REFLECTION AND MIRRORS

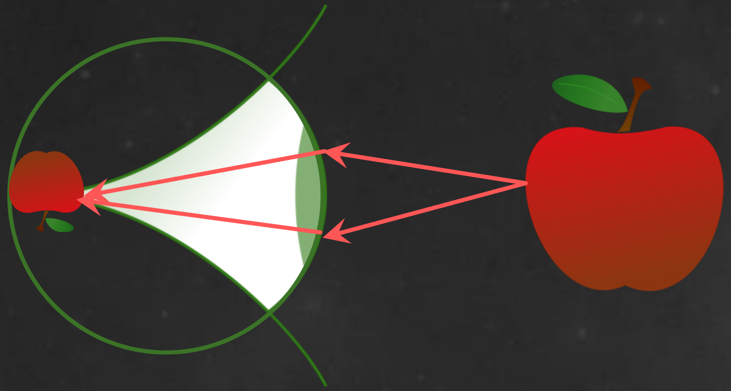
PES 1000 – PHYSICS IN EVERYDAY LIFE

DIVERGING RAYS AND PERCEPTION OF AN OBJECT

- We will treat light as a collection of rays radiating from the source
  - You can think of a ray as a stream of photons traveling the same direction.
  - You can also think of a ray as the direction the light wave is propagating.
- We are used to objects emitting light in all directions. The light rays from every point on the object (diffuse reflection) radiate diverging rays in all directions.
- Our vision is used to interpreting diverging rays as having come from an object.
- Our eyes and brain reverse the path of the rays and perceive a source at their origin.
- If the rays have been reflected during their travel from object to eye, our brain may be fooled into perceiving an image where there is no real object (behind a mirror, for example.) This is what we call a virtual image.

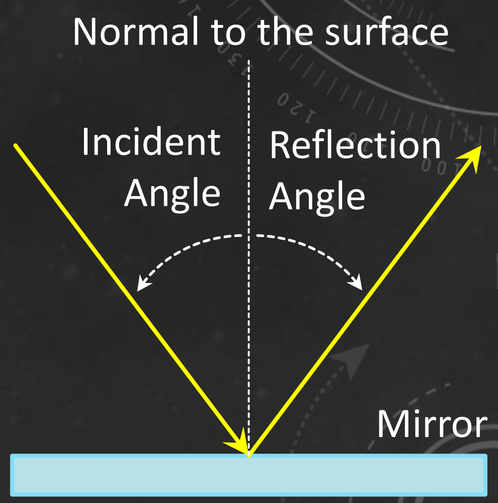
CONVERGING RAYS AND IMAGE FORMATION

- When light rays from the same source point come together (converge), they may add their energy together.
- If the converging rays come together on a screen, paper, or the retina of our eye, for instance, then an image of the source point will be produced. This is what we call a ‘real image’.
- Every source point on the object sends out rays that get focused to the same point in the image.



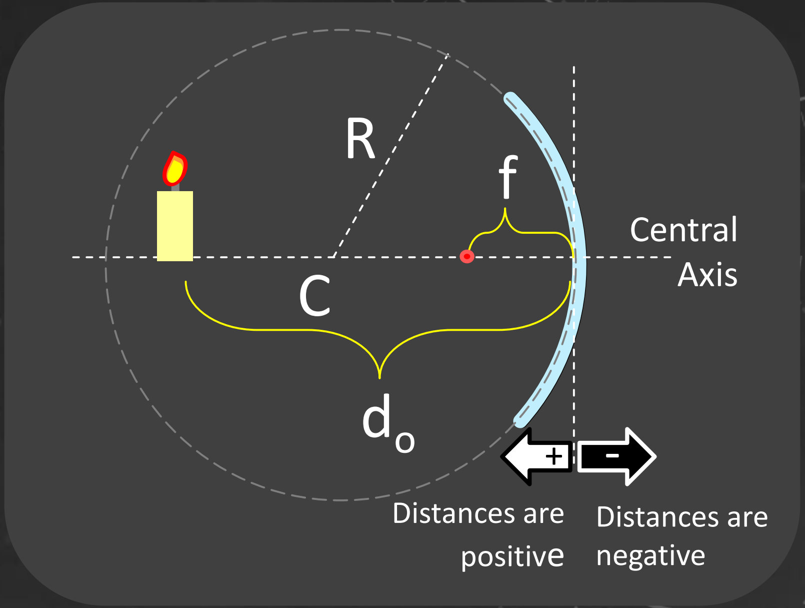
THE LAW OF REFLECTION

- When a light ray strikes a reflective surface, all of the energy is reflected.
- If the ray strikes the mirror at an angle, we measure that angle from the normal line, or the line perpendicular to the mirror surface.
- Conservation laws of energy and momentum explain what we observe: The angle of incidence is equal to the angle of reflection.
    - This is analogous to the pool ball hitting the edge of the pool table. The mirror provides a force to reverse the momentum.
    - There is an equal and opposite force of the light on the mirror; this is the concept behind using a light sail to navigate interplanetary space.



DEFINITIONS: GEOMETRY

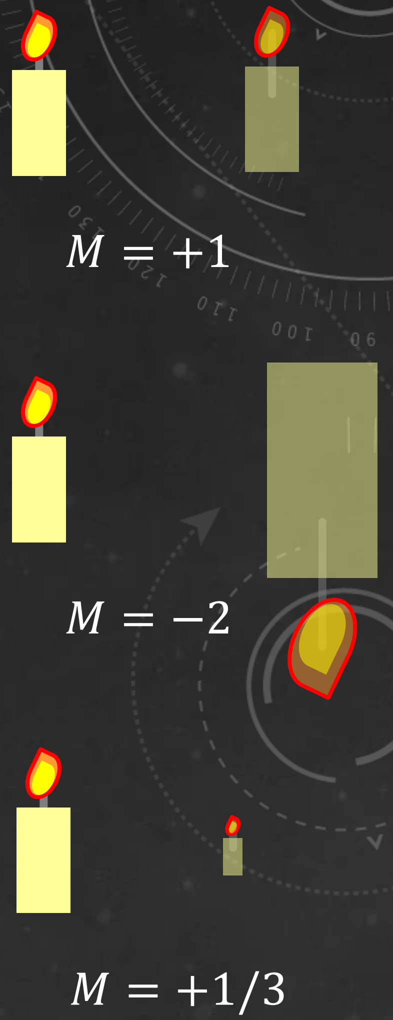
- Central axis: A line normal to the mirror's center
- Sign conventions: Distances on the side of the mirror where the light actually can pass are considered positive distances. Distances on the other side of the mirror where the light can't pass are negative.
- Center of curvature: If the mirror were extended to a complete circle, this would be the center of that circle, and the circle's radius is the radius of curvature, R.
- Focal point/length: The point through which the reflection of parallel rays would pass. It is half the radius of curvature (f = ½ R).
- Object distance: distance from the source object to the center of the mirror along the central axis
- Image distance: distance from any image formed to the center of the mirror along the central axis



DEFINITIONS: IMAGE LOCATION, SIZE, AND DIRECTION

Knowing the shape of the mirror and the location of the source object lets us find this information about the image that is formed.

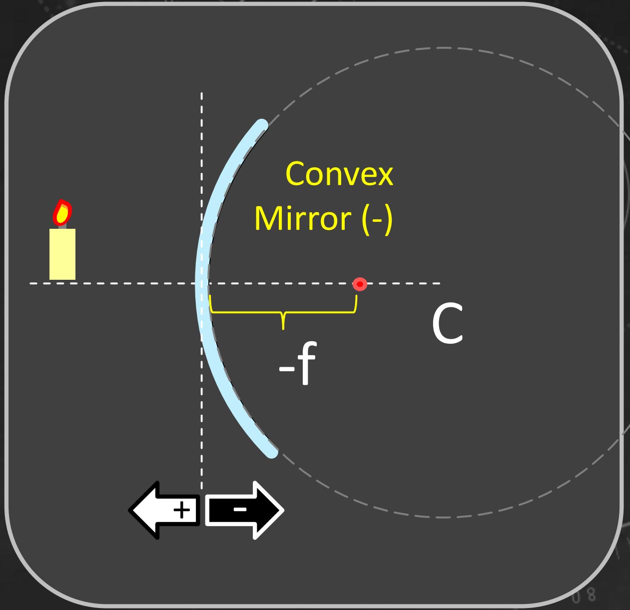
- Image location: The mirror equation relates focal length, f , object distance, d_o, and image distance, d_i
  - $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$
- Image size: Magnification (M) is the (unitless) ratio of the size of the image relative to the object.
  - $M = -\frac{d_i}{d_o}$
    - If $|M|$=1, image and object are the same size.
    - If $|M|$>1, image is larger than the object.
    - If $|M|$<1, the image is smaller.
- Image orientation: The magnification equation also tells which way the image points.
  - If M is positive, the image is upright (erect). If M is negative, the image is upside-down (inverted).

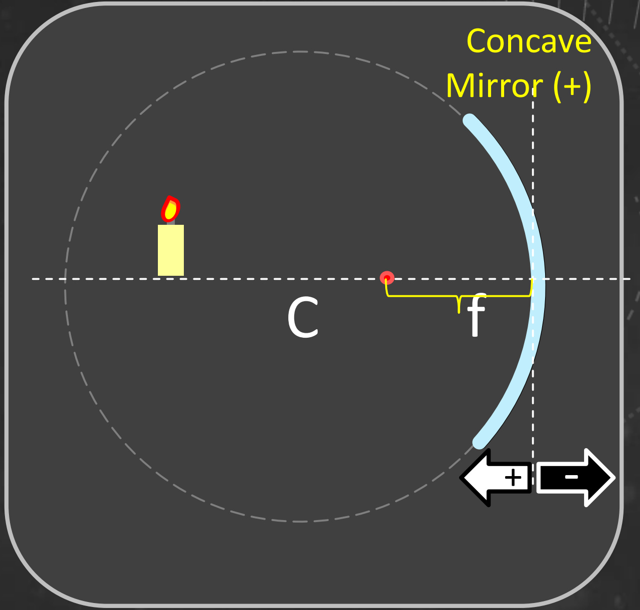


DEFINITIONS: CONVEX VS. CONCAVE

We will be considering spherical mirrors.

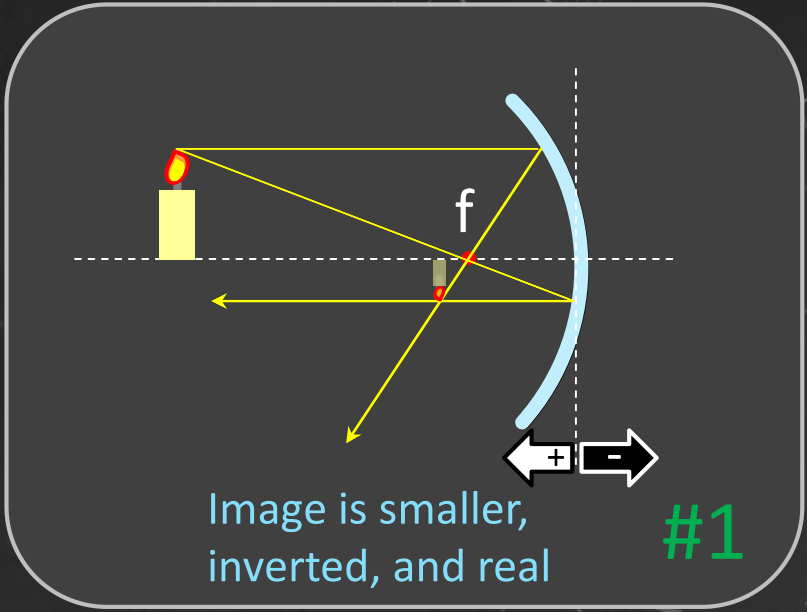
- Convex mirror:
  - Bulges toward the observer
  - Always diverges parallel light rays. (Sometimes called a ‘diverging mirror’)
  - Has a negative curvature and a negative focal length
- Concave mirror:
  - Bulges away from observer (forming a ‘cave’)
  - Either diverges or converges parallel light rays, depending on the object’s distance. (Sometimes called a ‘converging mirror’)
  - Has a positive curvature and a positive focal length





DEFINITIONS: PRINCIPLE RAYS

- We can find the location and size of the image by tracing just a few rays (principle rays) from object to mirror to image.
  - Rays from the top of the object determine where the top of the image is. Same for the bottom.
- Here are a couple of easy rays to draw and their rules for spherical mirrors:
  - In parallel (to the central axis), out through the focus
  - In through the focus, out parallel (to the central axis)
- The intersection of the principle rays is also the intersection of all other rays that come from that point of the object.
  - This locates the top of the object.
- The bottom of the image is on the central axis, since the bottom of the object is on the central axis.



EXAMPLE: FLAT MIRRORS

- When we stand in front of a flat mirror, what do we observe?
  - A flat mirror has *no curvature*, or *infinite radius of curvature*.
- Here are some rays that are received by our eyes.
- Our eyes and brain project the rays back as if they came from a source on the other side of the mirror.
  - People think flat mirrors reverse our left and right, but that's not correct.
  - If it was true, it would flip our head and feet if we were laying on our side!
  - The flat mirror actually performs a front-to-back reversal.
  - Because we are symmetric creatures, the front-back reversal of our left hand looks like a right hand, and vice-versa.
- The image appears to be standing as far behind the mirror as we are standing in front of the mirror.

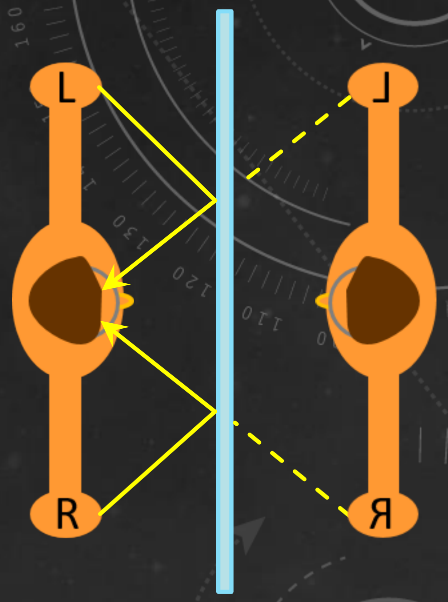
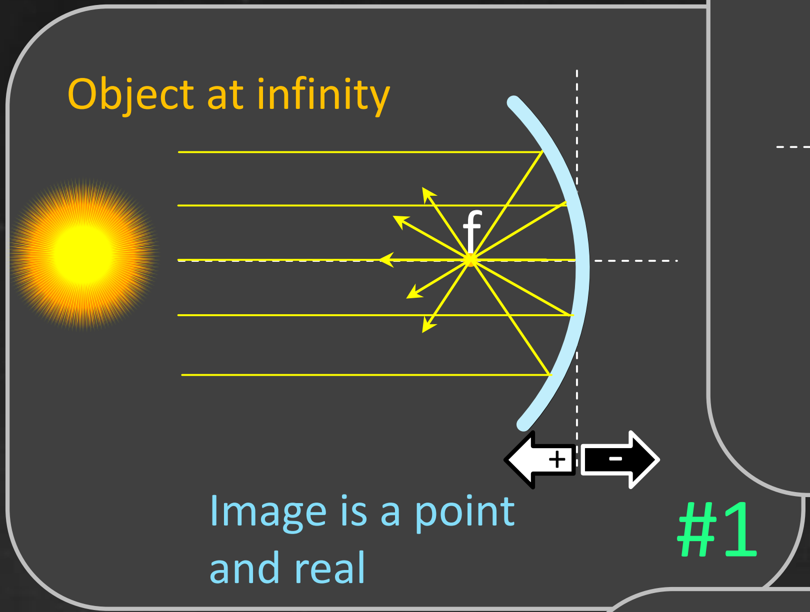
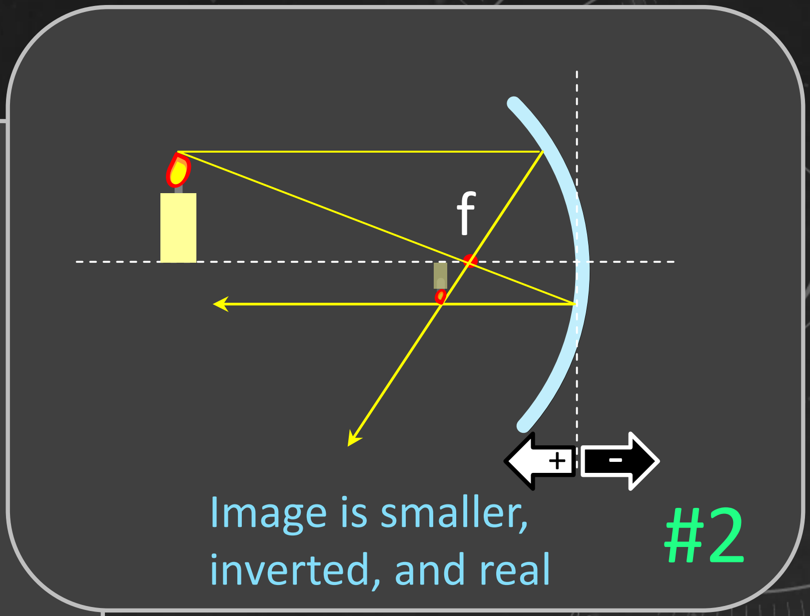


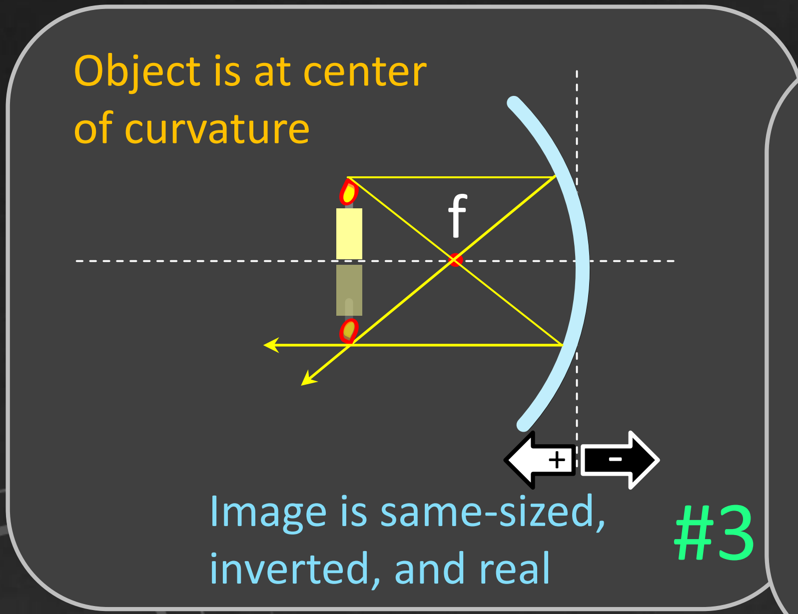
Image is same-sized, upright, and virtual

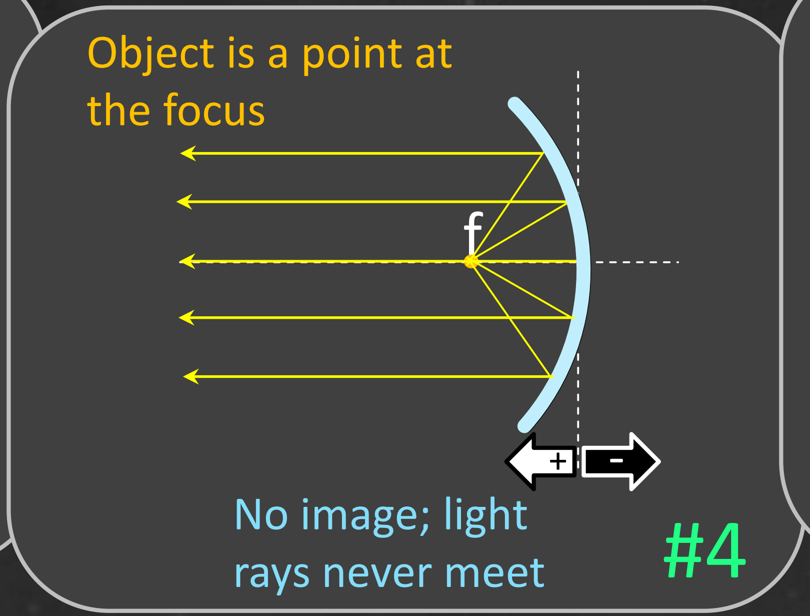
EXAMPLE: CONCAVE MIRRORS

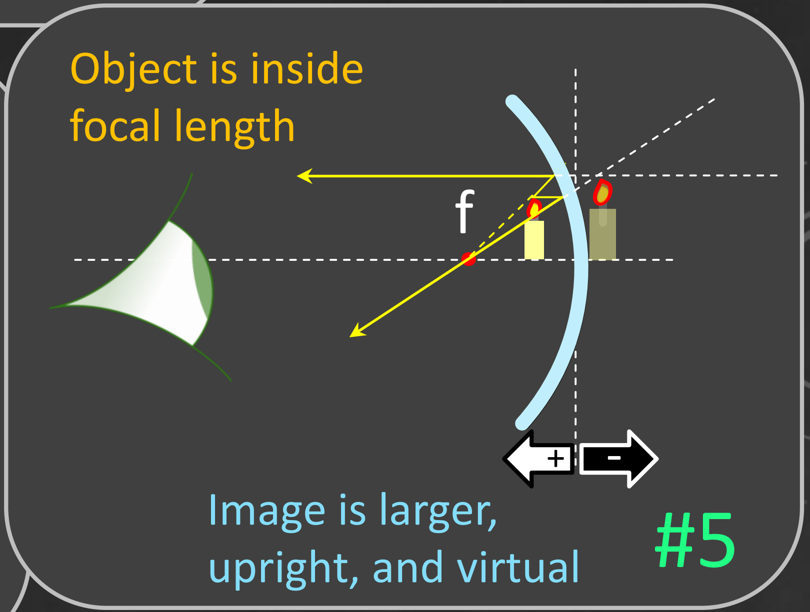
- Here are the ray diagrams for some interesting configurations for a concave mirror.





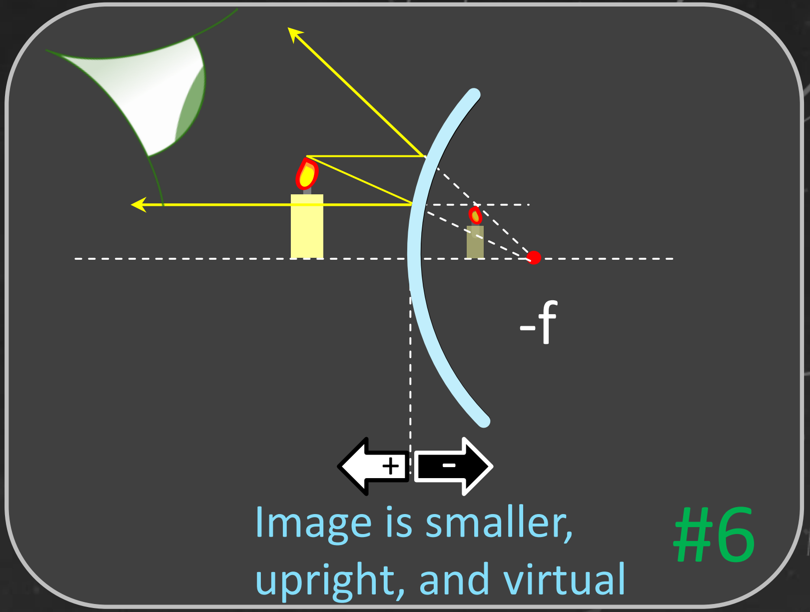






EXAMPLE: CONVEX

- If an object is placed in front of convex mirror (which has a negative focal length):
  - The light can't actually get to the focus, so the ray rules are modified slightly.
  - In parallel, out *as if* through the focus
  - In *as if* through focus, out parallel
- For a convex mirror, the image is always smaller, upright, and virtual, no matter the object's distance.
  - These mirrors have a large field of view, and the image is right-side up.
  - This makes them good for side-view mirrors and are also used for hallway corners.
  - The smaller image fools us into thinking the object is farther away.
  - "Objects in mirror are closer than they appear."



SPOONS, SOLAR COOKERS, HEADLAMPS

- Here is an experiment you can easily do at home. First, find a shiny spoon.
  - Look at the back of the bowl part from different distances. The back is a convex mirror, so you should see a small, virtual, upright image at any distance. (See ray diagram #6)
  - Look at the front of the bowl. The front is a concave mirror.
    - At a very near distance, you should see an image of your eye. It is upright and slightly bigger. You are inside the focal point of the spoon. (See ray diagram #5)
    - At arm's length, you should see a smaller, inverted image. (See ray diagram #2)
- Solar Cooker: See ray diagram #1.
- Headlamp: See ray diagram #4.

CONCLUSION

- Rays of light from an object can combine to form an image.
- Light rays reflecting from mirrors follow the Law of Reflection (angle of reflection equals angle of incidence.)
- Geometric optics with spherical mirrors depend on the object's location and the mirror's focal length or curvature.
- Spherical mirrors can be concave or convex.
- Images can be real or virtual, and they can be enlarged, reduced, or unchanged in size. They can also be oriented upright or inverted.
- The location, size, and orientation of the image can be found by drawing principle ray diagrams or by using the mirror and magnification equations.
- Flat mirrors cause an image that is a front-back reversal of the object.
- Convex and concave mirrors have several applications in everyday lives.

IMAGE ATTRIBUTION

- The Bean: https://www.flickr.com/photos/22711505@N05/15263743930
- Rearview mirror: https://poletosoul.me/2014/03/25/objects-may-seem-larger/
- Solar cooker: https://commons.wikimedia.org/wiki/File:%22Sungril%22_solar_cooker_photo1.jpg
- Spoon1: https://pixabay.com/en/spoon-tin-silver-cutlery-shiny-644559/
- Spoon3: http://maxpixel.freegreatpicture.com/Cutlery-Spoon-Fork-Teeth-1281162
- Sun: https://openclipart.org/detail/172455/sun-abstract-design
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