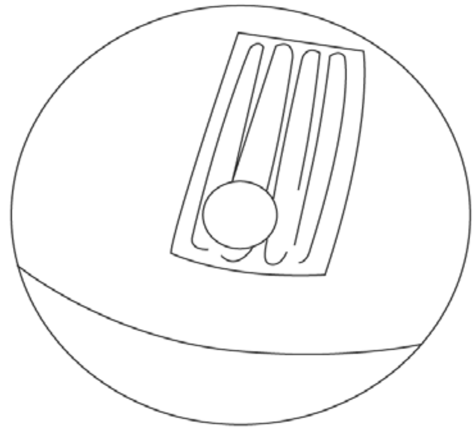
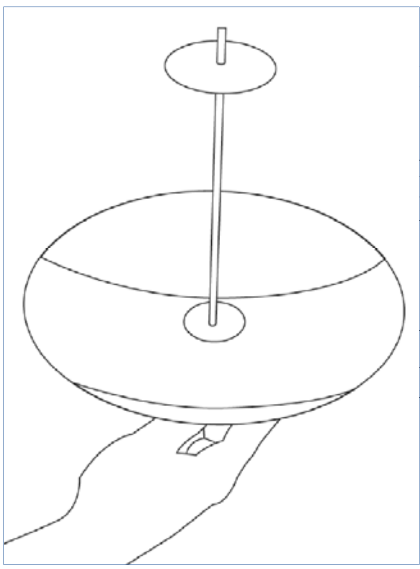
16285 Floating Images

Purpose:

Two concave reflectors with an assortment of stands and holders allow rea
in the context of focal length, image distance and object distance. A separa
reflectors in close proximity in order to display the familiar floating image
require only one reflector can run in parallel.



A concave mirror on a desktop will float a real image of the ceiling lights above the mirror. Try it! Locate the image.

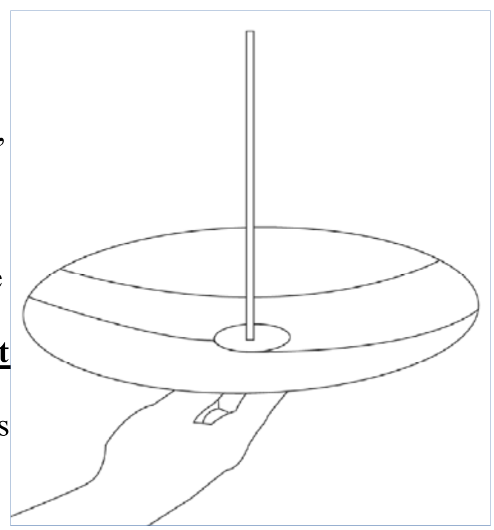


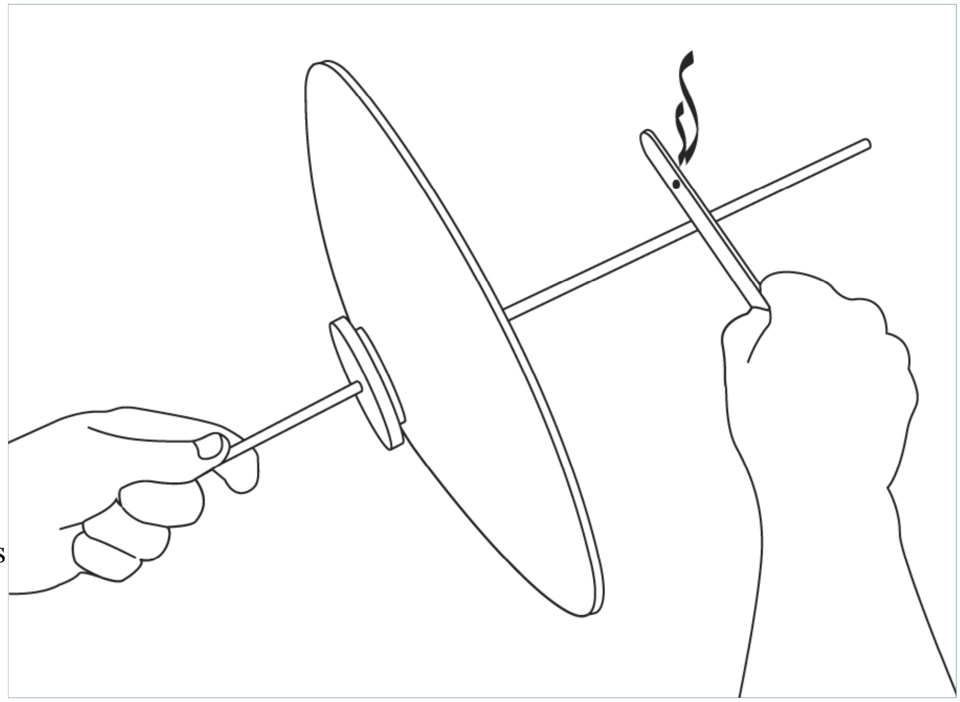
Early Explorations:

Assemble one mirror, one large and one small wood wheel as in the illustration. Pass the dowel through the hole in the mirror and firmly push the mirror onto the smaller wood wheel to secure it. Add a white cardboard wheel as in the illustration and then explore again the image of the ceiling light. By raising and lowering the assembly, find the place where the ceiling light is imaged on the underside of the cardboard wheel in the clearest way. Have a partner measure the distance from the bottom of the mirror to the ceiling light and from the bottom of the mirror to the cardboard wheel. Save this measurements for future calculations.

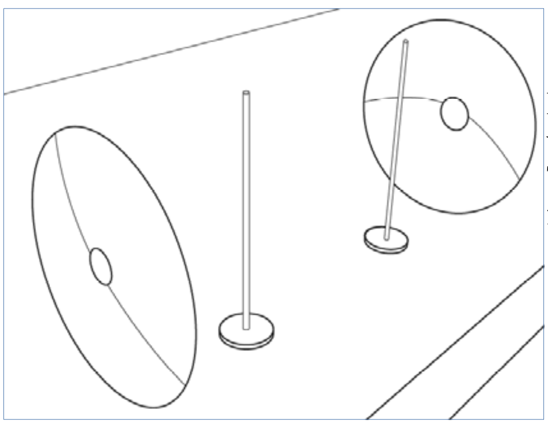
Finding the Focal Length:

Now it is time to find the focal length of the concave mirror. The handiest source of parallel rays would be the sun. So, on a sunny day, remove the paper wheel from the top of the dowel and take the remainder (the mirror, large wood wheel, small wood wheel and dowel, assembled as before) into the bright sunlight. Aim the dowel at the sun so that it casts no shadow. Use a Craft Stick (tongue depressor) to explore along the dowel for the position that gives the smallest image of the sun. Do this quickly because the image of the sun will scorch the stick. **Caution: Wear sun glasses, so not stare at the sun, do not stare at the solar image on the stick — it will be very bright! Do not try to form an image on a finger, let the sun scorch the stick.** It is actually safer to choose a day when the sun is partially obscured. In this case, the image will be of a sun-brightened patch of clouds and the image may not scorch the stick.

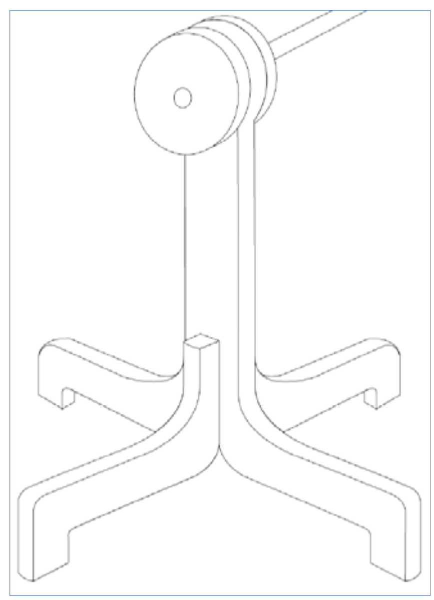




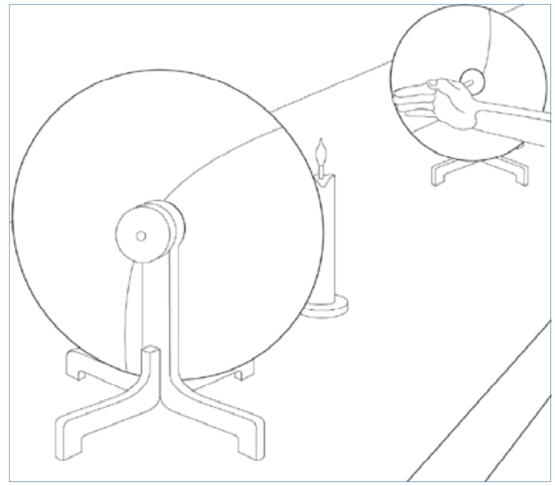
Make a mark on the dowel where the stick gave the smallest sharpest image. This is the **focal point**, a position on the principal axis (depicted by the dowel) where all rays parallel to the principal axis intersect. Measure and record the distance from this mark to the vertex of the mirror, approximately the position of the small wooden wheel inserted in the hole in the mirror. This distance is the **focal length** of the mirror, a constant that will have the same value for all subsequent investigations with that mirror. It will be useful to permanently mark the focal point on the dowel, or to reposition the dowel so that it protrudes exactly the focal length from the concave side of the mirror. This will facilitate subsequent set up and alignment.



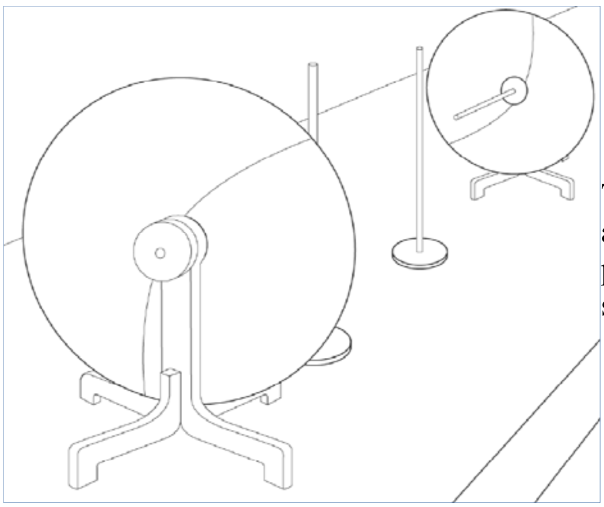
It will be useful to assemble two more sets each of a dowel and a wheel to serve as the position markers portrayed in this illustration. These will serve as needed to help align and position the components for the investigations that follow.



One long and one short stand leg are assembled as in the illustration. This stand is then sandwiched between two wooden wheels with a dowel run through the assembly. If the dowel is left to protrude exactly the amount of the focal length, then the set up will be most useful for supporting the mirrors for individual and combined investigations.



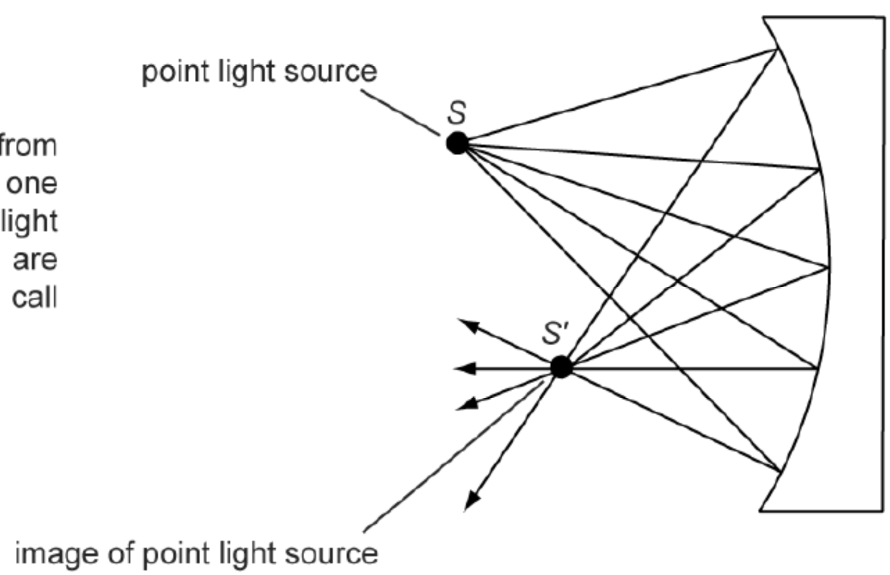
If the dowels on the stands are set for the focal length of the mirrors and the stands are aimed towards one another along the same line as in the illustration, then a candle (or burner or similar heat source) at one focal point is easily perceived by hand at the other focal point. This can be compared with the use of curved reflectors in various communications networks involving towers and satellites. This same arrangement of parabolic reflectors can be used to image the light from the candle or the sound of a lab burner. In the latter case, a stethoscope would be used at the other focal point as a receiver.



These illustrations are plentiful enough and large enough to offer a form of "clip art" that can be duplicated for instructional purposes and used to illustrate locally prepared materials and student reports that are based on the accompanying apparatus.

Point Light Source:

After reflection, all the light rays from a point light source intersect in one point, the image of the point light source. Only a few of these are easy to locate. These few are call **principal rays**



Principal Rays:

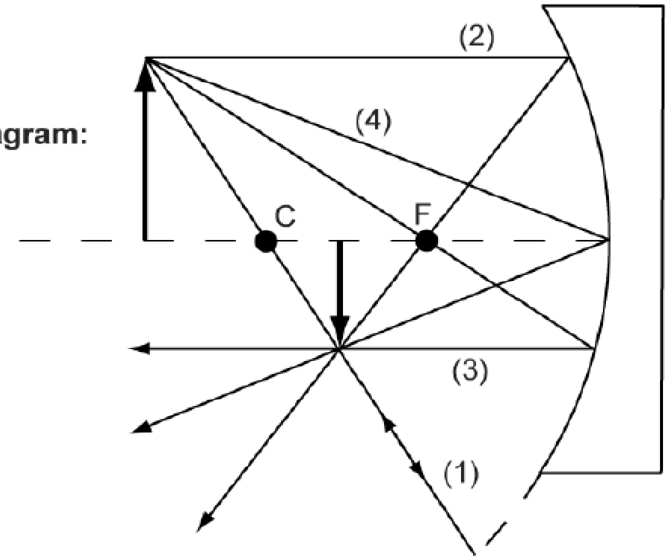
The position of the image of a point light source and the positions of the image plane corresponding to an object plane can be found graphically in a **ray diagram** by constructing the intersection of two or more **principal rays** passing through the light source

principal rays:

(1) a ray along the radius (i.e. through the center, C) reverses its path upon reflection
(2) a ray parallel to the axis passes through the focal point after reflection
(3) a ray through the focal point is reflected parallel to the axis
(4) a ray incident at the center of the mirror makes the same angle with the axis after reflection

Objects and images are represented by half arrows drawn perpendicular to the axis. Therefore only one point needs to be imaged.

ray diagram:

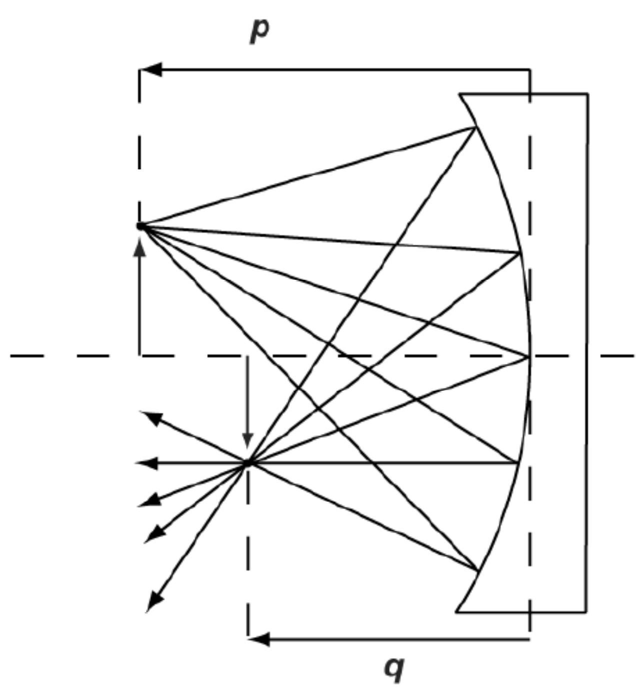


Light rays will always be shown as coming from the left

Mirror Equation:

When the object distance, *p*, image distance, *q*, and focal length, *f*, are defined as outlined they are related through the following, very important, **mirror equation**

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

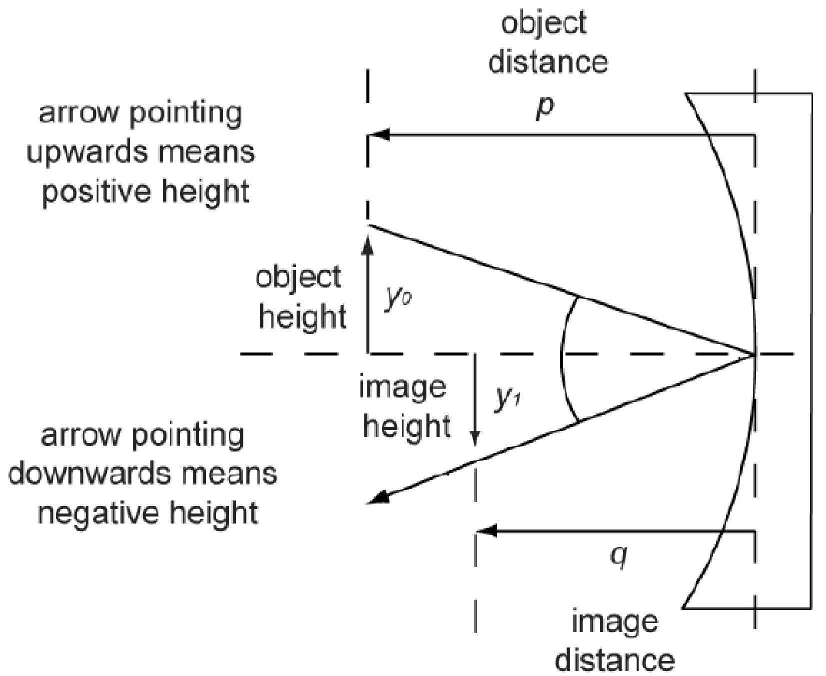


Where:
- **f**= focal length (distance)
- **p**= object distance
- **q**= image distance

Calculations of M:

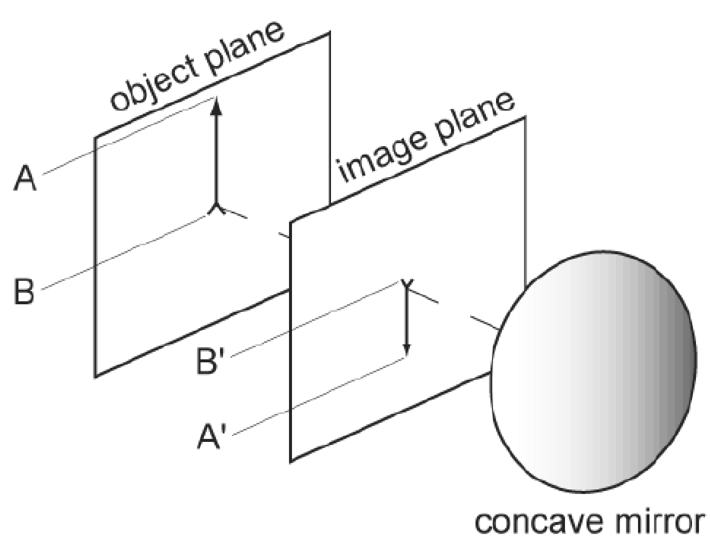
The factor ***m*** by which the image is larger than the object is called the linear magnification or transverse magnification of the imaging process.
Consider an object of arbitrary size y_0, represented diagram by an arrow of length $|y_0|$ and direction sign (y_0) (arrow points upwards means y_0 is positive, arrow pointing downwards means negative y_0)
Construct its image

$$m = \frac{y_1}{y_0} = -\frac{q}{p}$$

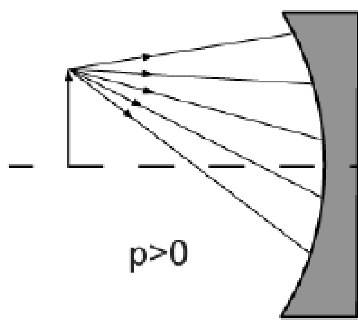
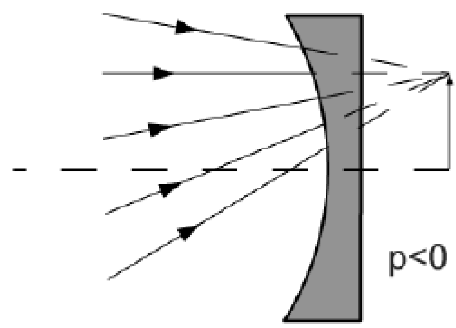
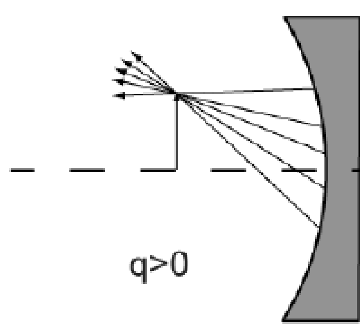
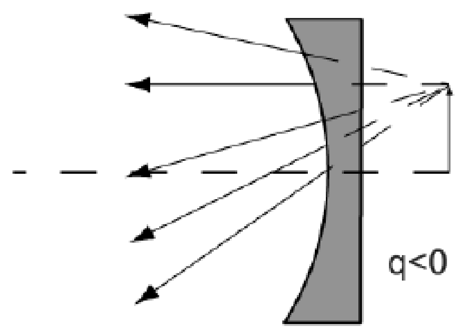


Extended Light Source:

Light distribution in a plane normal to the optical axis, the object plane, is the light source. Every point (e.g. A, B) in the **object plane** acts like a point light source.
The images of all those point light sources (A', B') lie in another plane normal to the optical axis, the **image plane.**
The light distribution in the image plane is a stretched copy of the light distribution in the object plane.



Real and Virtual Objects and Images:

	real: light rays actually intersect; positive object/image distance	**virtual**: light rays do not intersect, but their continuations do; negative object/image distance
object: at intersection of incident *light* rays		
image: at intersection of *reflected* light rays		

The geometric procedure for locating the image produced by a spherical mirror is straightforward. As you read these steps, follow along with the aid of Fig. 1.

(A) Select an appropriate scale and mark the position of the object and the mirror on the optical axis, as shown.
(B) Draw a line MM' through the center of the mirror and perpendicular to the optical axis.
(C) Mark the focal point F of the mirror at f=R/2 on the optical axis and locate the object on the axis , all to the same scale.
(D) Draw the following rays to locate the image. Any two of these reflected rays are sufficient to locate the image position at their intersection, but you should always draw the third ray as a check.

1. Ray 1 is drawn from the object through the center of curvature. It reflects back along itself upon striking the mirror.
2. Ray 2 is drawn parallel to the optical axis from the object to the mirror (MM'), where it is reflected through the focal point of a concave mirror.
3. Ray 3 is drawn from the object to the mirror (MM') along a path through or toward the focal point and is reflected parallel to the optical axis.

(E) IF the reflected rays converge on the same side as the incident light, the image is real and is located at the intersection of these three rays. If the reflected rays diverge, the image is virtual and is located where these three rays appear to originate. You can measure the position and image height directly from the scale drawing.

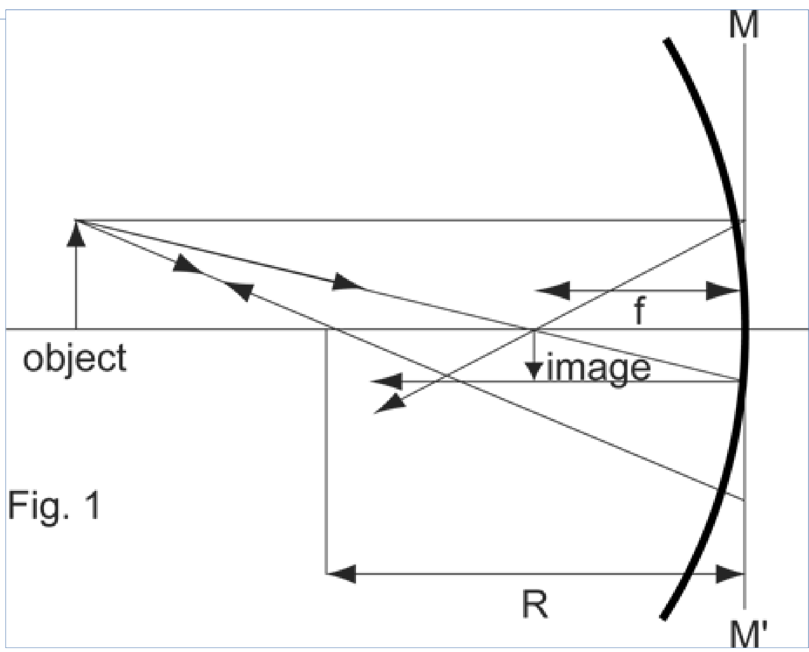
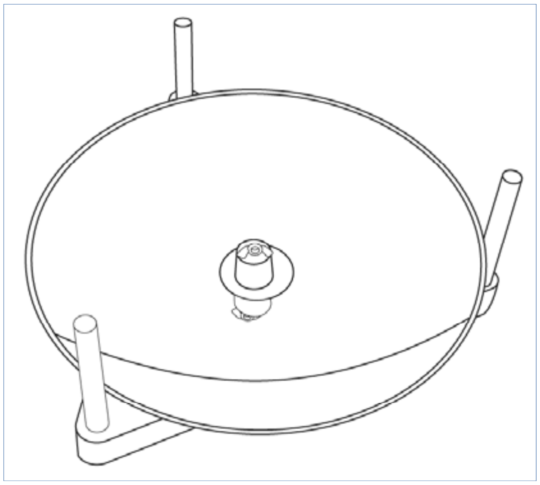
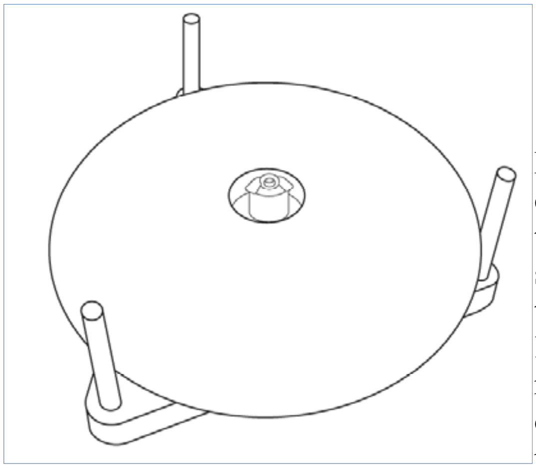


Fig. 1

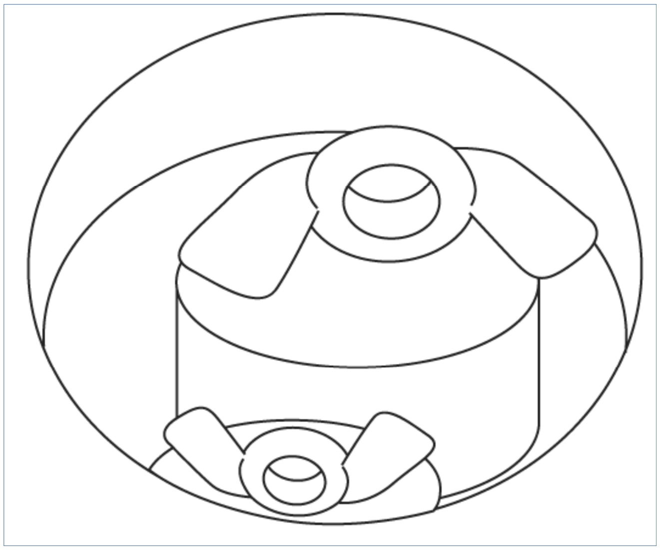
Another Floating Image:



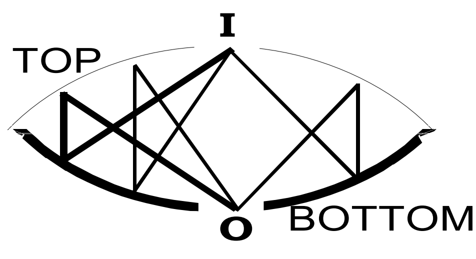
The interplay of object and real image becomes very interesting as the two mirrors are brought together until they touch. Here we will see that the holes in the center of the mirrors have another purpose besides enabling an easy vertical mounting. Place the triangular platform on a level surface with the longer part of the dowels facing upward. Set one of the mirrors between the dowels with its concave side upward. Place the rubber stopper in the center hole and the wingnut on the stopper.



Place the second mirror between the dowels, this time with the concave side down. Notice that a real image is formed sticking up through the hole in the second mirror. How much of that image one sees depends on the viewing angle. All of the useful rays must come to the observer's eye through the hole, so the observed image will be limited by the hole boundary. Notice the orientation of the image with respect to the wingnut object. It is instructive to shine a laser pointer down through the hole and watch what happens to the image as the pointer scans the object.



Notice the orientation of the real image of the wingnut. Object is below the real image in this view.



RAY DIAGRAM FOR THE CONFOCAL REFLECTORS

Light shines through the hole in the upper mirror to illuminate the object. Light from the **Object** is reflected from the top mirror vertically downward to strike the bottom mirror, which reflects and focuses it to form a real **Image**. Typical rays are shown from a point on **O** to the corresponding point on **I**.

Time Allocation:

To prepare this product for an experimental trial should take less than twenty minutes. Actual experiments will vary with needs of students and the method of instruction, but logical segments of this string of demonstrations and laboratory activities are easily concluded within one class period.

Feedback:

If you have a question, a comment, or a suggestion that would improve this product, you may call our toll free number.