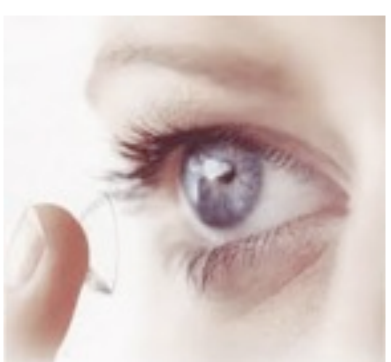
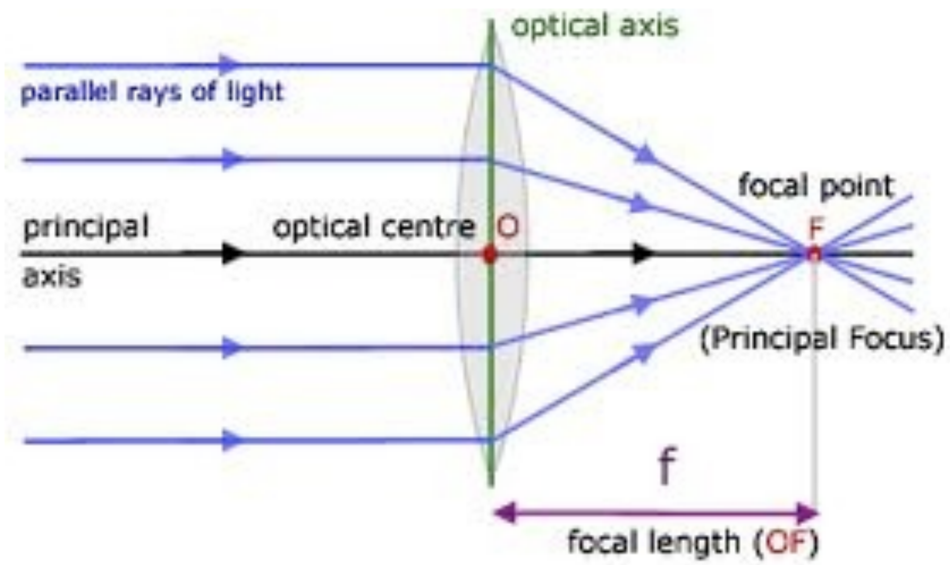
Optics overview

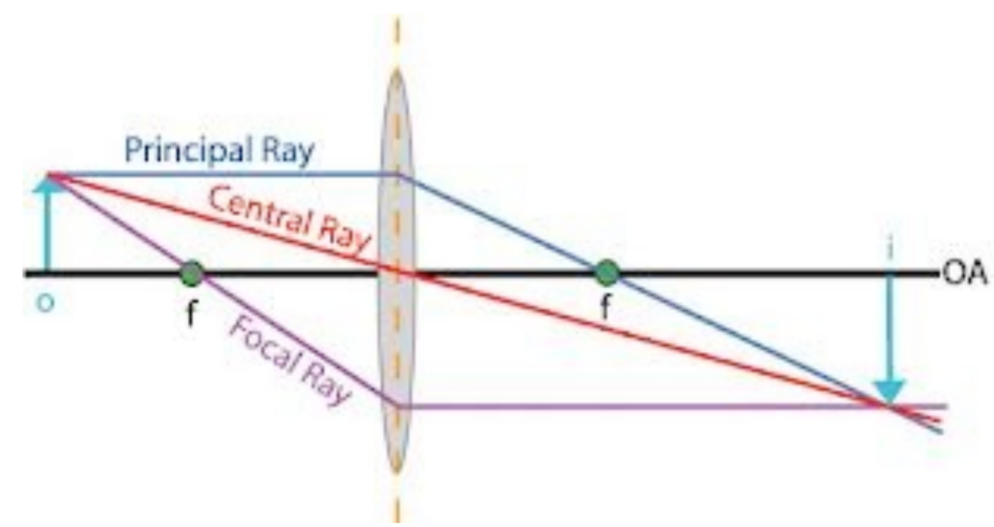
Ken Intriligator's week 8 lectures, Nov.24, 2014



Recall Fermat principle

Light always takes the path of least (better: extremal) time. Ray diagrams: all paths take the same time.

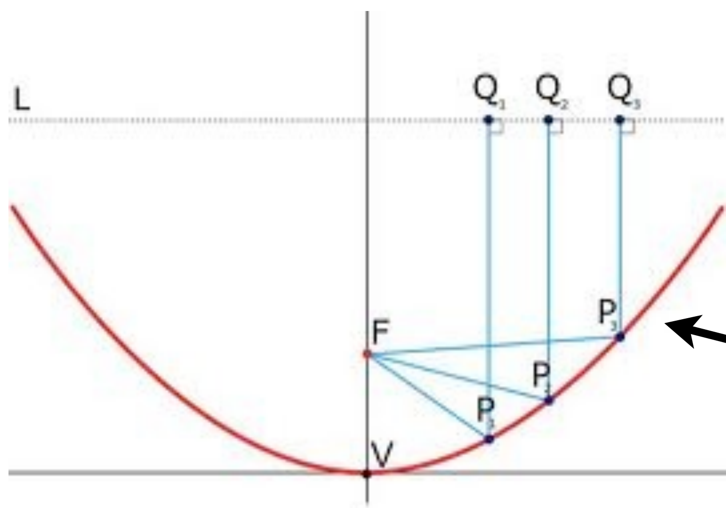




Fermat's principle gives a nice way to derive all of the formulae we'll be discussing this week. Another way is to just use Snell's law at each surface (see the book for this way).

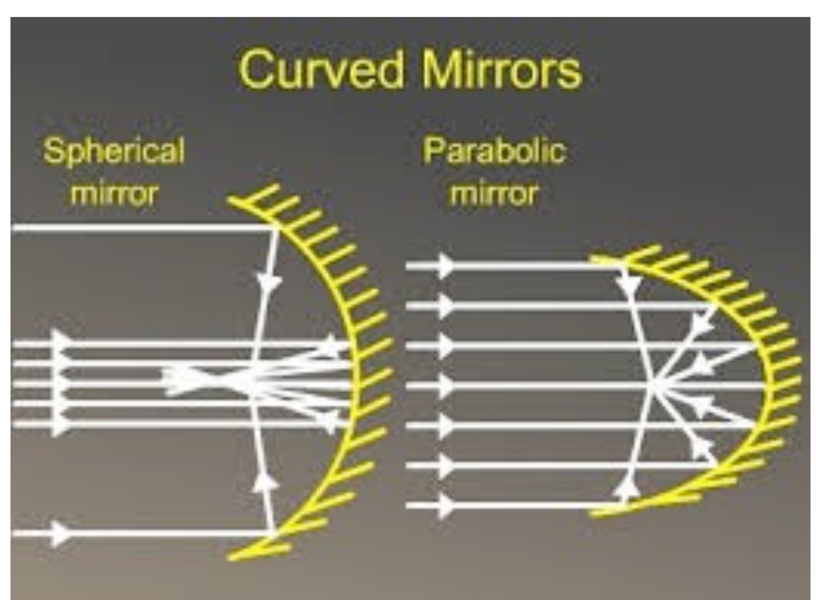
Focus plane waves:

(By reflection)



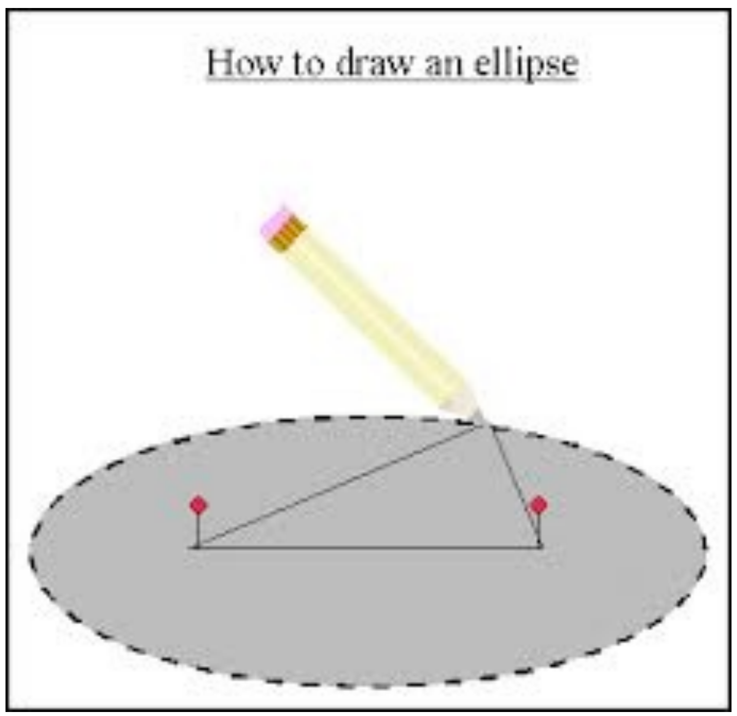
All these ray paths take same time, so same distance. The red curve is a **parabola, or paraboloid** in 3d. The shape of satellite dishes.

It is easier to make a spherical surface than a parabolic one, gives approximately good focusing.

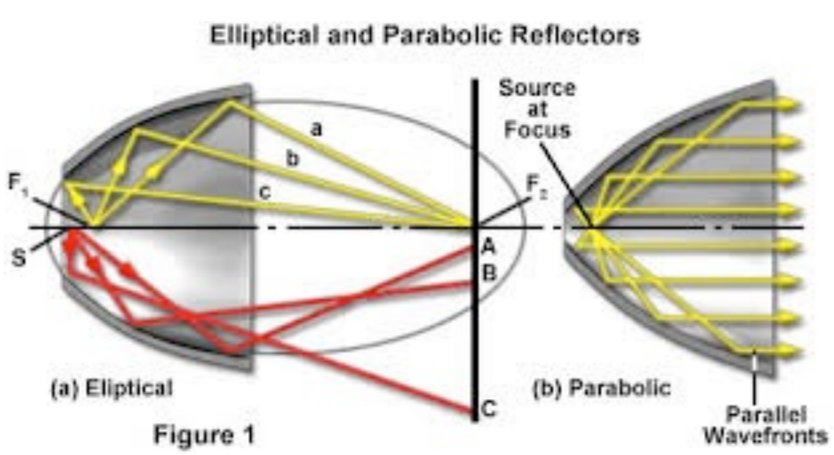


Focus point to point

Find the shape to focus the light rays, coming off a point source, to an image point.



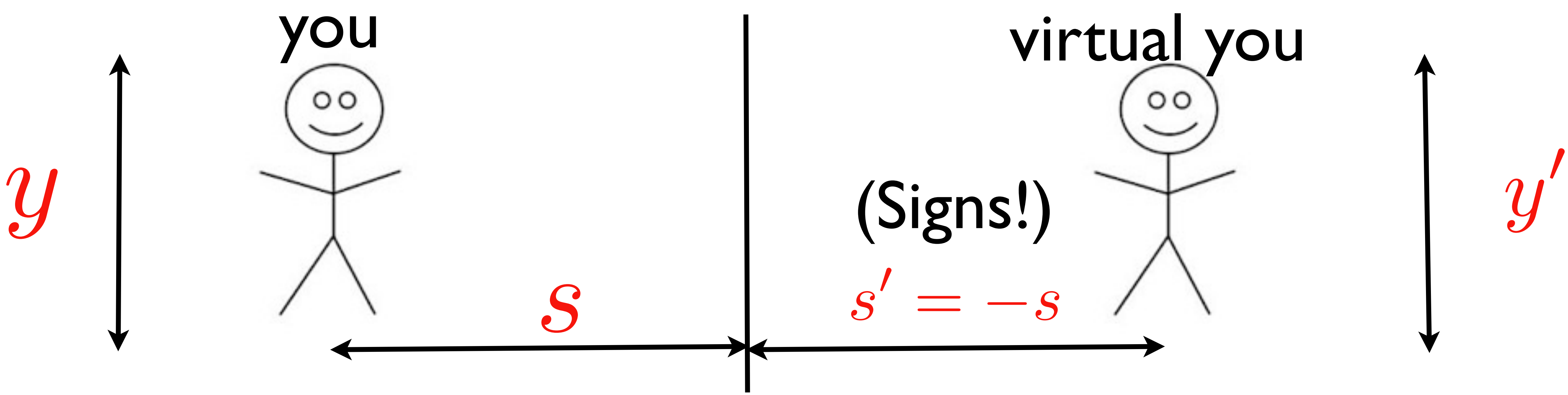
Ellipse does this.   Sometimes you can find an elliptical room. Listening from one focal point, you can perfectly hear your friend wispering at the other focal point. (At SD science center, with just ends.)



Taking one of the focal points to infinity gives the parabola.

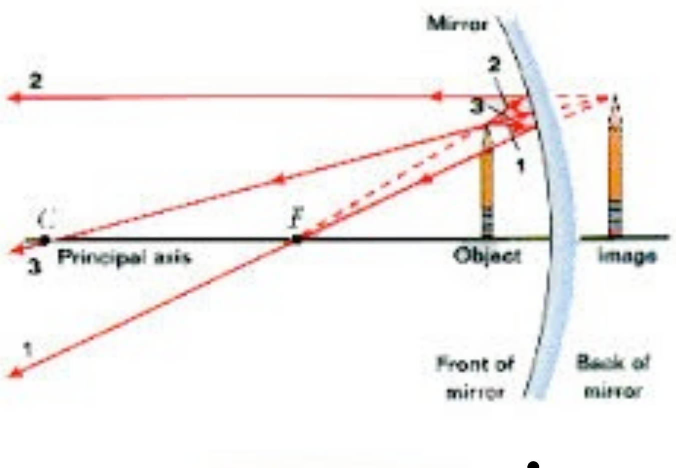
Real vs virtual images

Previous examples were focusing light to a point, gives a "real image," i.e. one that can be projected on a screen. A "virtual image" is only apparent, e.g. your reflection in a plane mirror:

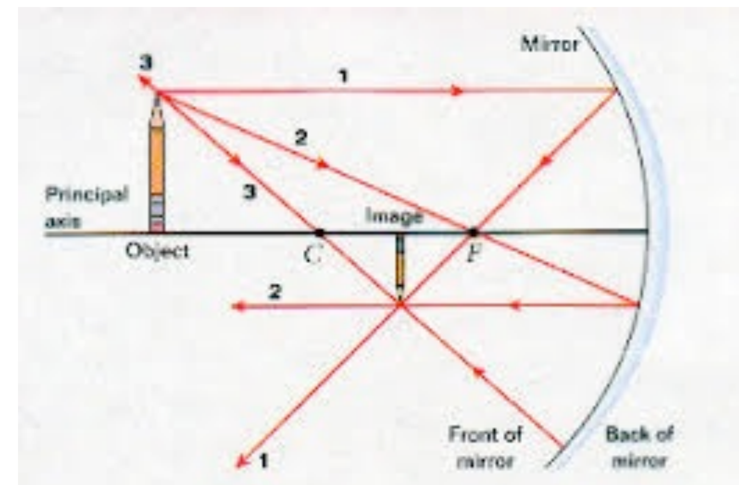


Magnification $m \equiv \frac{y'}{y}$ $m_{plane\ mirror} = 1$

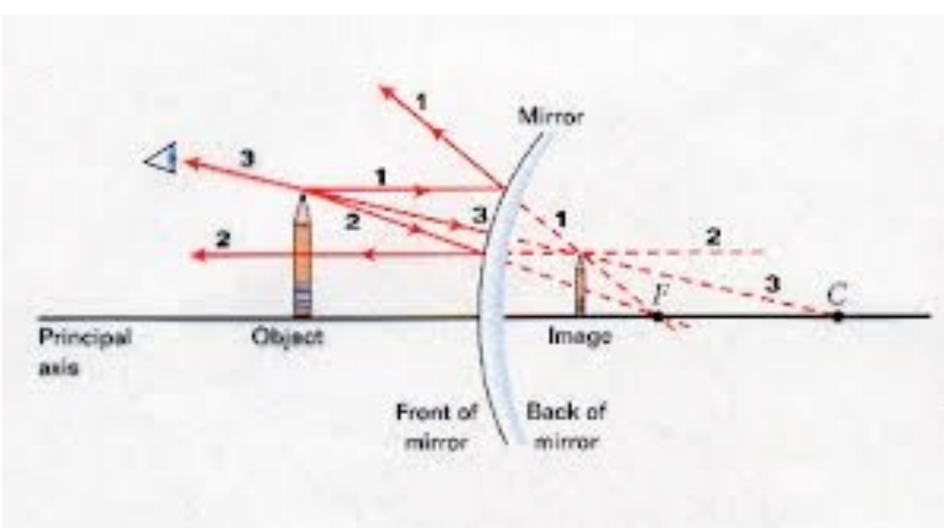
spherical mirrors



or



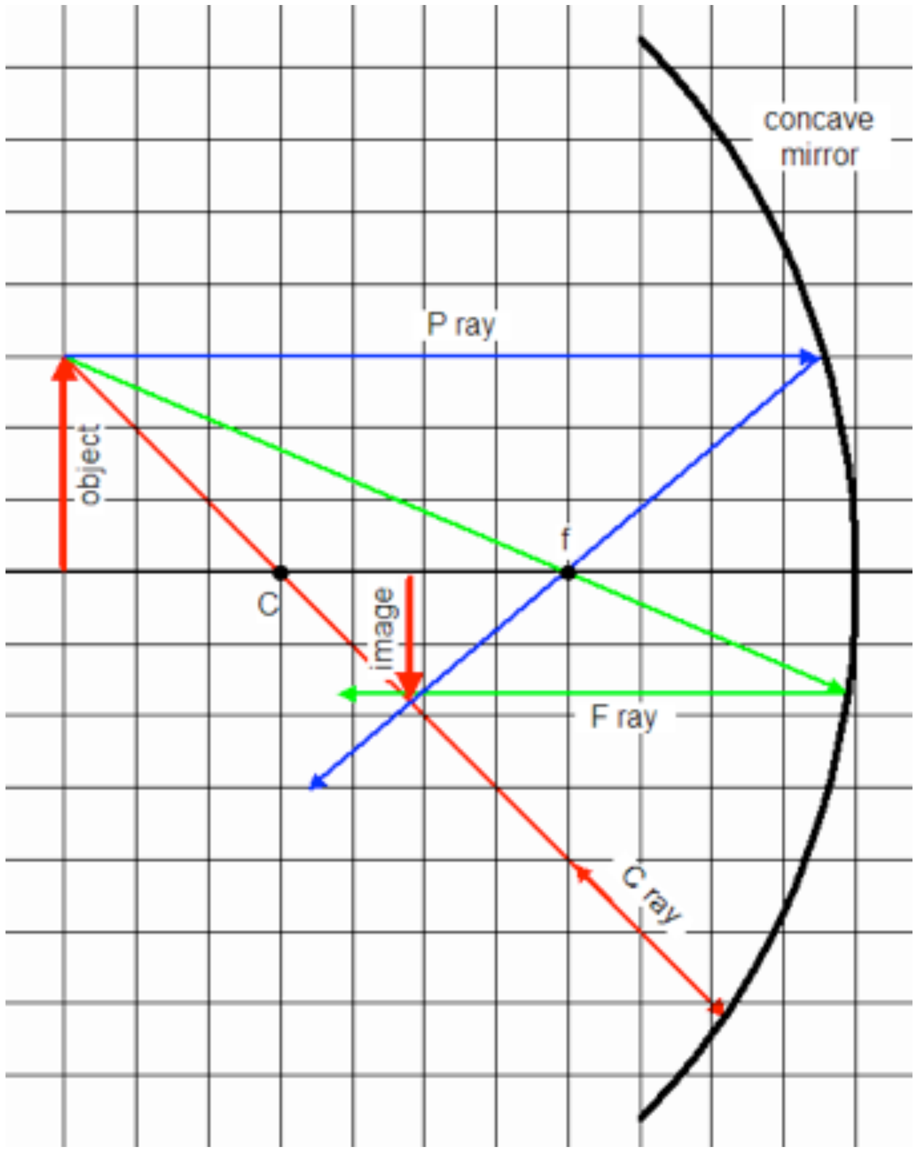
try it with a spoon..



Darrell suspected someone had once again slipped him a spoon with the concave side reversed.

Spherical mirror eqn.

Can derive from Fermat's principle:



$$\frac{1}{s} + \frac{1}{s'} = \frac{2}{R} = \frac{1}{f}$$

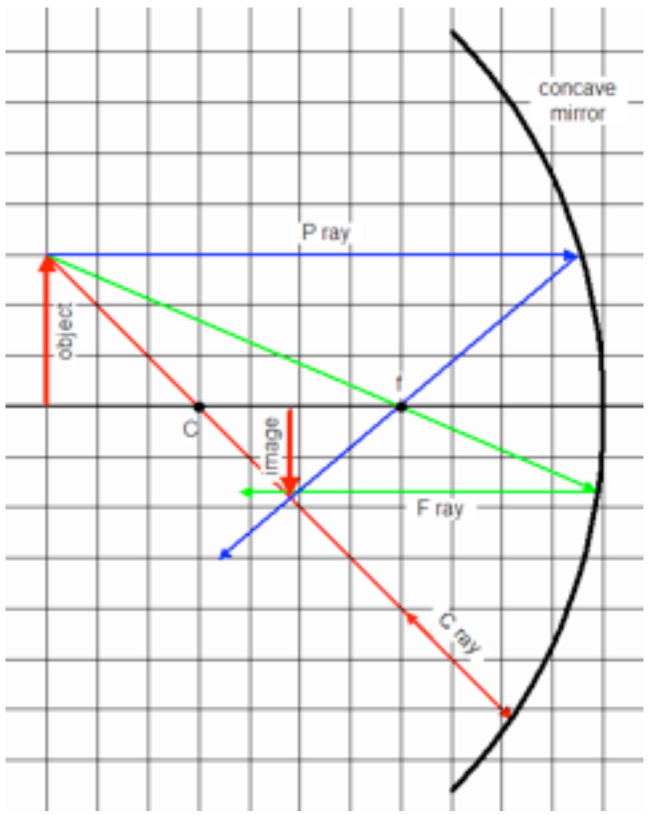
s = distance of object to mirror along axis.

s' = distance of image to mirror along axis. s'>0 if a real image, on same side of mirror as object. s'< 0 if virtual image, on the other side of mirror.

R = radius of sphere. Positive for concave mirror, and negative for convex mirror. Infinite for flat mirror.

f= focal length. Rays from s=infinity go here.

Concave* mirror



$$\frac{1}{s} + \frac{1}{s'} = \frac{2}{R} = \frac{1}{f} \overset{*}{>} 0$$

$s > f \rightarrow s' > 0$ real image

$s < f \rightarrow s' < 0$ virtual image

magnification: $m = \frac{y'}{y} = -\frac{s'}{s}$

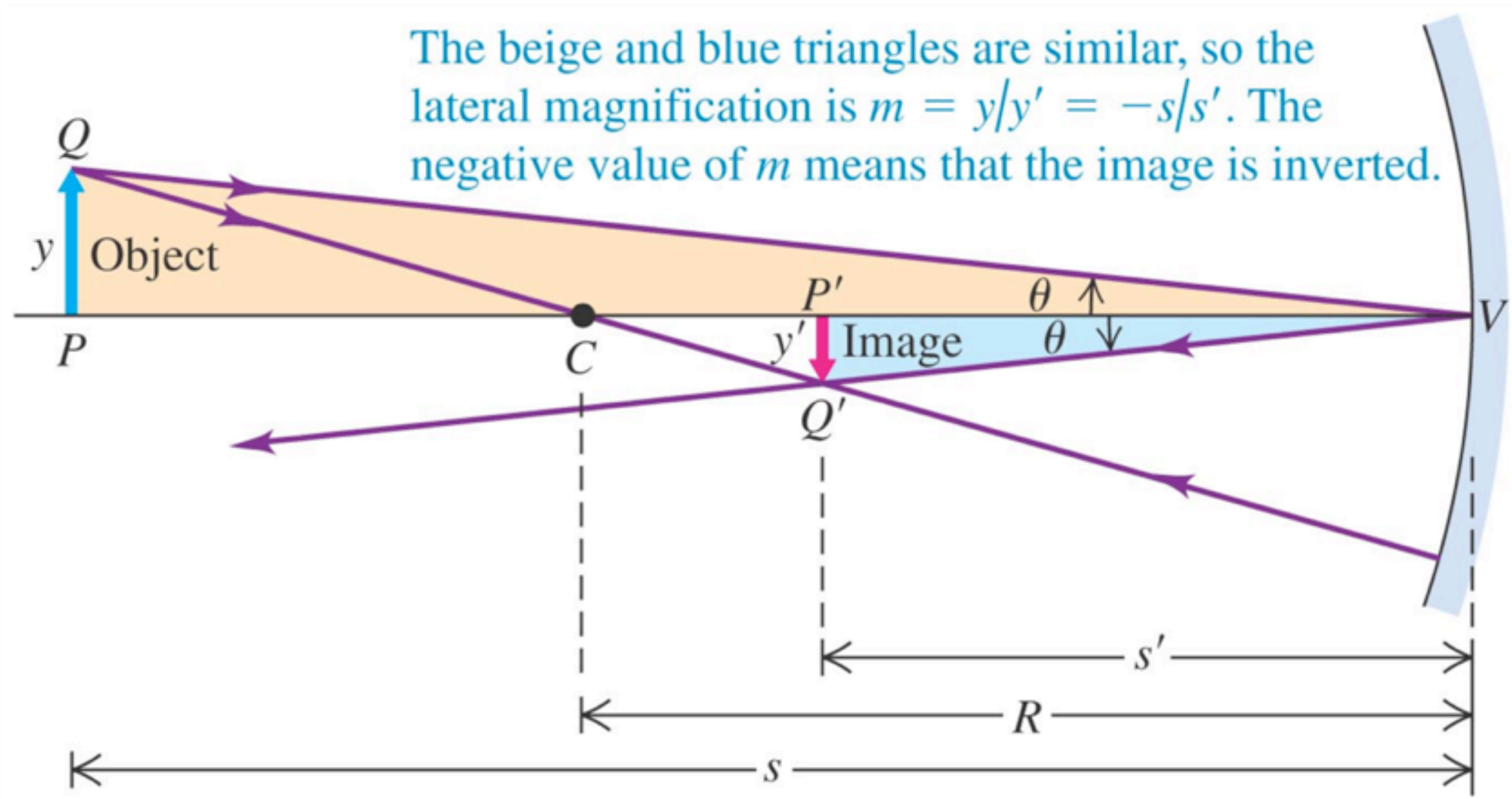
m>1: bigger, rightside up
0<m<1: smaller, rightside up.
m<0: upside down

E.g. plane mirror: infinite R, s'=-s, m=1.

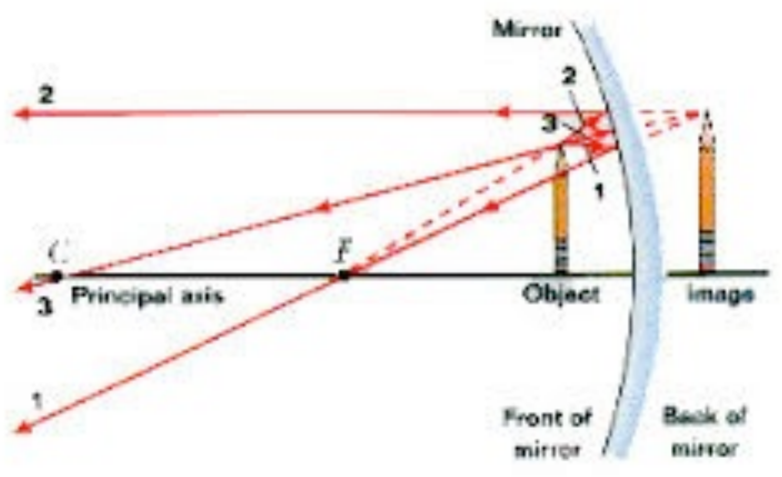
Can get upside down real image or rightside up virtual image.

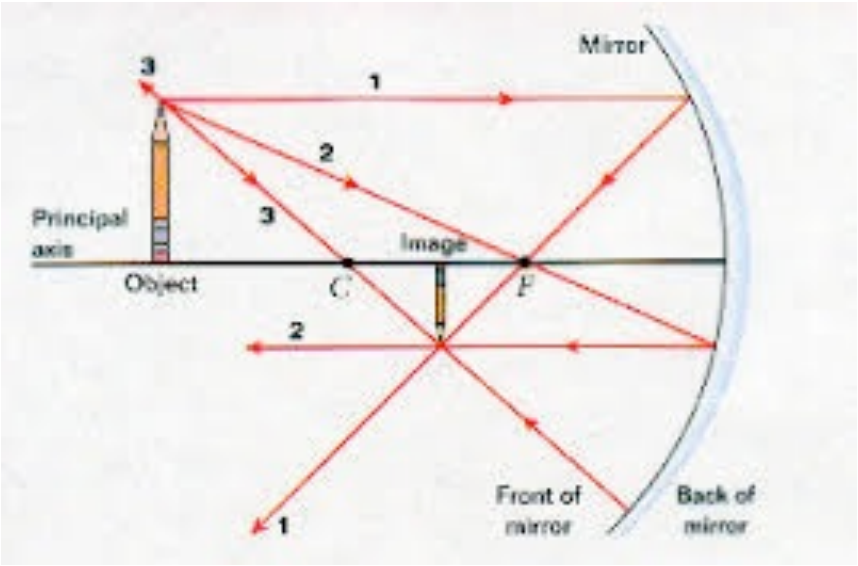
Image of an extended object

- Figure 34.14 below shows how to determine the position, orientation and height of the image.



Concave mirror, cont.



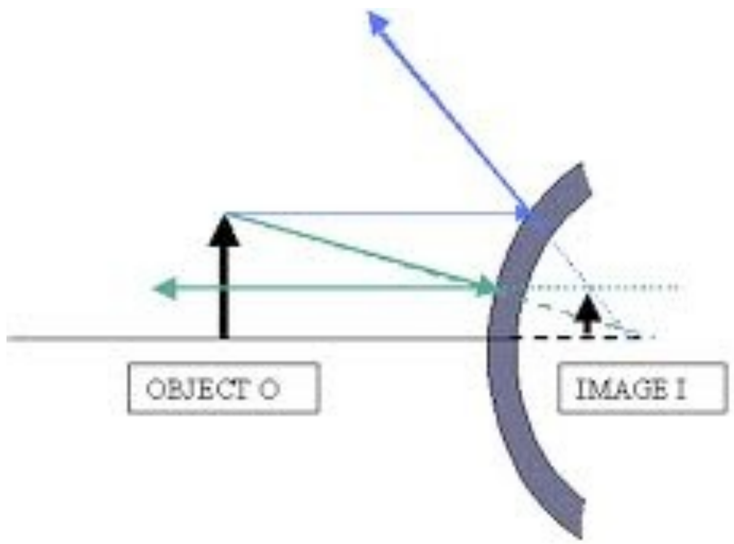


$s > f \rightarrow s' > 0$ real image

$s < f \rightarrow s' < 0$ virtual image

$$m = \frac{y'}{y} = -\frac{s'}{s}$$

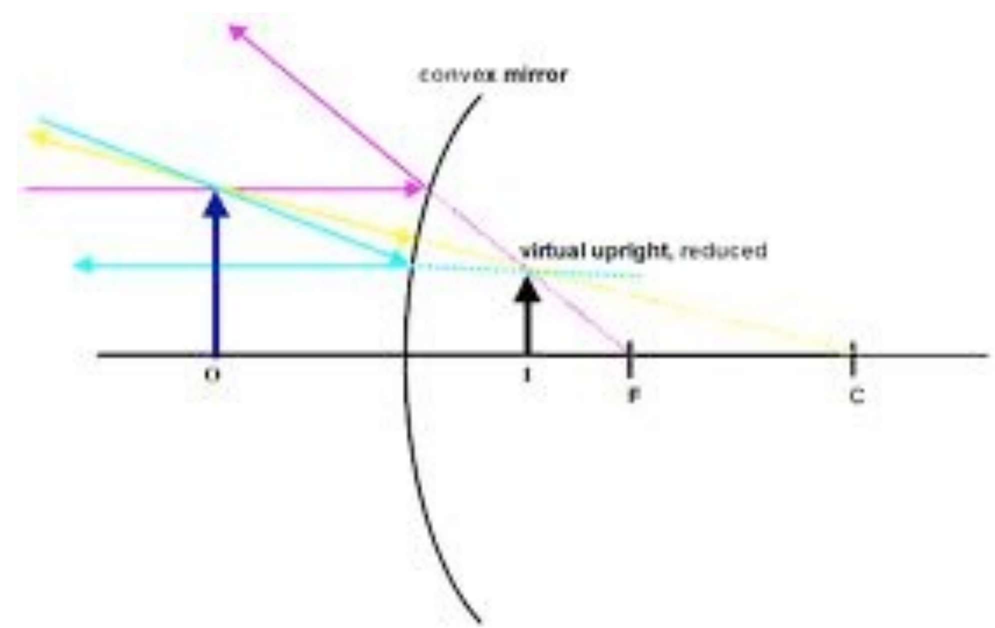
Convex* mirror



$$\frac{1}{s} + \frac{1}{s'} = \frac{2}{R} = \frac{1}{f} \overset{*}{<} 0$$

$$s' < 0 \qquad |s'| < s$$

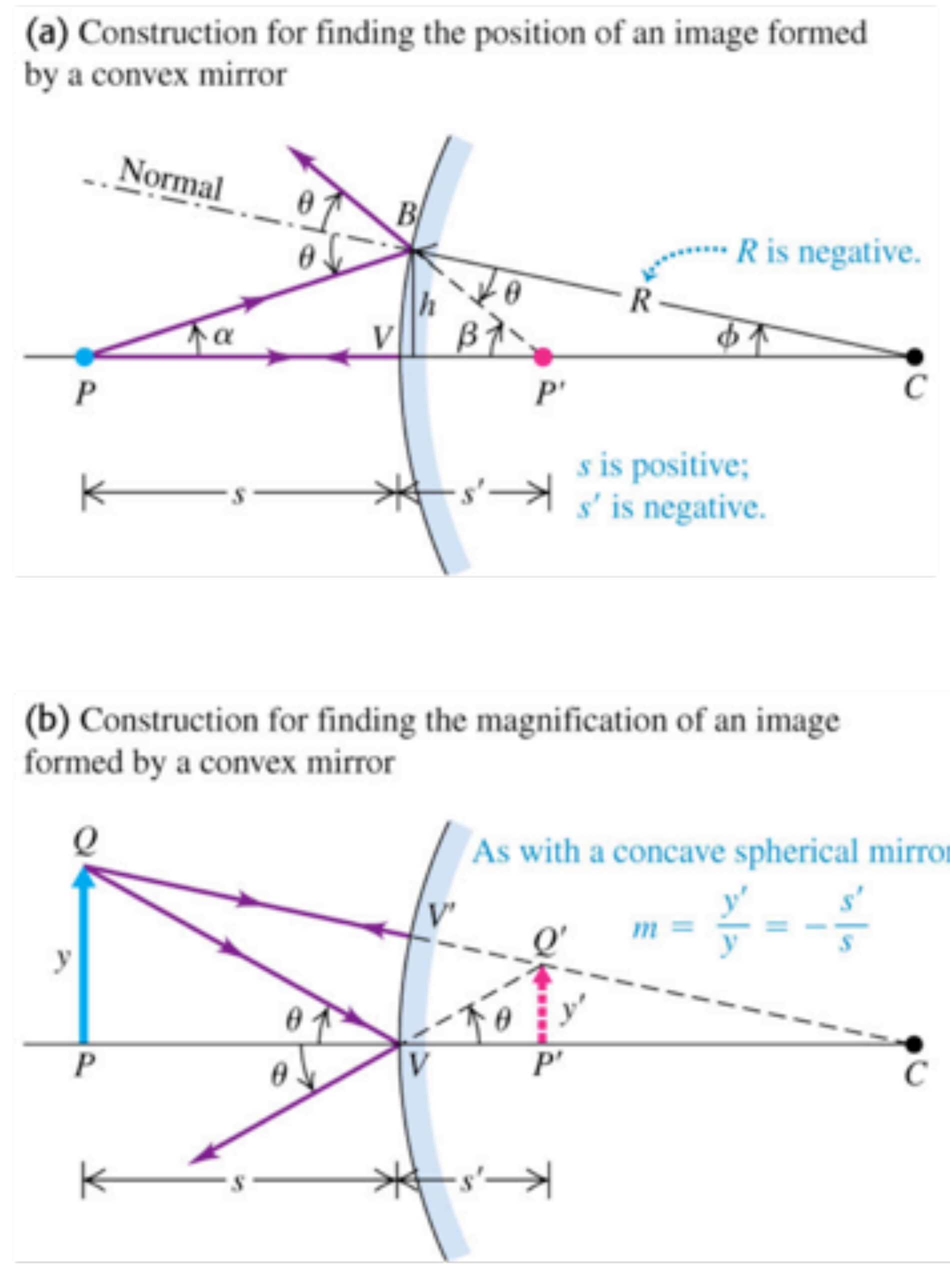
magnification: $m = \frac{y'}{y} = -\frac{s'}{s}$



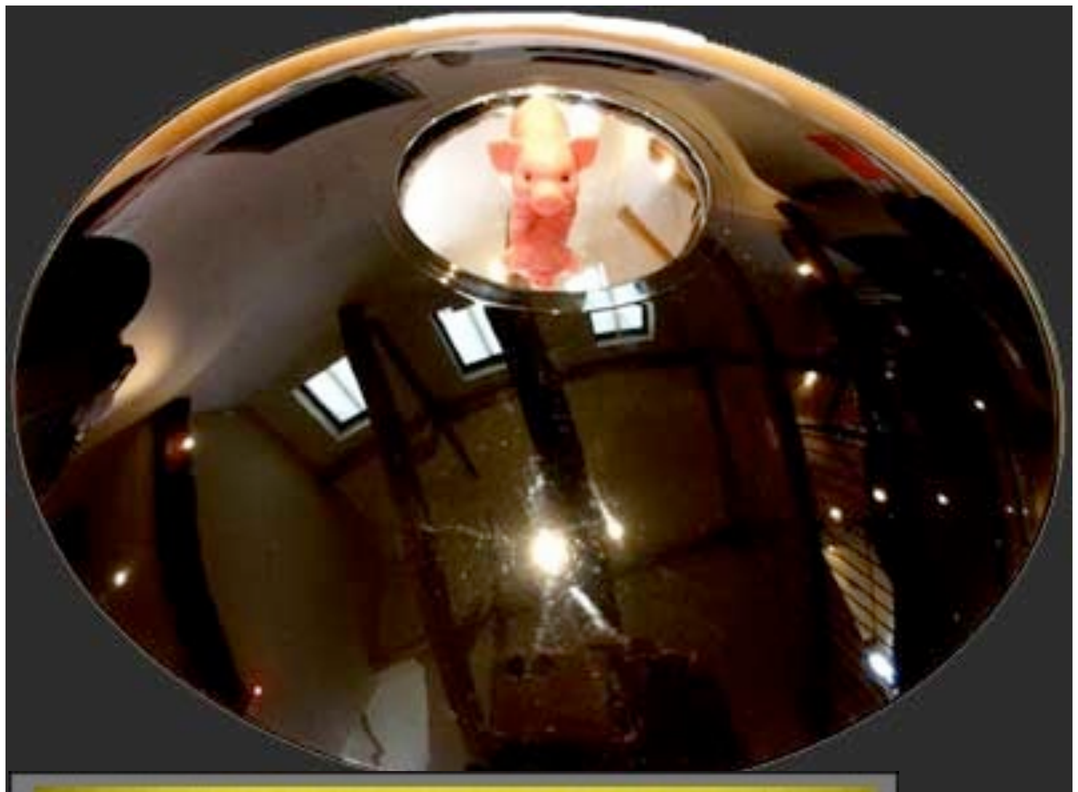
0<m<1: smaller, rightside up

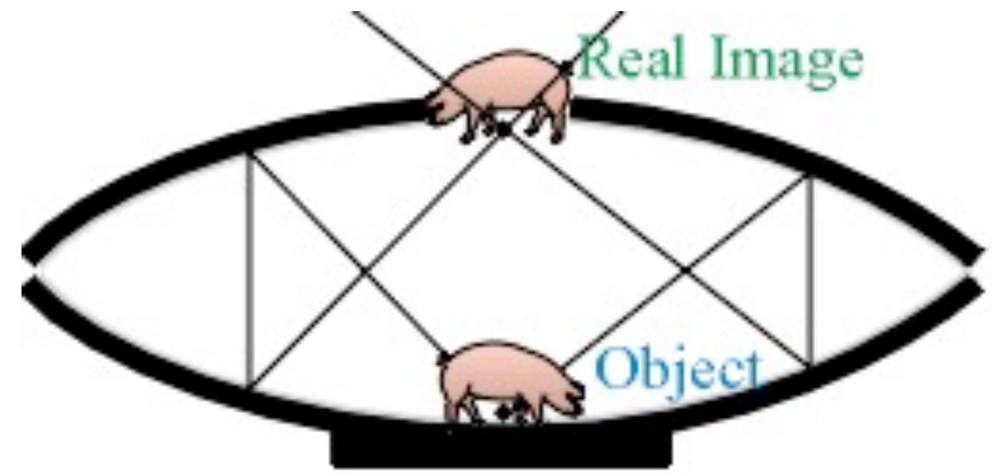
Image formation by a convex mirror

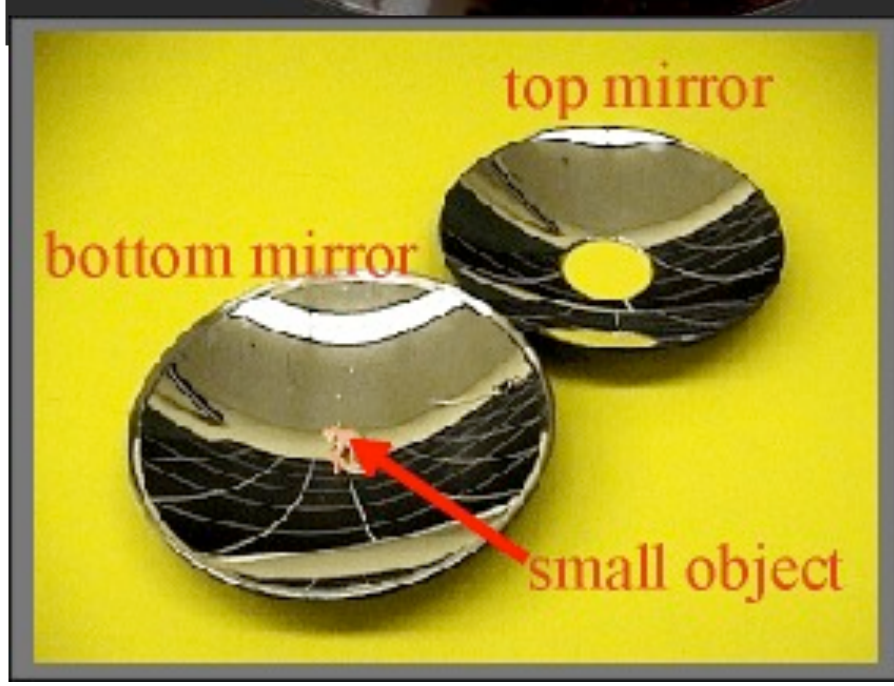
- Figure 34.16 (right) shows how to trace rays to locate the image formed by a convex mirror.



Mirage mirror demo



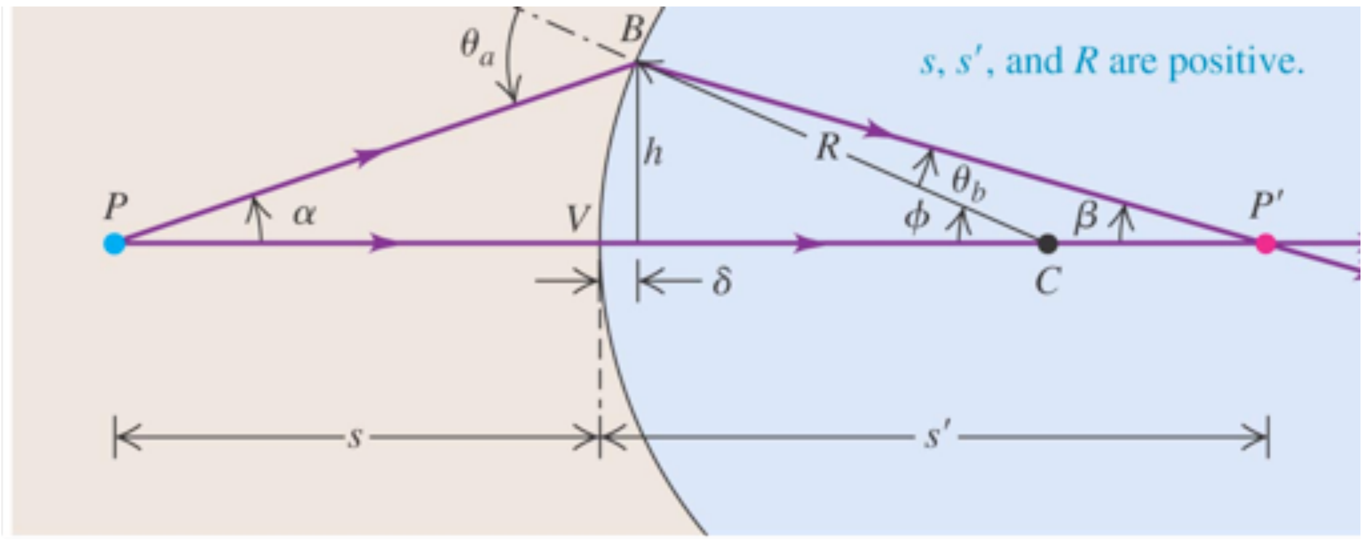




great gift for the holidays!

http://www.amazon.com/Mirage-3-D-Instant-Hologram-Maker/dp/B0002W3J7M

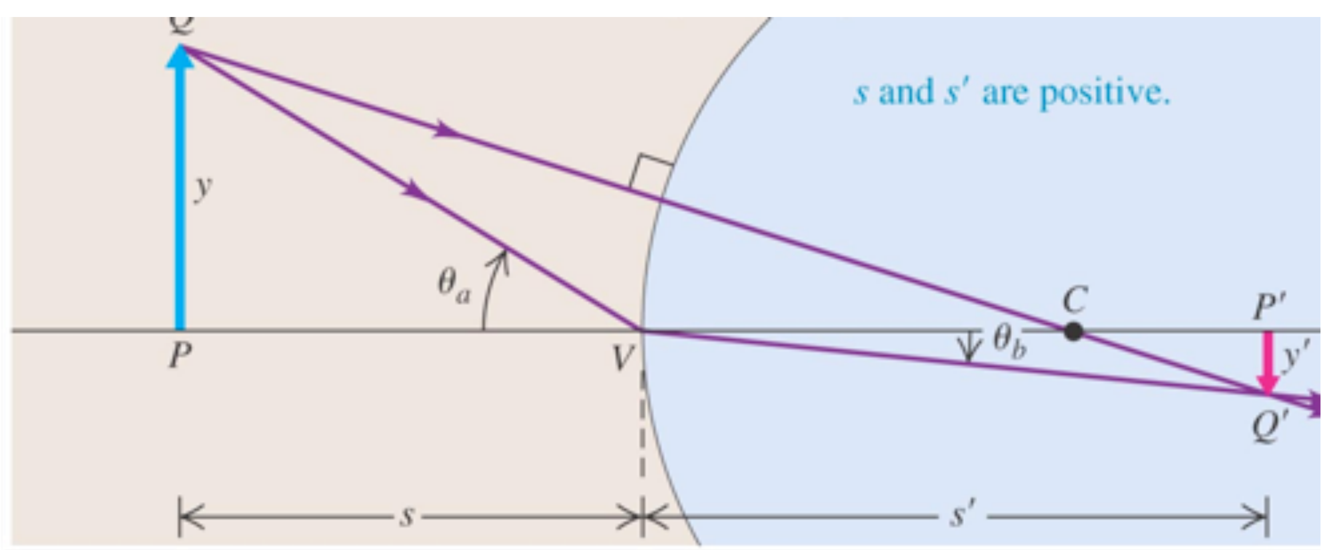
spherical refracting lens



$$\frac{n_1}{s} + \frac{n_2}{s'} = \frac{n_2 - n_1}{R} \equiv \frac{1}{f}$$

Again follows from Fermat principle:
all rays from object to image take same time.

Here R>0 means convex surface. General rule: R>0 if center on same sign as outgoing rays.



$$n_1 \sin\theta_a = n_2 \sin\theta_b$$

$$(n_1 \equiv n_a, \;\; n_2 \equiv n_b)$$

$$m = \frac{y'}{y} = \frac{-s' \tan\theta_b}{s \tan\theta_a} \approx -\frac{s' \sin\theta_b}{s \sin\theta_a} = -\frac{n_1 s'}{n_2 s}$$