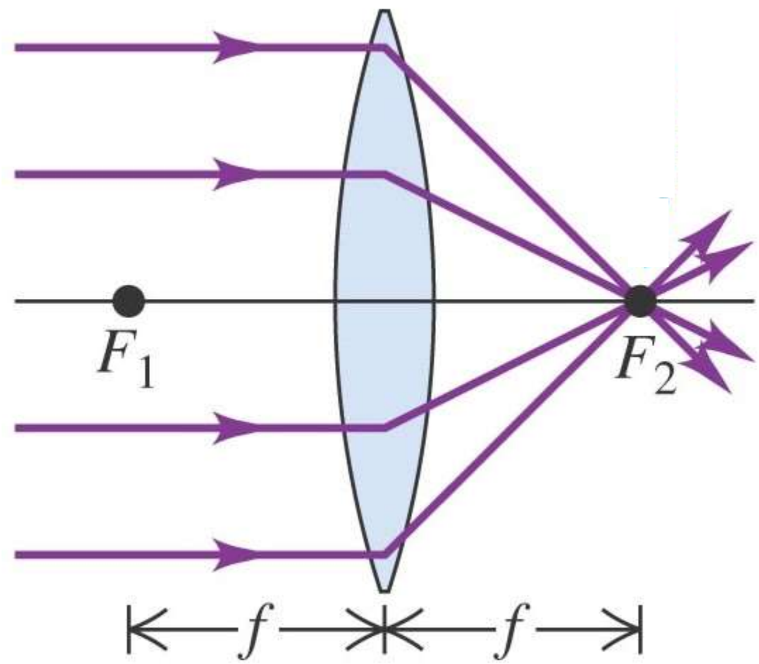
Diverging Lens

$f < 0$

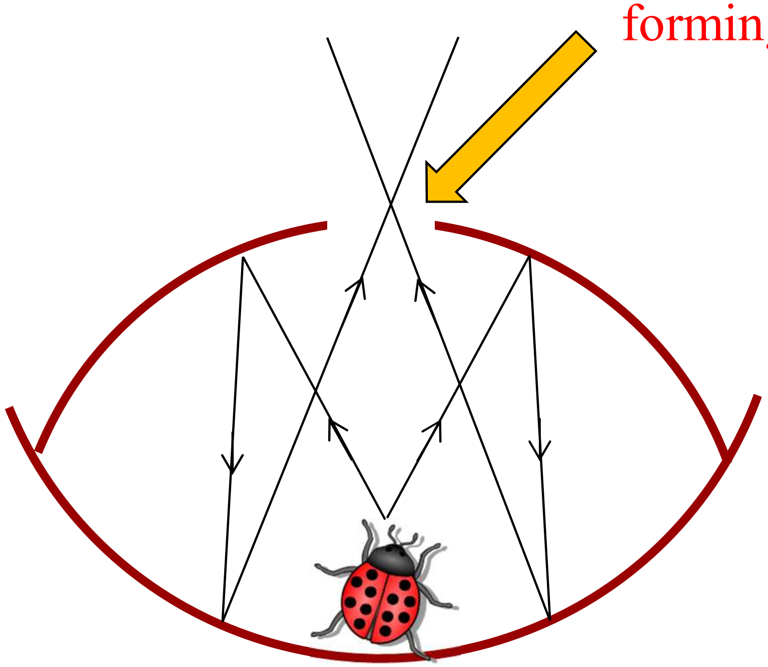


Converging Lens

$f > 0$



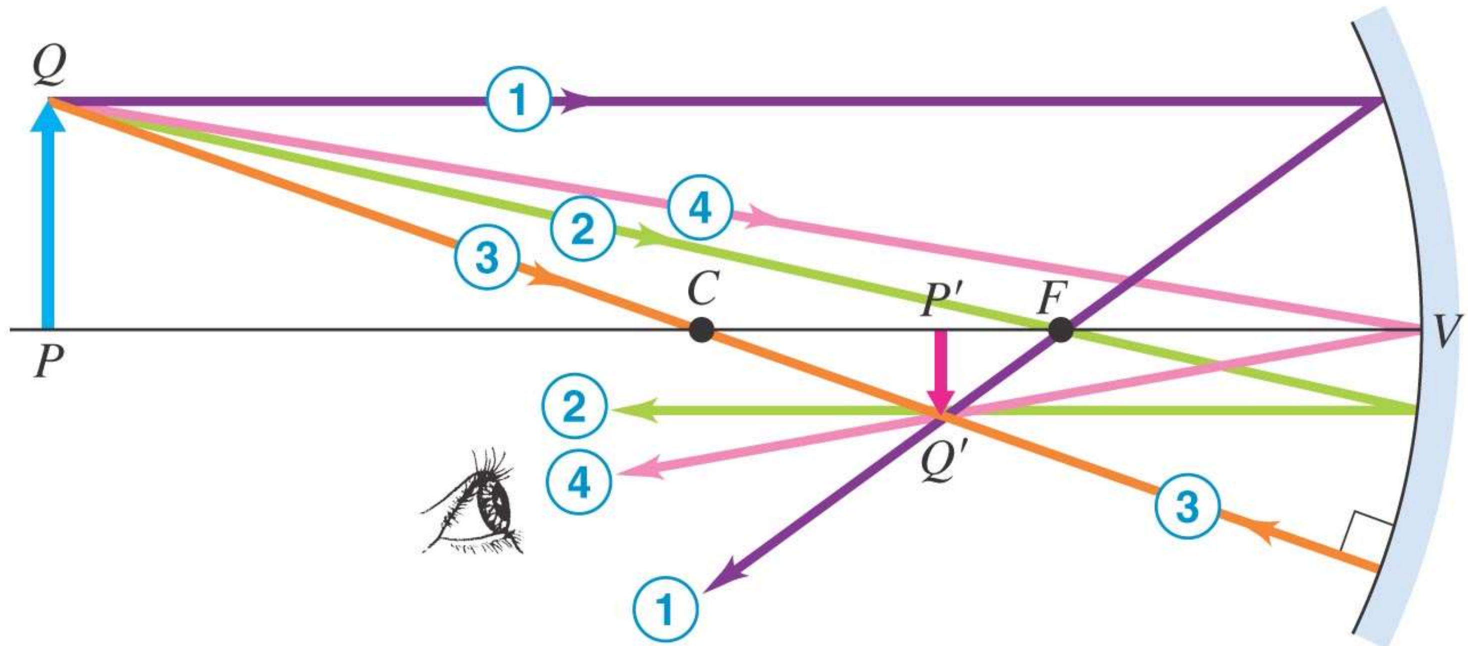
Demo with Two Circular Mirrors



$D_{sp\ mirror}$ $D_{double\ mirror}$

Geometric Methods: Rays Tracing

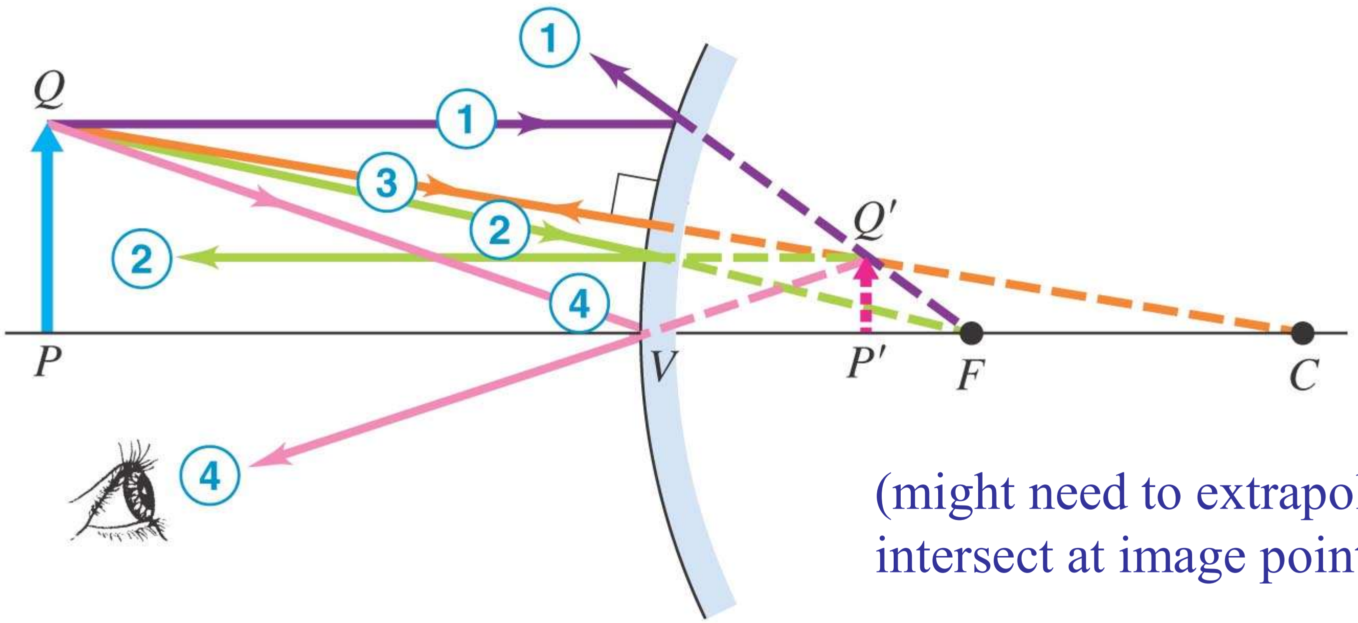
Principal rays for concave mirror



1. Ray parallel to axis reflects through focal point.
2. Ray through focal point reflects parallel to axis.
3. Ray through center of curvature intersects the surface normally and reflects along its original path.
4. Ray to vertex reflects symmetrically around optic axis.

Geometric Methods: Rays Tracing

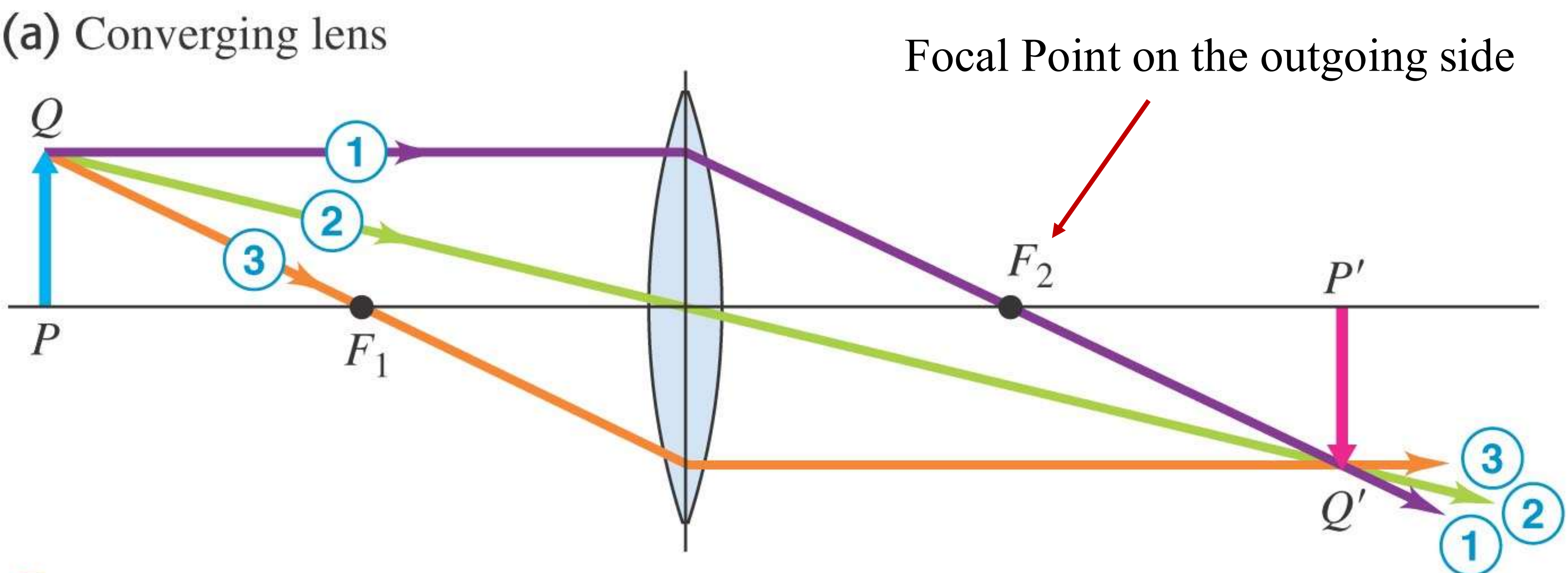
Principal rays for convex mirror



(might need to extrapolate lines to intersect at image point)

1. Reflected parallel ray appears to come from focal point.
2. Ray toward focal point reflects parallel to axis.
3. As with concave mirror: Ray radial to center of curvature intersects the surface normally and reflects along its original path.
4. As with concave mirror: Ray to vertex reflects symmetrically around optic axis.

Ray Tracing Methods for Lenses

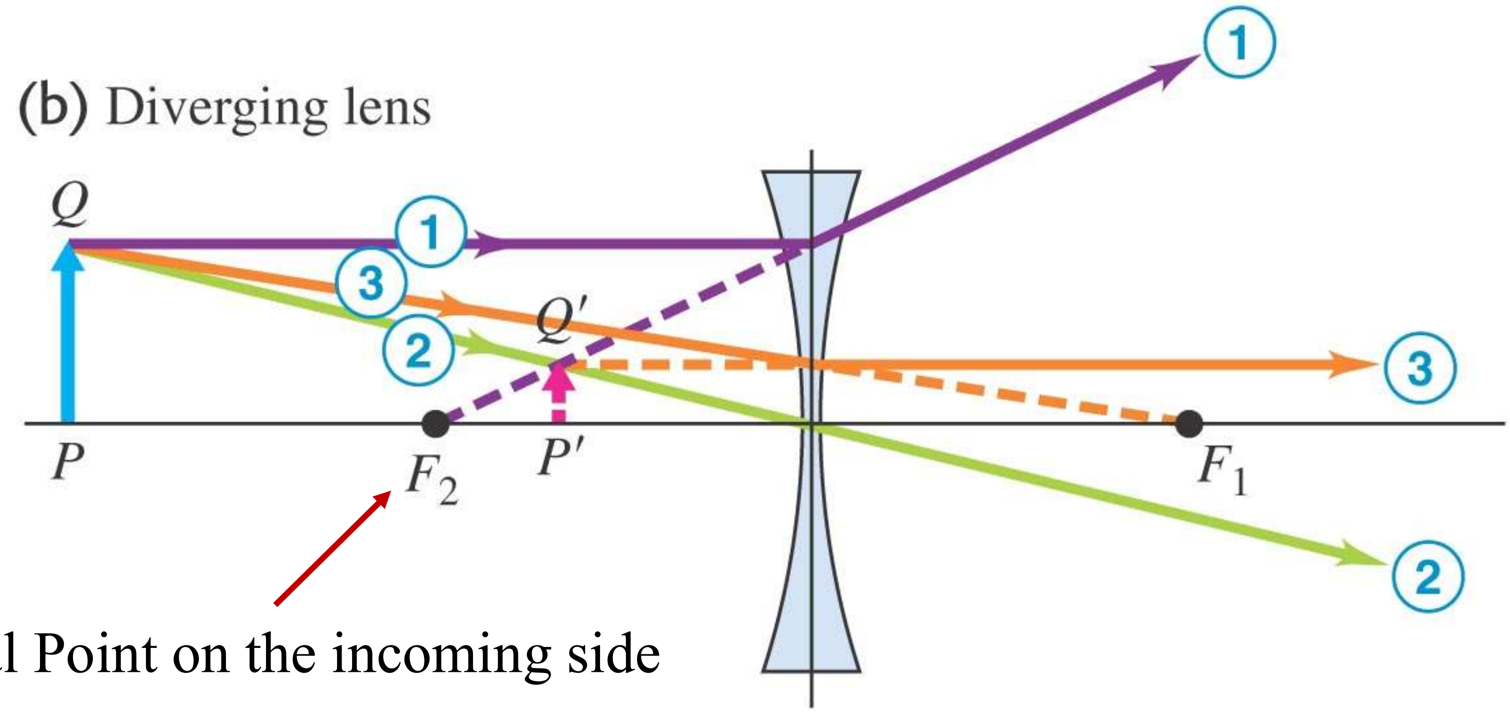


(1) Parallel incident ray refracts to pass through second focal point F_2.

(2) Ray through center of lens does not deviate appreciably.

(3) Ray through the first focal point F_1 emerges parallel to the axis.

Rays Tracing Methods for Lenses



1. Parallel incident ray appears after refraction to have come from the second focal point F_2.
2. Ray through center of lens does not deviate appreciably.
3. Ray aimed at the first focal point F_1 emerges parallel to the axis.