Geometric Optics

- Rays/Images

- Mirrors
  - plane mirror
  - spherical mirrors

- How to find images
  - graphically
  - numerically
Geometric Optics

- Based on simple rules from Laws of Reflection and Refraction
  - **Light rays** — not real, imaginary line drawn perpendicular to plane of wave, arrow points in direction of travel
    - Can cross
    - Can turn sharply
    - Go off in all directions
    - From all parts
    - But we normally only care about one particular ray
Reflection

Angle of incidence = Angle of reflection

\[ \theta_i = \theta_r \]

That’s all of the physics – everything else is just geometry!
All you see is what reaches your eyes

You think object’s location is where rays *appear* to come from.

All rays originating from peak will *appear* to come from same point *behind* mirror!
1) Draw first ray perpendicular to mirror \( 0 = \theta_i = \theta_r \).

2) Draw second ray at angle. \( \theta_i = \theta_r \).

3) Lines appear to intersect a distance \( d \) behind mirror. This is the image location.

"Virtual Image"
No light rays actually pass through intersection point.
Virtual Image – rays don’t really pass through inception point

Real Image – rays do really pass through inception point

More on lenses later....
You will also get Images from Curved Mirrors:
**Concave**: Consider the case where the shape of the mirror is such that light rays *parallel to the axis* of the mirror are all “focused” to a common spot a distance $f$ in front of the mirror:

These mirrors are often sections of spheres (assumed in this class).

For such “spherical” mirrors, we assume all angles are small even though we draw them big to make it easy to see...
Where is the focal point?

**Concave:** Consider the case where the shape of the mirror is such that light rays parallel to the axis of the mirror are all “focused” to a common spot a distance $f$ in front of the mirror:

- $y/R = \sin\Theta$
- $y/(R-f) = \sin2\Theta$
- Small angle approx: $\sin\Theta \sim \Theta \sim \tan\Theta$
- $2*(R-f) = R$
- $f = R/2$
Recipe for Finding Image (2 Principle rays)

1) Draw ray parallel to axis reflection goes through focus

2) Draw ray through focus reflection is parallel to axis

You now know the position of the same point on the image

Note: any other ray from tip of arrow will be reflected according to \( \theta_i = \theta_r \) and will intersect the two rays shown at the image point.
Recipe for Finding Image (2+ Principle rays)

1) Draw ray parallel to axis reflection goes through focus

2) Draw ray through focus reflection is parallel to axis

3) Draw ray that intersects the axis

4) Draw ray that goes through the center of the sphere
Calculating the Image Distance

\[ \frac{h_o}{h_i} = - \frac{S}{S'} \]

\[ \frac{h_o}{h_i} = - \frac{S - f}{f} \]

\[ 1/f = 1/S + 1/S' \]

Define: \[ m = \frac{h_i}{h_o} = - \frac{S'}{S} \]
Example 26.1: Spider in the mirror

A 2cm tall spider sits 25cm in front of a spherical mirror whose focal length is 40cm.

Where is the image of the spider located?

What is the height of the image of the spider? Is it upright or inverted?
A 2cm tall spider sits 25cm in front of a spherical mirror whose focal length is 40cm.

Is the image of my spider real or imaginary?
   A) real
   B) imaginary
Example 26.2: Spider in the mirror

Now my spider crawls back to 1 meter from the mirror.

Where is the image of the spider located?

What is the height of the image of the spider? Is it upright or inverted?
Example 26.3: Spider with convex mirror

Now the spider sits 1m from a convex mirror with a focal length of 40cm.

Where is the image of the spider located?

What is the height of the image of the spider? Is it upright or inverted?
Example 26.4: Spider in the mirror

Now the spider crawls to 40cm from the mirror.

Where is the image of the spider located?

What is the height of the image of the spider? Is it upright or inverted?
An arrow is located in front of a convex spherical mirror of radius $R = 50\text{cm}$. The tip of the arrow is located at $(-20\text{cm},-15\text{cm})$.

Where is the tip of the arrow’s image?
Summary

\[ \frac{1}{S} + \frac{1}{S'} = \frac{1}{f} \]

\[ f > 0 \implies \text{concave} \]
\[ f < 0 \implies \text{convex} \]

\[ S, S' > 0 \text{ in front of mirror} \]
\[ m > \text{upright} \]

“On the same side of the mirror as the light is coming from”
Will be different for lenses