Image Formation and Optical Instruments

Chapter 34

Mirrors

Lenses

Image Formation

We will use geometrical optics: light propagates in straight lines until its direction is changed by reflection or refraction.

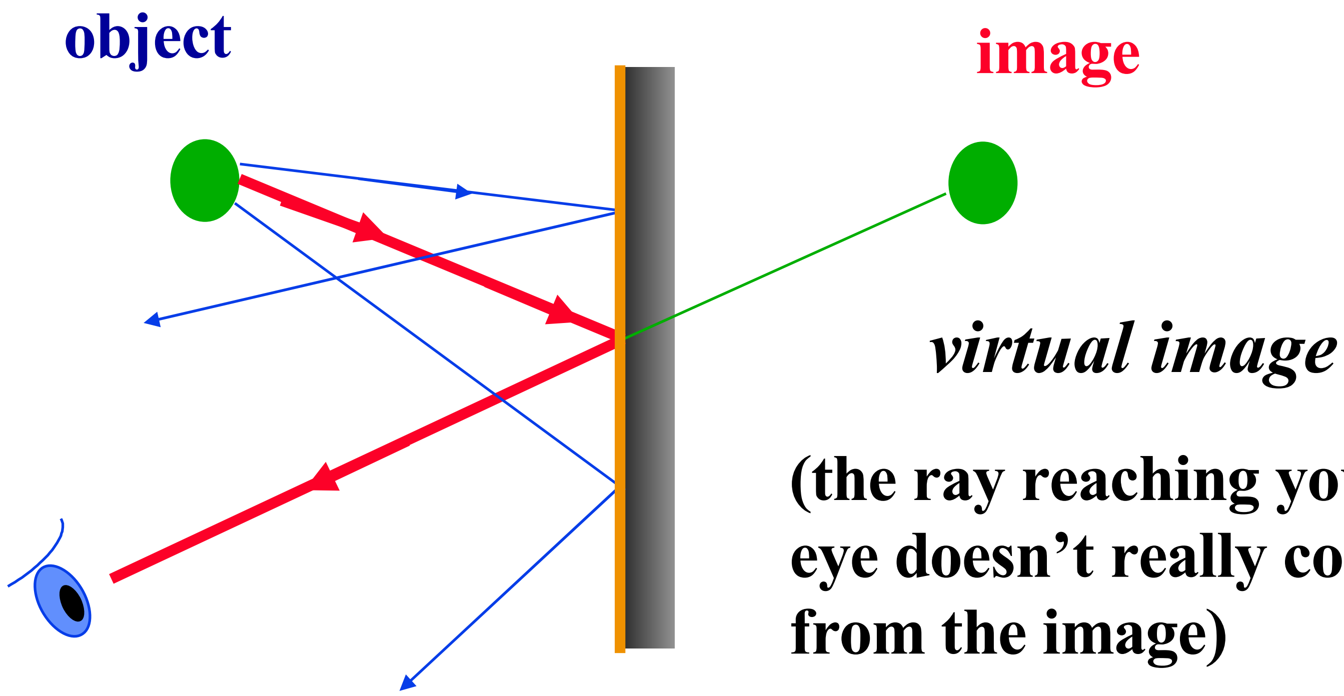
When we see an object directly, light comes to us straight from the object.

When we use mirrors and lenses, we see light that seems to come straight from the object but actually doesn't.

Thus we see an image (of the object), which may have a different position, size, or shape than the actual object.

Images Formed by Plane Mirrors

When we use mirrors and lenses, we see light that seems to come straight from the object but actually doesn't. Thus we see an image, which may have a different position, size, or shape than the actual object.



(the ray reaching your eye doesn't really come from the image)

But…. the brain thinks the ray came from the image.

Images Formed by Plane Mirrors

You can locate each point on the image with two rays:
1. A ray normal to the mirror

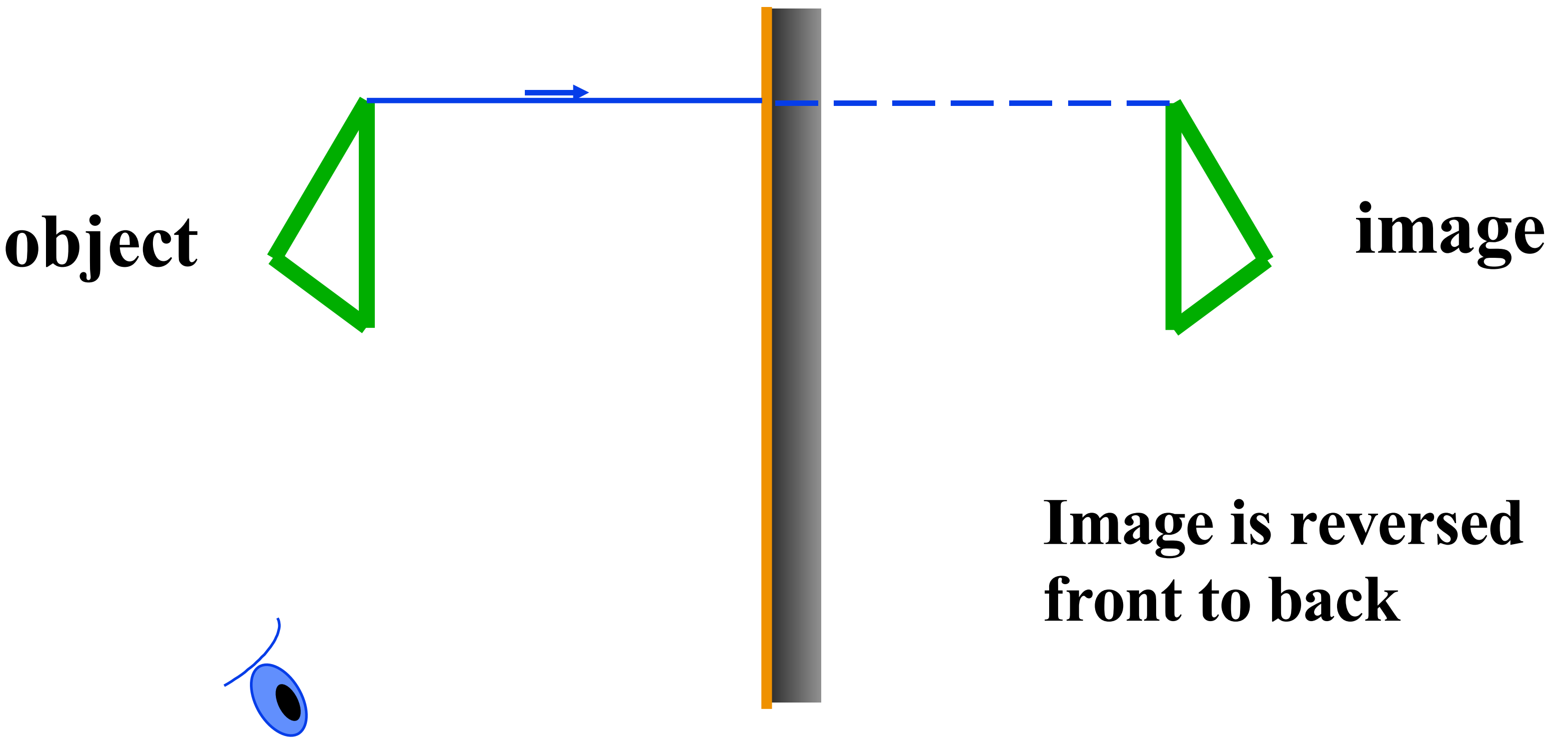


Image is reversed front to back

Images Formed by Plane Mirrors

You can locate each point on the image with two rays:

1. A ray normal to the mirror

2. The ray that reaches the observer's eye

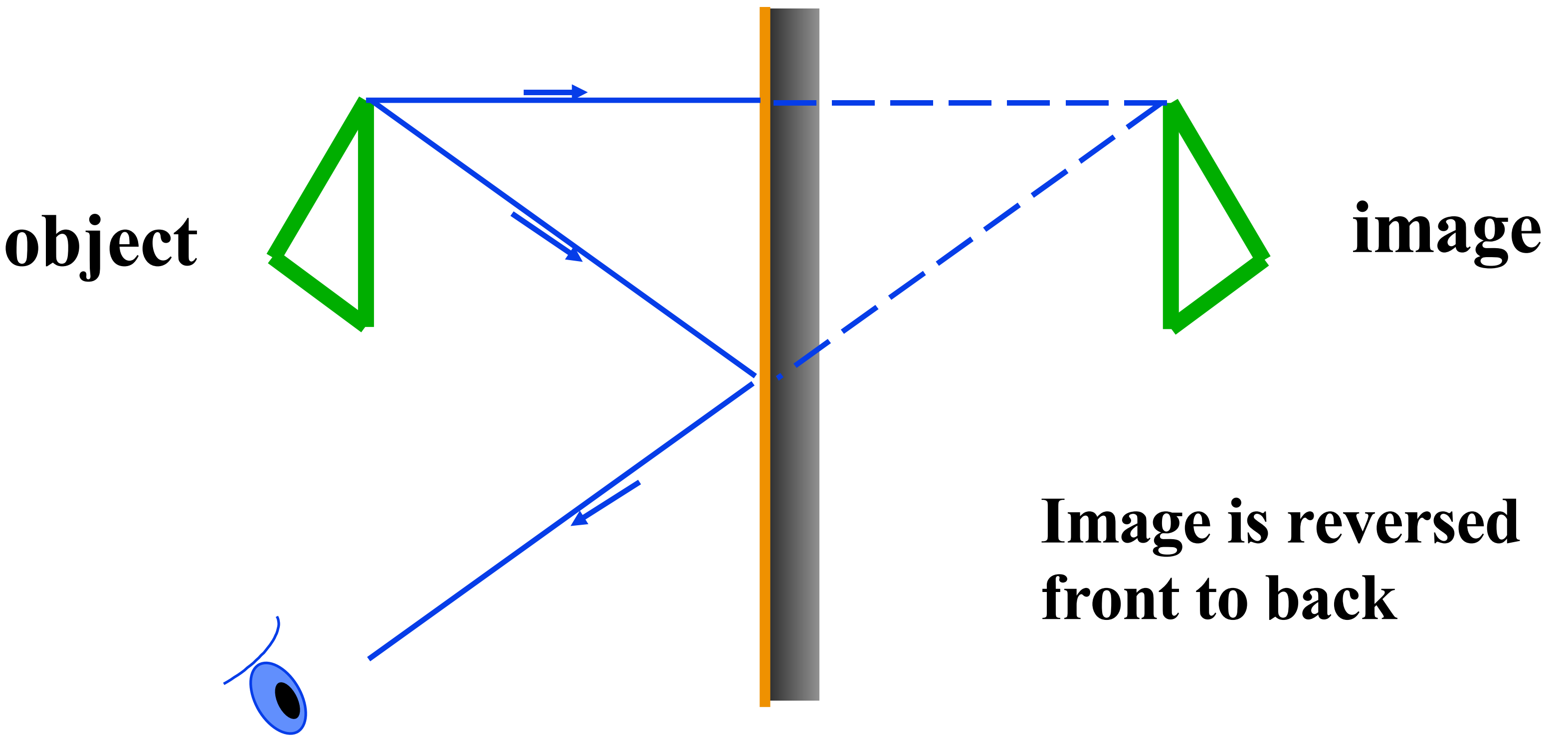


Image is reversed front to back

Images Formed by Plane Mirrors

You can locate each point on the image with two rays.

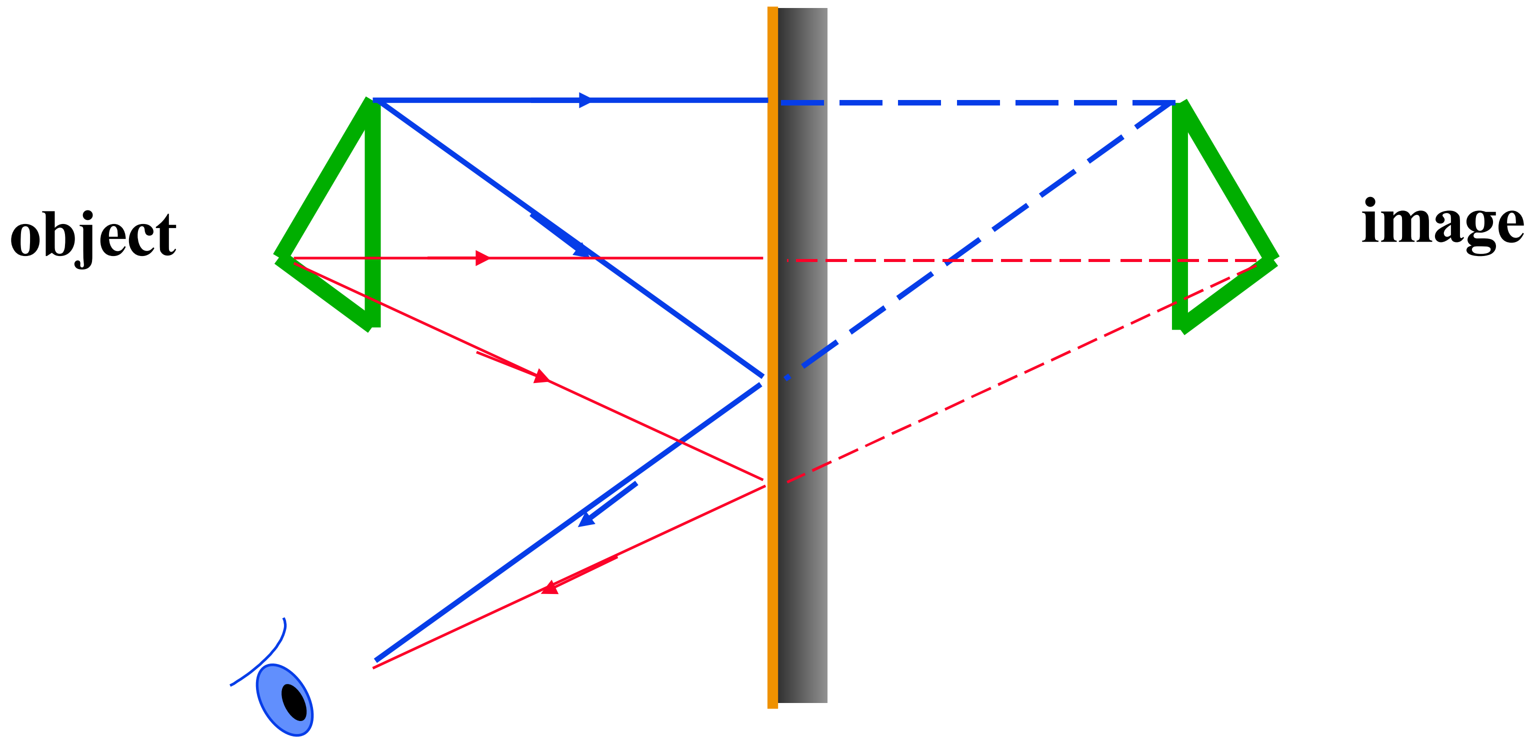


Image is reversed (front to back)

Images Formed by Plane Mirrors

You can locate each point on the image with two rays.

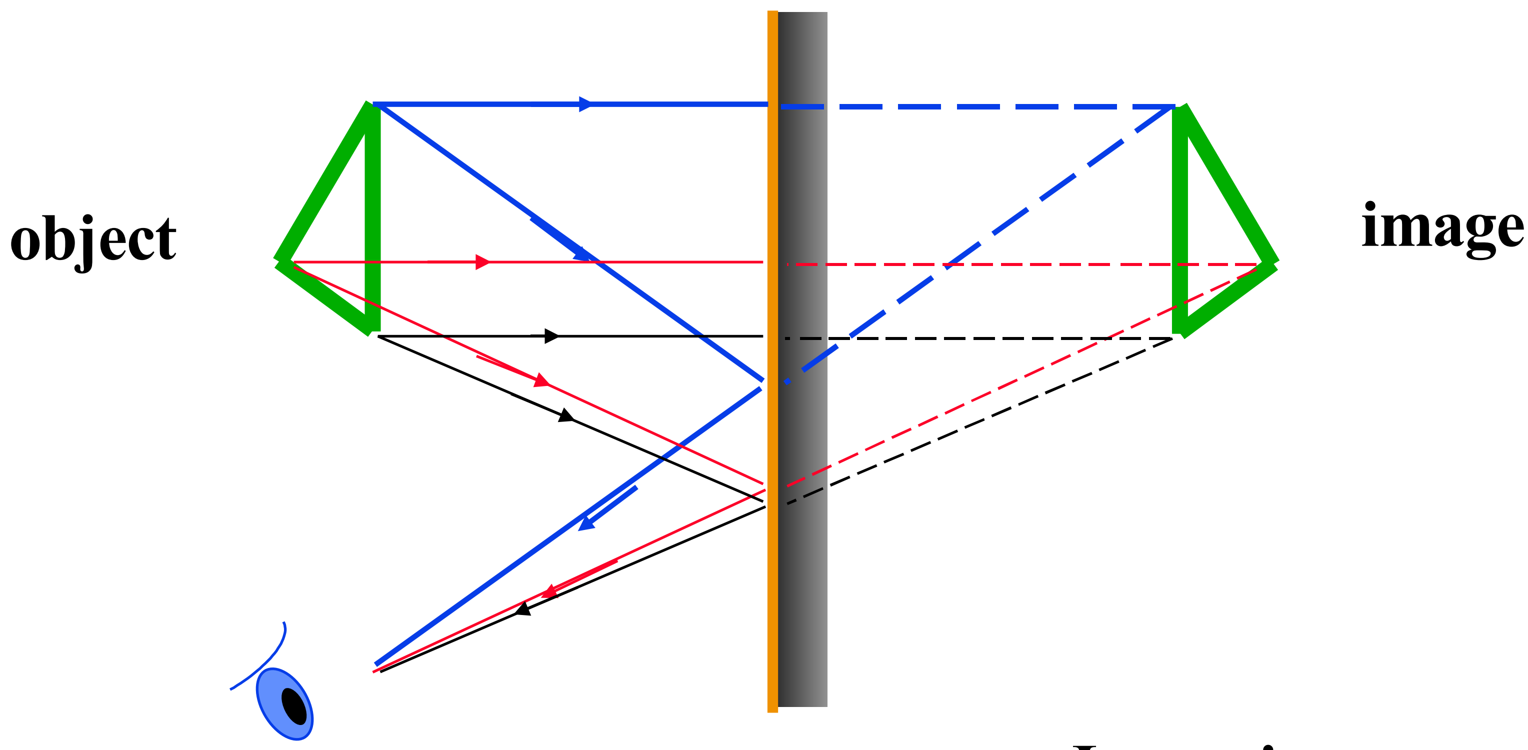
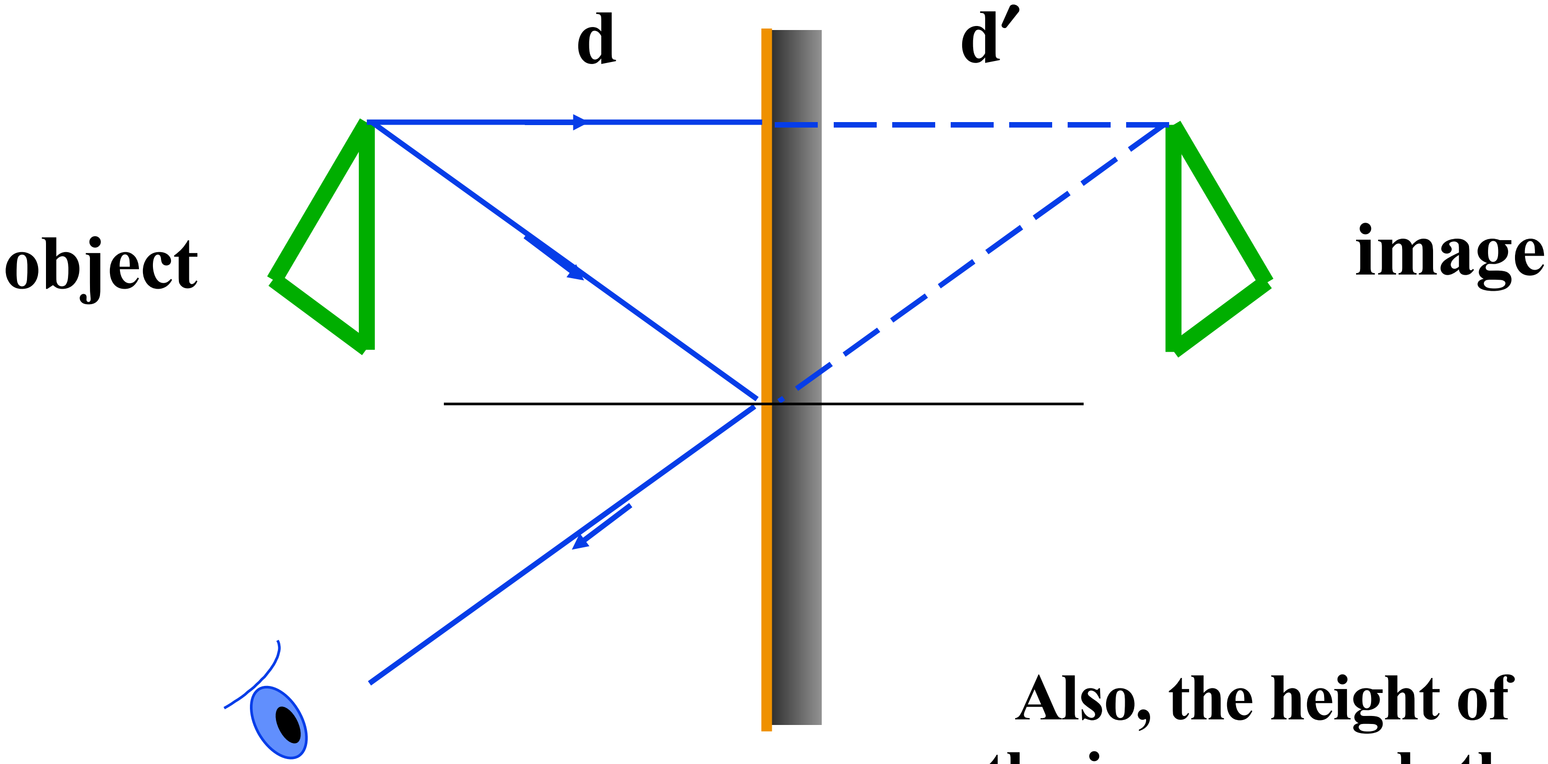


Image is reversed (front to back)

Images Formed by Plane Mirrors

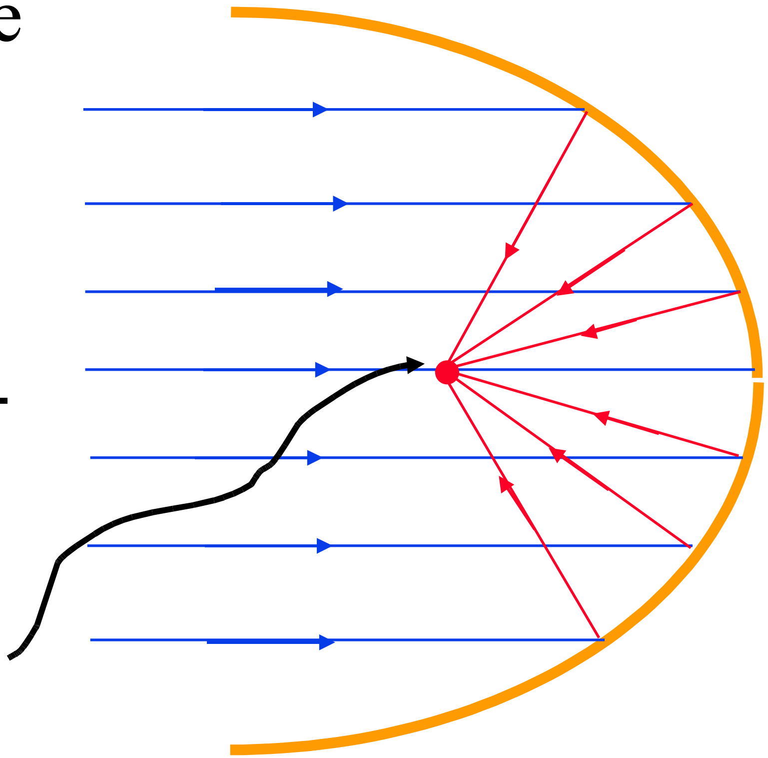
The distance from the image to the mirror equals the distance from the object to the mirror: d = d′



Also, the height of the image equals the height of the object

Parabolic Mirrors

- Shape the mirror into a parabola of rotation (In one plane it has cross section given by $y = x^2$).
- All light going into such a mirror, parallel to the parabola's axis of rotation, is reflected to pass through a common point - the focus.
- What about the reverse?

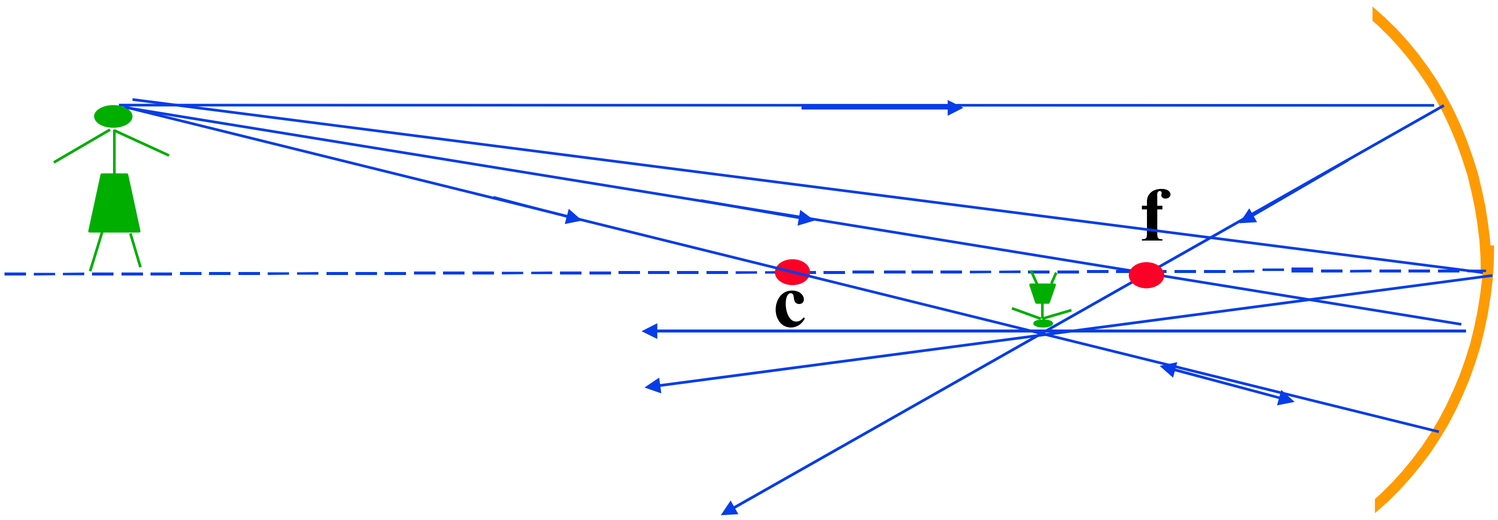


Parabolic Mirrors

- These present the concept of a focal point - the point to which the optic brings a set of parallel rays together.
- Parallel rays come from objects that are very far away (and, after reflection in the parabolic mirror, converge at the focal point or focus).
- Parabolas are hard to make. It's much easier to make spherical optics, so that's what we'll examine next.

Spherical Mirrors

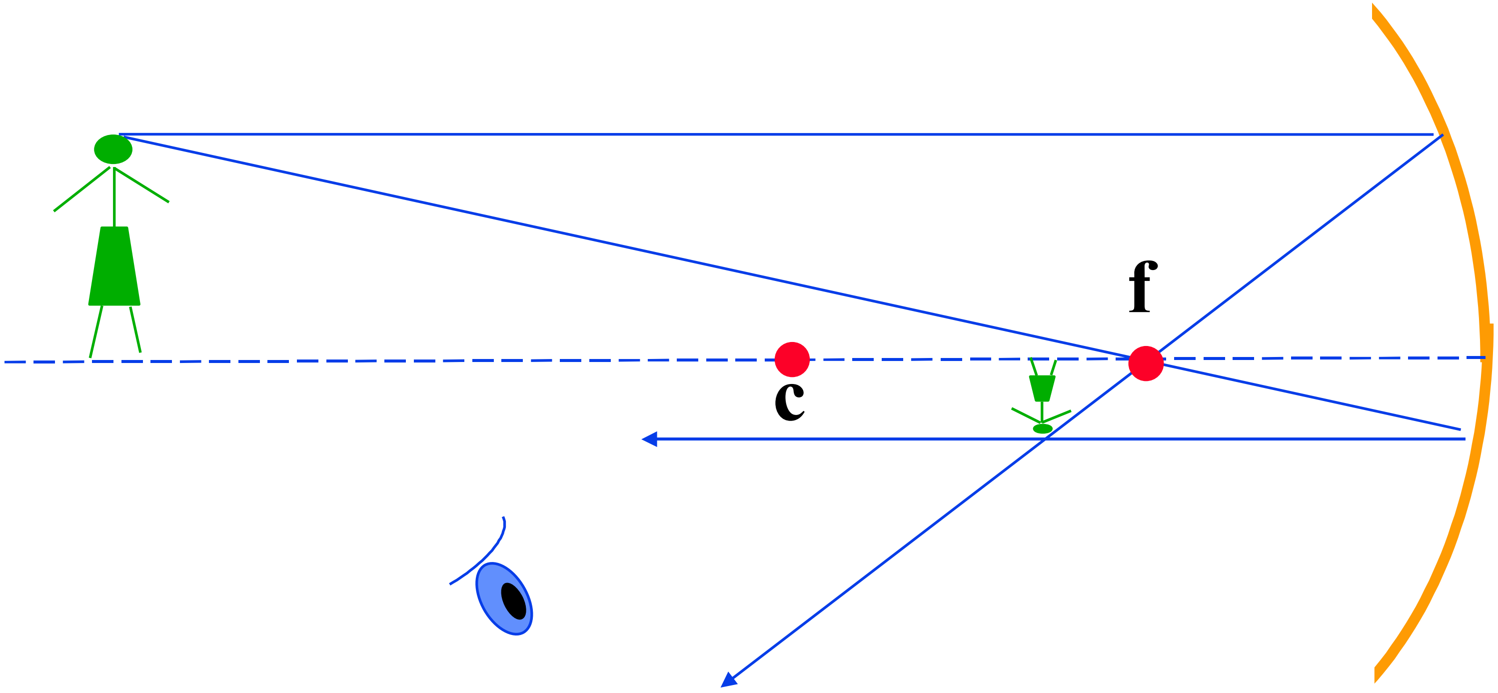
To analyze how a spherical mirror works we draw some special rays, apply the law of reflection where they strike the spherical surface, and find out where they intersect.



A ray parallel to the mirror axis reflects through the focal point f
A ray passing through the focus reflects parallel to the axis
A ray that strikes the center of the mirror reflects symmetrically
A ray passing through the center of curvature c, returns on itself

Spherical Mirrors

When the object is beyond c, the image is: real (on the same side as the object), reduced, and inverted.



Spherical Mirrors - Concave

Object between c and f.

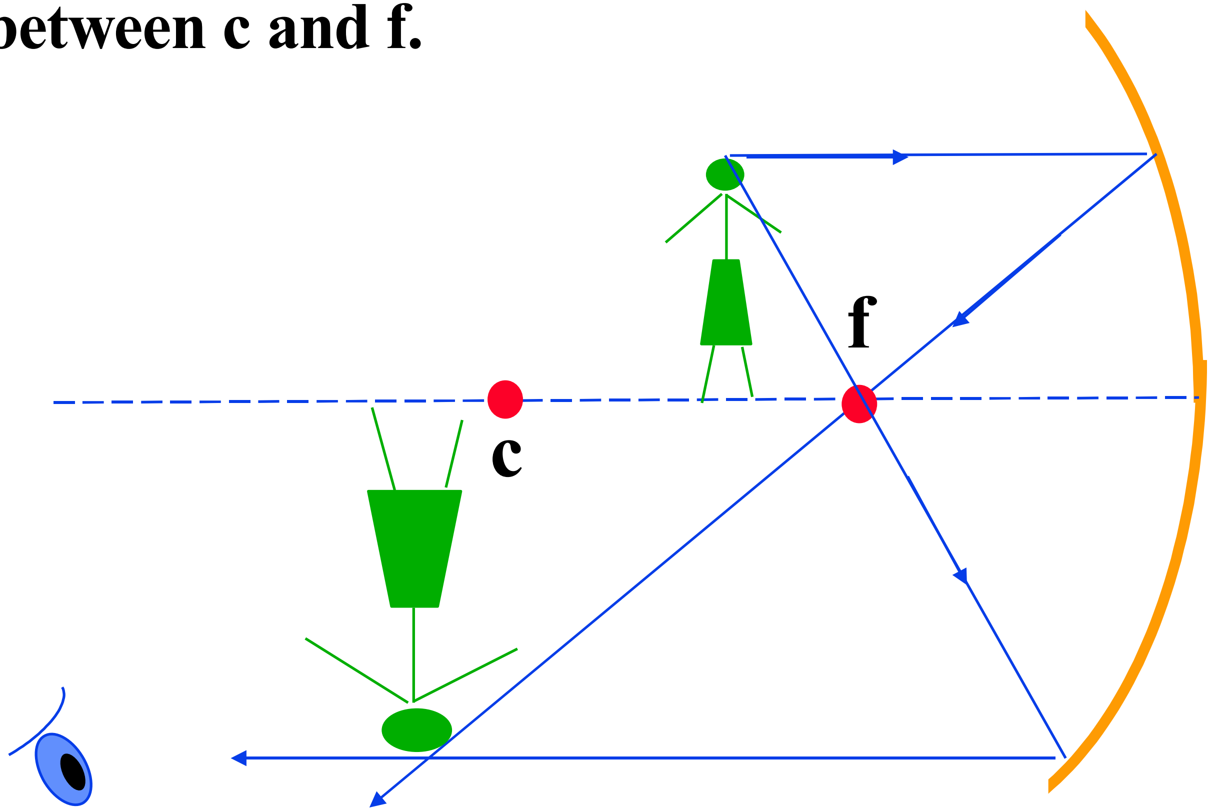


Image is real, inverted, magnified

Spherical Mirrors

Object between f and the mirror.

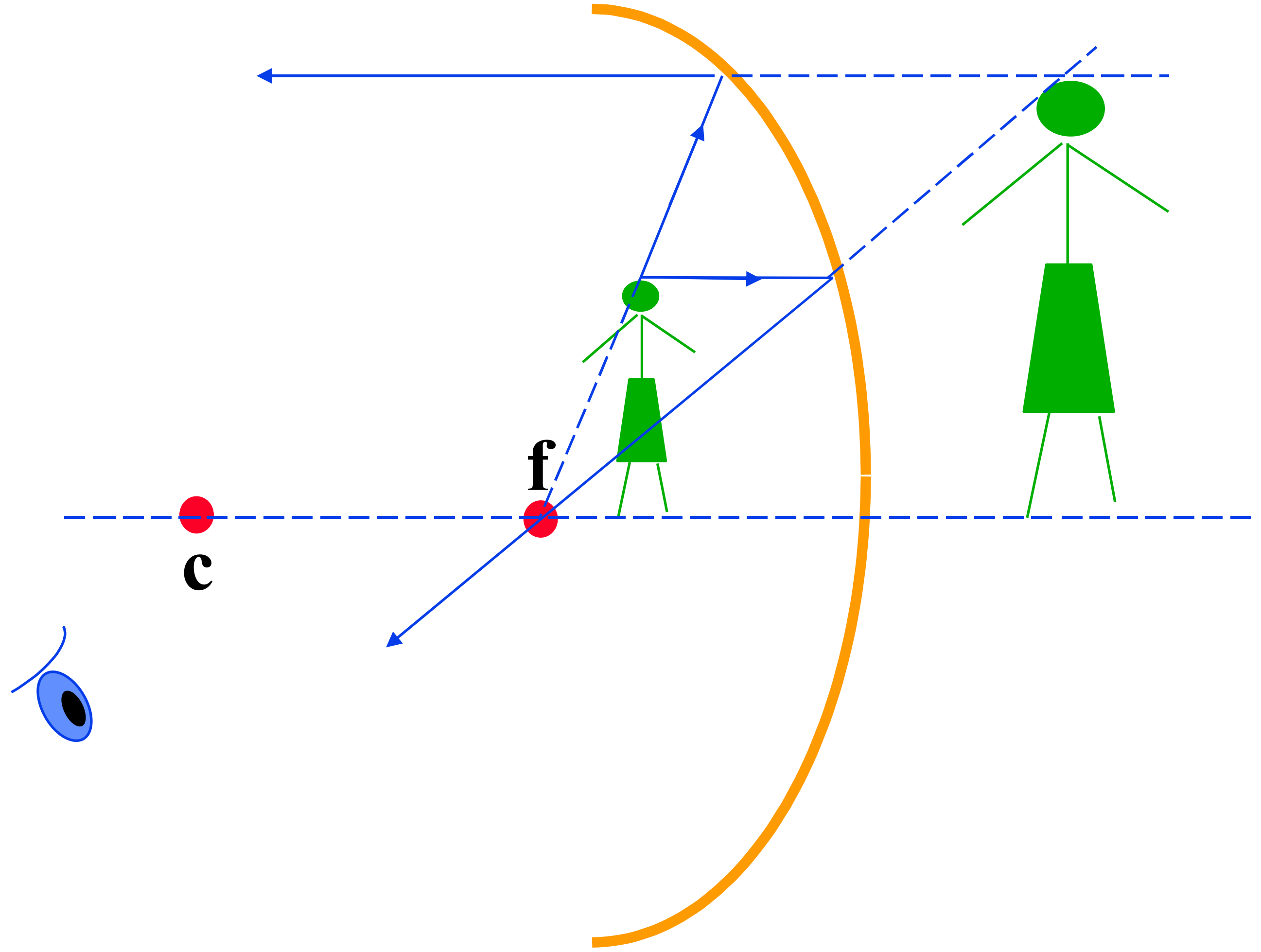
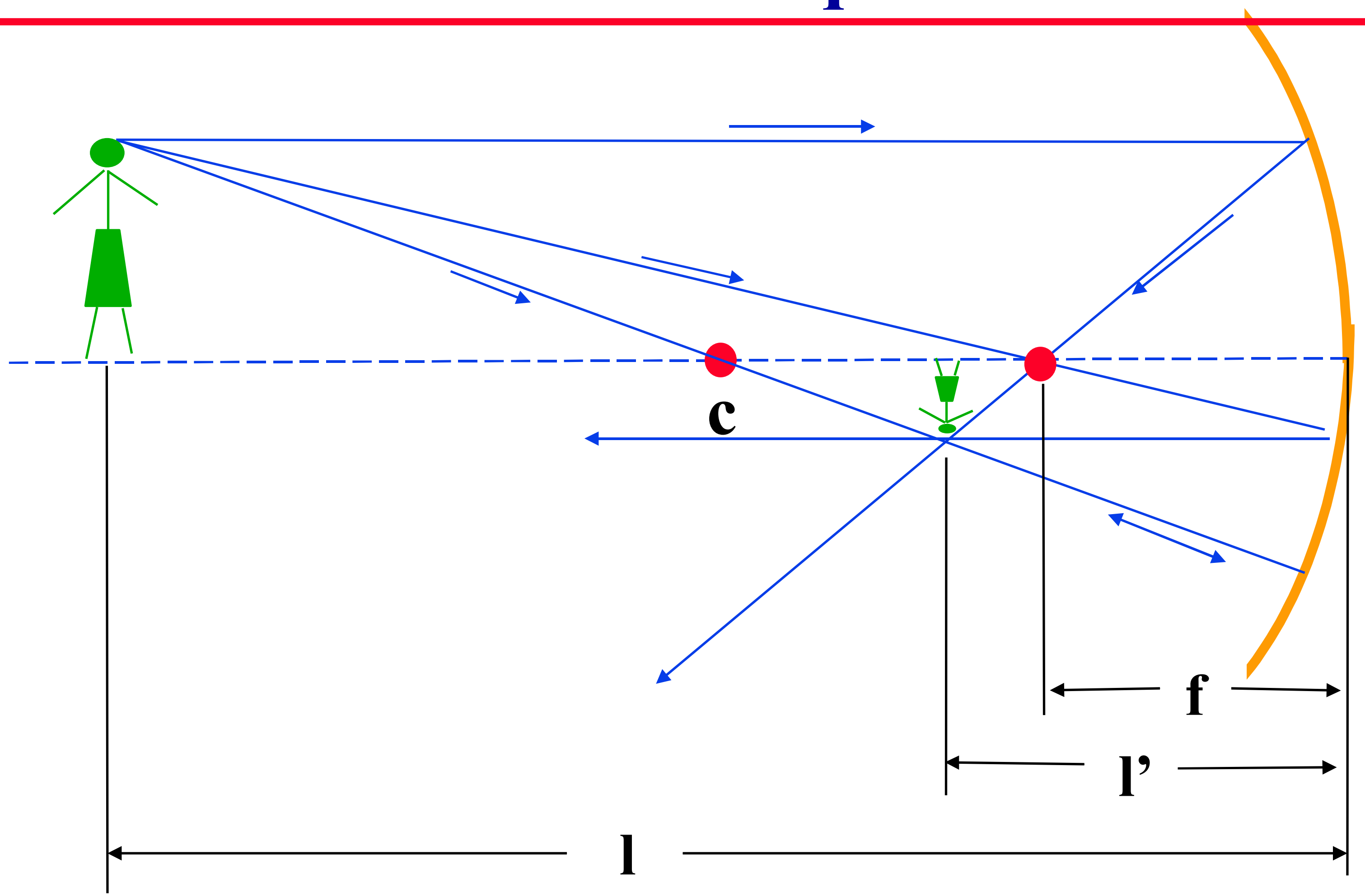


Image is virtual, upright, magnified

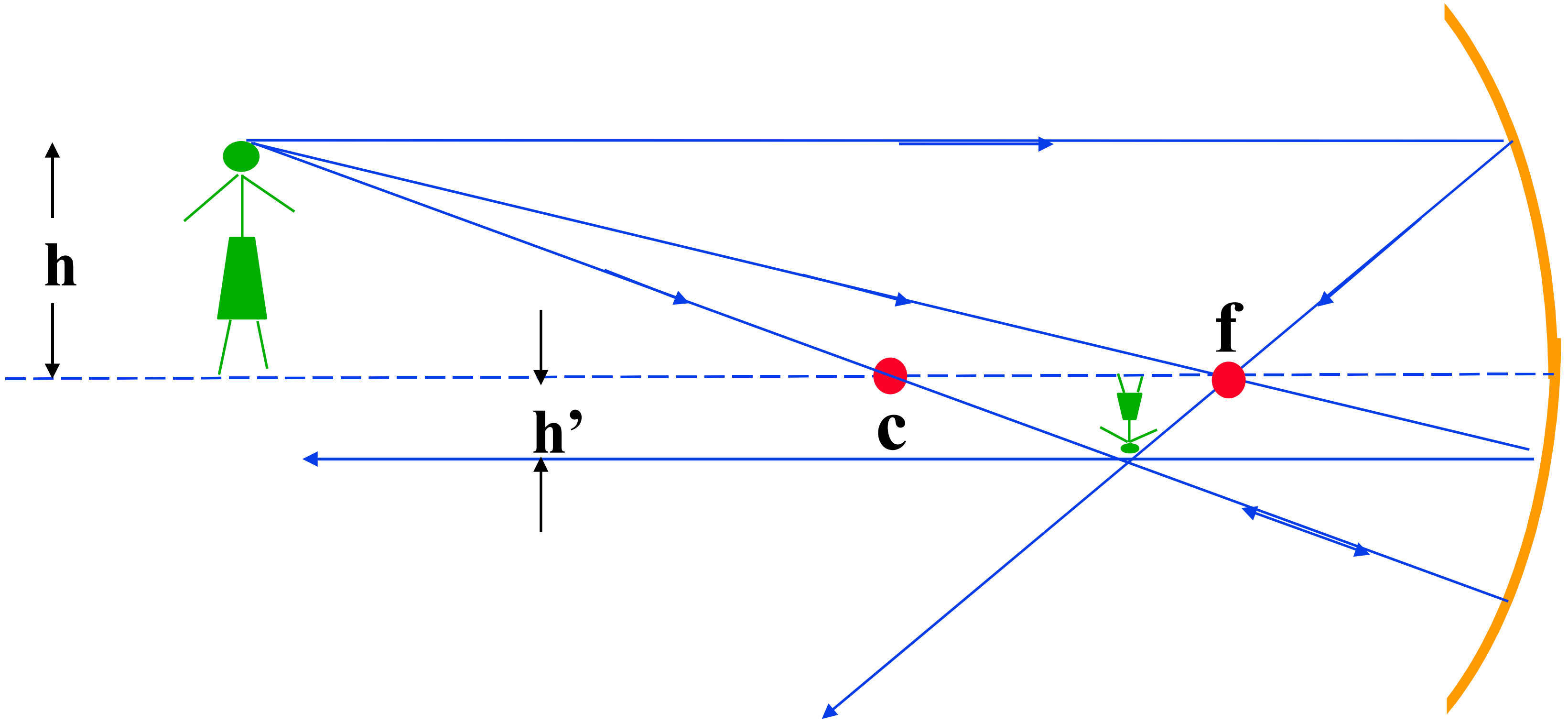
The Mirror Equation



$$\frac{1}{f} = \frac{1}{l} + \frac{1}{l'}$$

Here f = R / 2

Magnification



The magnification is given by the ratio $M = h' / h = - l' / l$

Curved Mirrors

mirror equation

$$\frac{1}{l} + \frac{1}{l'} = \frac{1}{f}$$

focal length

$$f = R/2$$

magnification

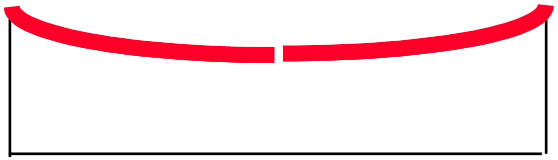
$$M = \frac{h'}{h} = -\frac{l'}{l}$$

Sign conventions:

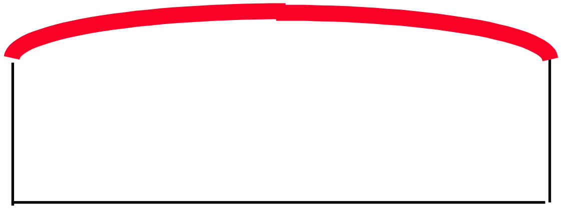
Distance in front of the mirror ≡ positive
Distance behind the mirror ≡ negative
Height above center line ≡ positive
Height below center line ≡ negative

Positive and Negative Mirrors

- You can fill a positive mirror with water.
- You can't fill a negative mirror.

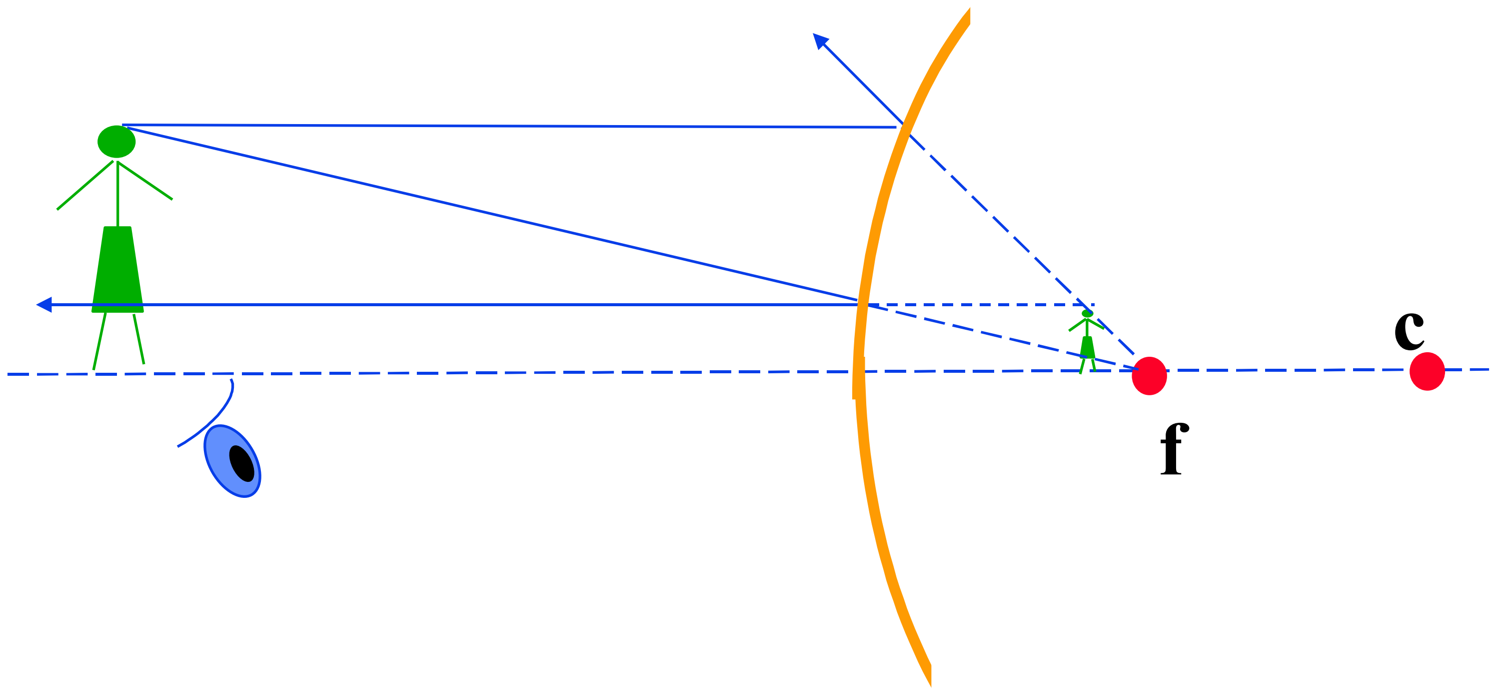


positive mirror is concave



negative mirror is convex

Image With a Convex Mirror



Here the image is virtual (apparently positioned behind the mirror), upright, and reduced. Can still use the mirror equations (with negative distances for f, c=R, and l').