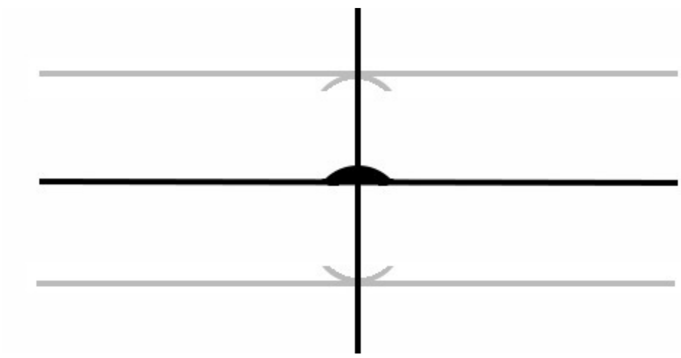
# Spherical mirrors

*Shannon and Ian Jacobs*

A large magnifying glass comes with two spherical mirrors. A convex mirror on top and a concave one below. The mirrors are not silvered but each air/glass interface reflects about 4% of the light it receives: more than enough to make bright images when the object is a ceiling light.

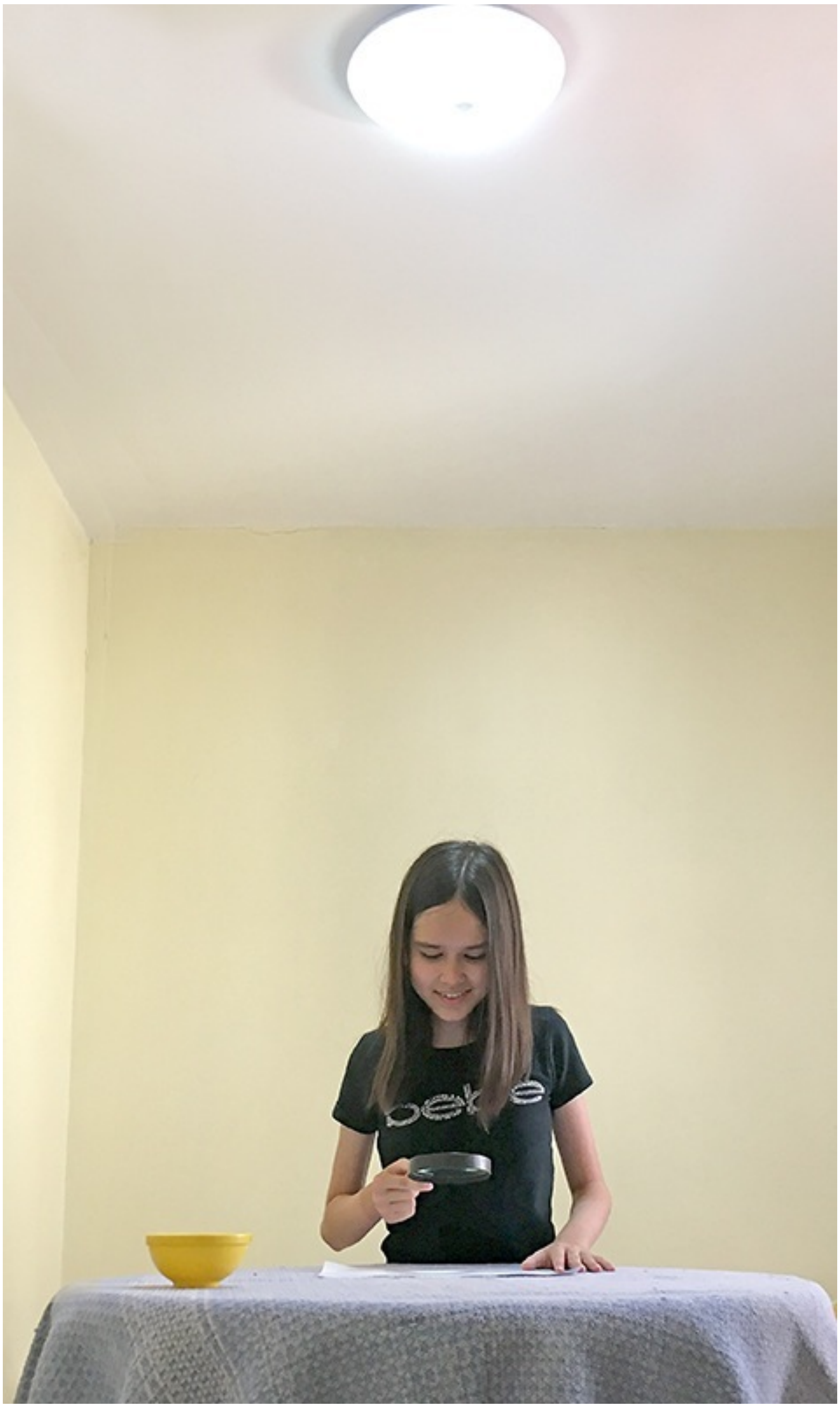
A large magnifying glass (biconvex lens).



We have separated the functions of the glass into there parts.

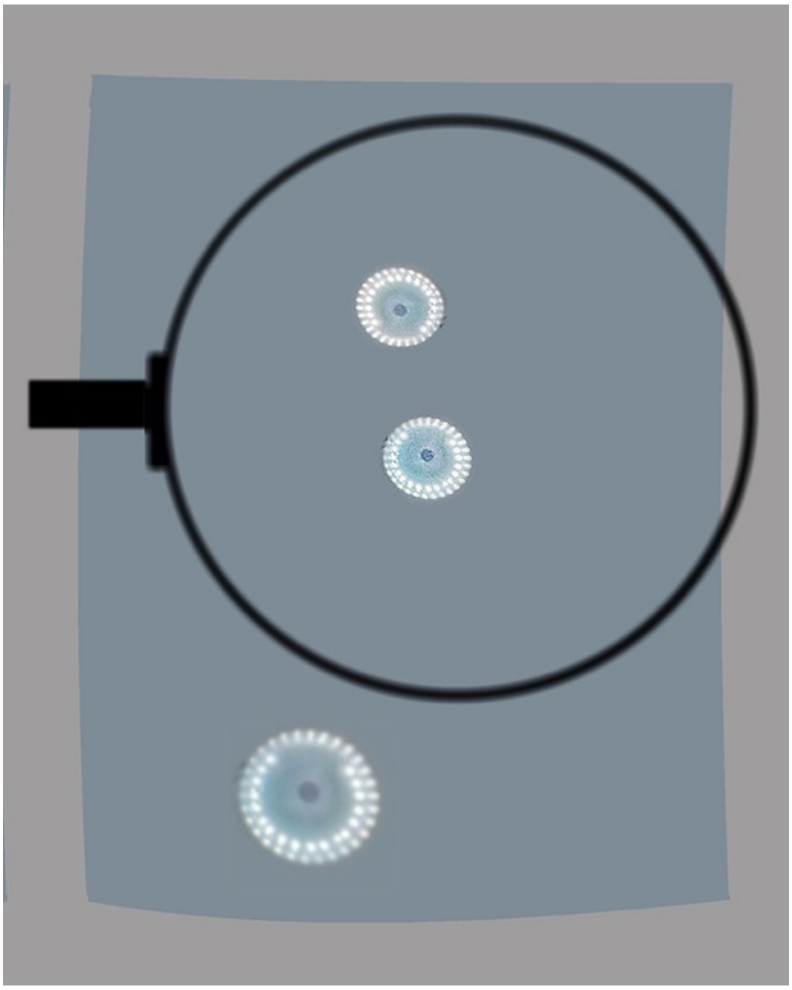
The upper spherical surface is a convex mirror. The upper glass surface is a convex lens.The lower glass surface is a concave mirror. The mirror lines and symbols are made pale because they reflect only 4% of the incident light and allow 96% to pass through.

Two refections of a ceiling light are seen in a large magnifying glass when it is used as a mirror.



The lens should be large so that both reflected images can be viewed with both eyes at the same time. It’s not possible to focus on both images at the same time: very curious.

Three images can be found.

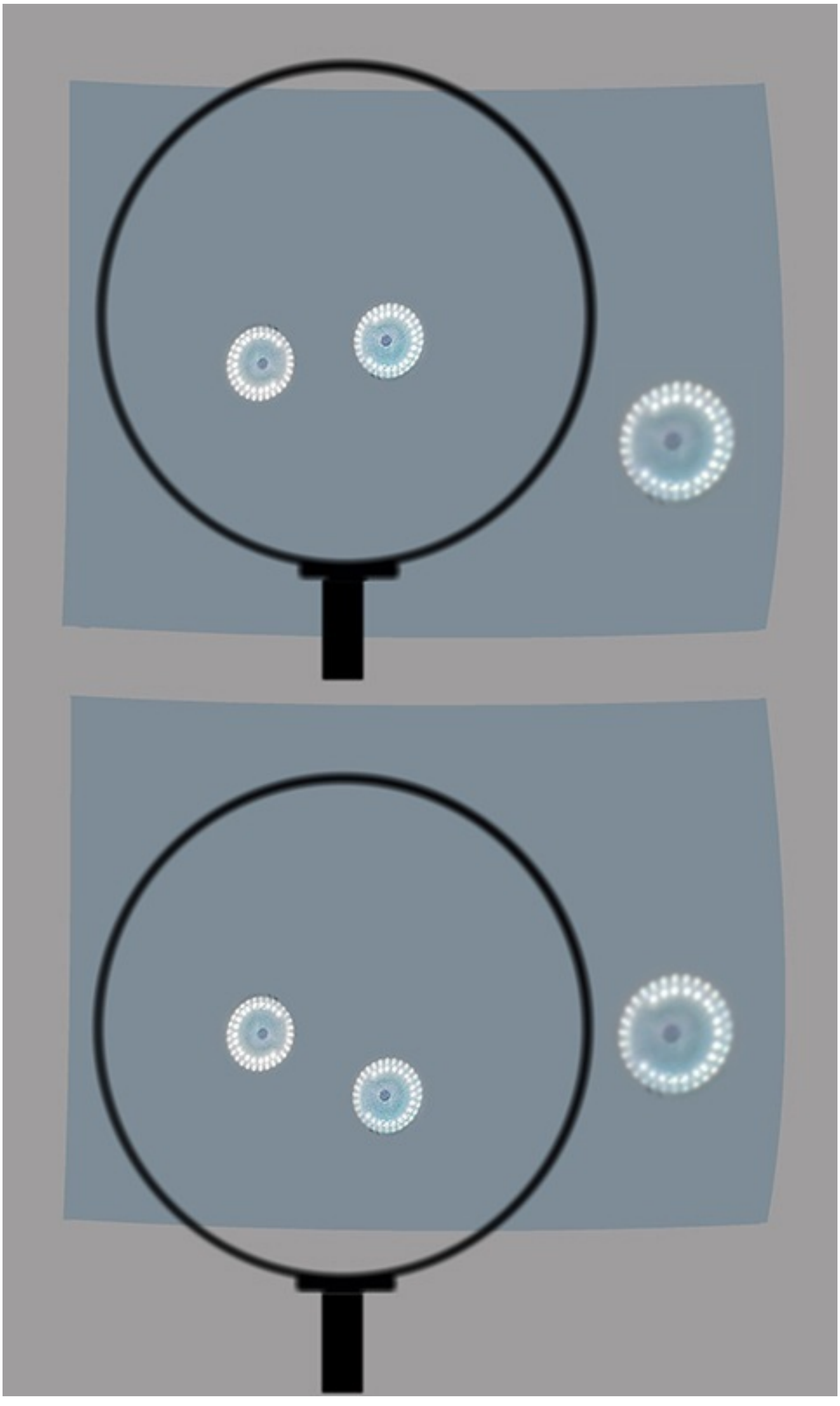


The image formed by refraction is on the paper below the lens, slightly blurred, and the largest of the three.

The two reflections in the glass move through each other as the lens is tilted back and forth. One is rotated by 180° when compared to the image on the paper below. They are the same size in the illustration, but the relative size you see will vary depending on several factors, including how close your head is to the lens, because one of the images is above the lens and the other is below it.

*Use both eyes*. Look at each reflection in turn and think about where they are. Point to each image with a pencil point. You will find you can locate the image above the lens to within about a mm. If you can't do that right away, try again. Allow time for your brain the catch on to what you want to do.

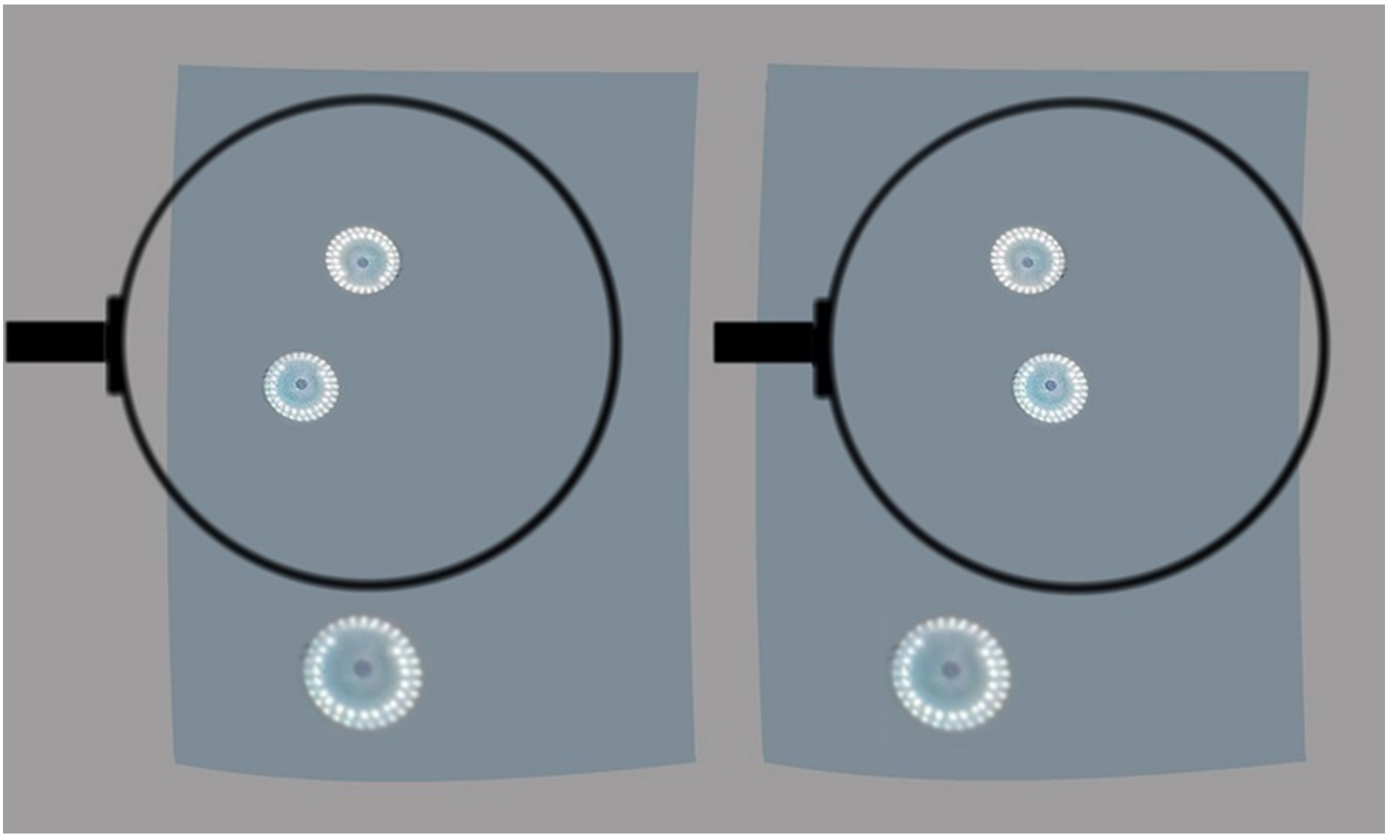
**A cross view stereo pair**



See the next page for help with viewing as a 3D image.

## Cross view 3D

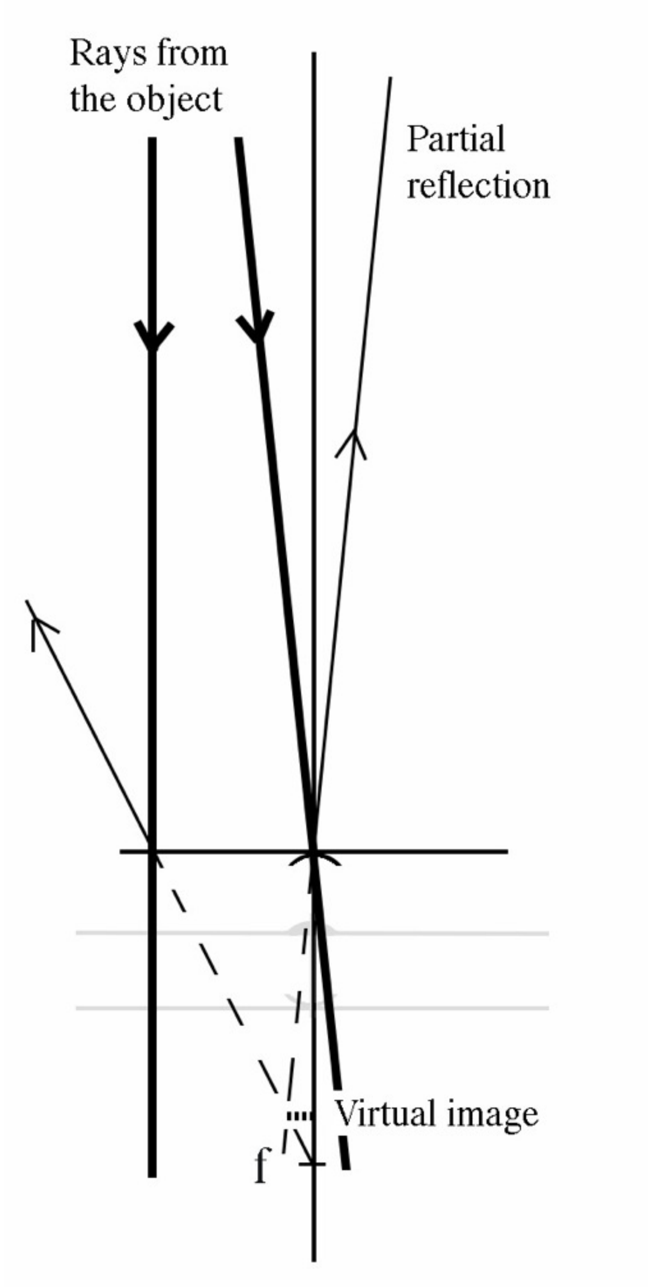
If you are on a phone or a tablet download the pdf and use landscape view to make the stereo pair image on the previous page as large as possible. If you are working on a larger monitor use the image below.



Look at the side-by-side image pair in the middle and cross your eyes until you see three blurred rectangular images in a line. Pay attention to the blurred rectangle in the middle and wait for your brain to refocus your eyes. Pay attention to the black ring. It might take up to ten seconds if you haven't done this before. When you get it to work the central image will come into sharp focus in 3D. If that doesn't happen, look away for a minute and try again. *Trust me*: 199 out of 200 kids can do this: *and it's really cool when it happens*.

When you have the 3D view in focus, carefully shift your gaze to look around the image. *Yes you can*. The largest image is down on the paper. Shift your gaze to look at the image in the centre of the ring. It is floating high above it. Now look at the other reflection that hangs in space below the ring and above the paper. Look back at the high reflection. *Your brain thinks it's closer and makes it smaller*!

**The image below the glass**

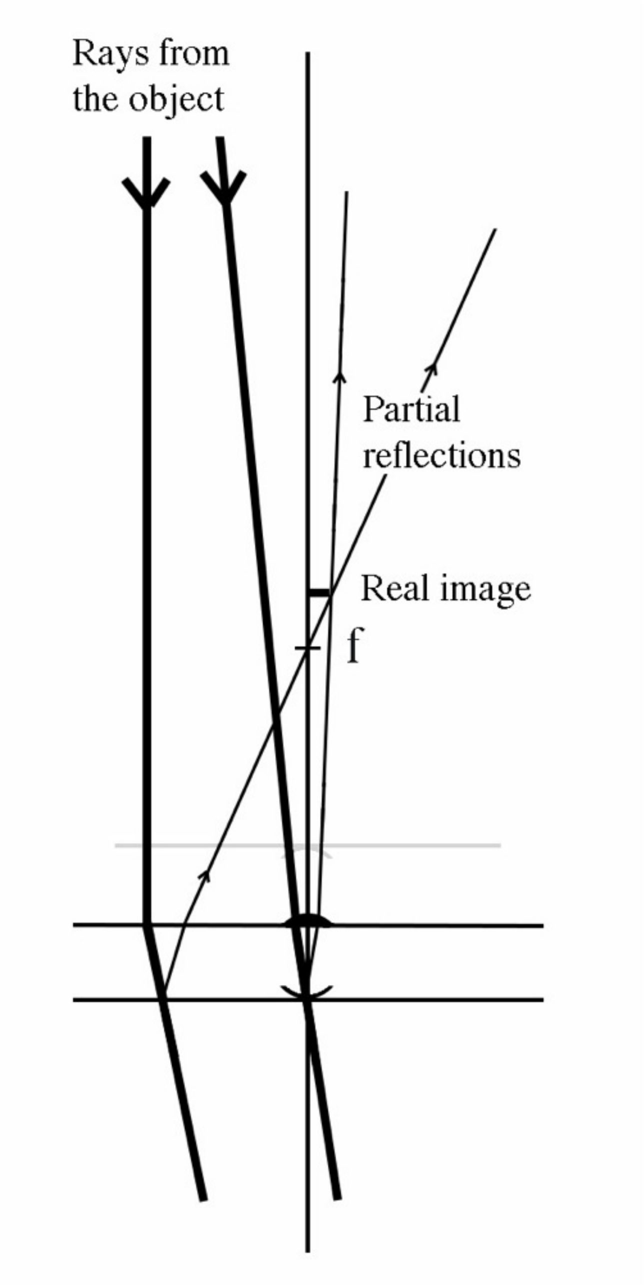



This image is formed by the top convex glass mirror so the two lower components have been made pale on the diagram.

Just 4% of light from the edge of the ceiling light that's parallel to the axis is reflected away to the left as though it came from a point on the axis labelled *f* (the focal point of the mirror) and 4% of a ray from the same place on the object to the centre reflects at the same angle.

From high above, the reflected rays appear to have come from a *virtual image* above the focal point, which is below the glass.

## The image above the glass




The top surface mirror has been made pale on the ray diagram.

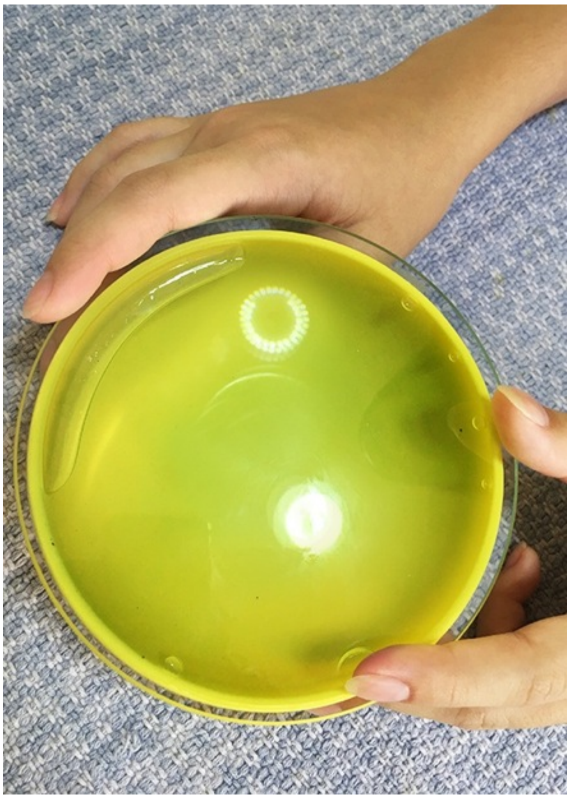
Most (96%) of an outer ray parallel to the axis passes into the glass and bends towards the axis. Just 4% of that is reflected from the concave mirror and is bent again as it leaves the upper surface to pass through *f*, the combined focal point of the lens and lower mirror. A ray from the same place to the centre bends and reflects as shown.

From high above the lens the rays appear to have come from a real image above the focal point.

**A demonstration**

Putting the lower glass surface in water reduces the reflection from the concave mirror to about 1%. The change affects only the intensity of the upper image in the photographs below, not their size or position.

The bowl is full to the brim with water. Two intense reflections are seen on the left when the lens is held above the water.

Putting the lens on the bowl to immerse the lower glass surface in water dramatically reduces the intensity of one image, without affecting the intensity of the other or the size and position of either.

*When doing this for yourself you'll be able to confirm that the affected image is the back reflection (the one floating in space above the lens) with your natural ability to locate images in space.*

Note: the stereo pair was made by replacing overexposed parts of real stereo images taken with a camera moved left and then right.