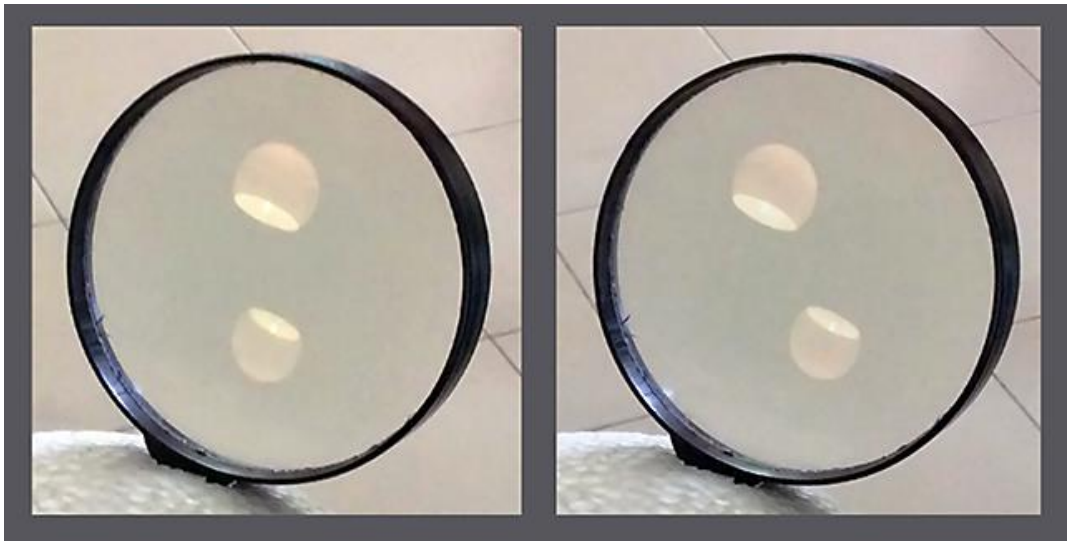
Conceptual questions

Mirrors and lenses

1 Two images of a lamp that hangs from a ceiling are seen reflected in a symmetrical biconvex lens.



The illustration is a cross-view stereo pair. To view in 3D, cross your eyes so that you see three blurred images in a line. Pay attention to the central image. Give your brain time to refocus your eyes. When the central image becomes sharp you will looking at the black ring and the two reflections in 3D. A larger image is on the web here … https://www.flickr.com/photos/jacobs_ian/37129020830/in/dateposted-public/

The lens is circular and was photographed at an angle. The upper reflection is upright and behind the lens. The lower reflection is in front of the lens (floating out from the monitor). *The upper image is thought by a student to be formed by partial reflection from the front surface of the glass and the lower image by partial reflection from the back surface.*

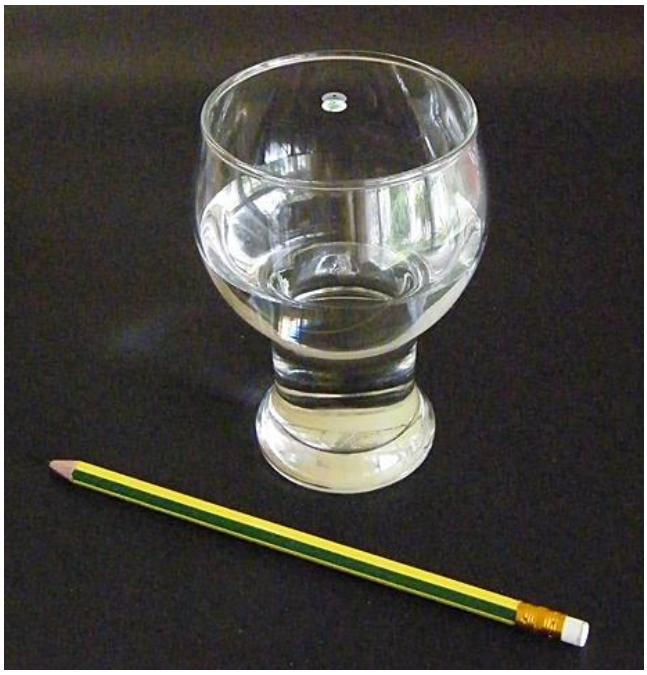
a Outline as many observations as you can to confirm these assignments.

b What changes (if any) would be seen if the lower surface of the lens had been immersed in water?

c The distance from the lens to the upper image is measured by the method of no parallax to be 15 cm. Explain the meaning of "*no parallax*", and how to apply that method in this case. Write down the radius of curvature of the glass.

d Find an approximate focal length for the lens if the refractive index of the glass is 1.5, and estimate the distance from the lens to the near image.

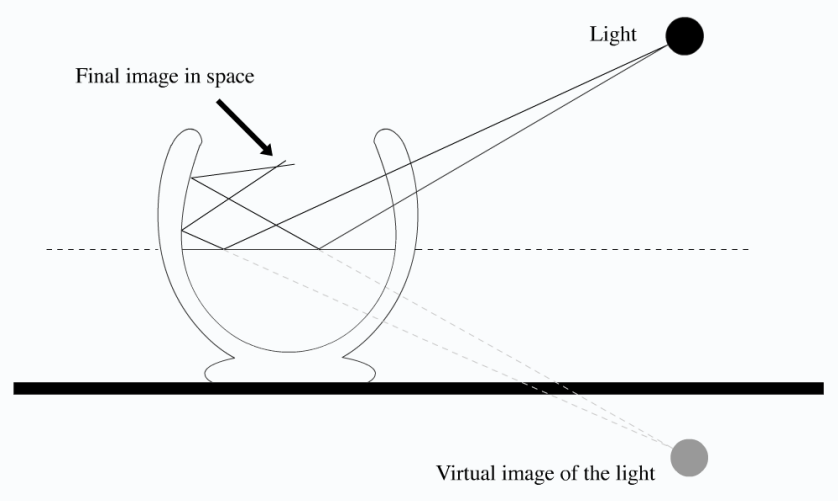
2 A glass that is half full of water rests on a table under a ceiling light. The light is above and a little behind the photographer.



a Why are reflections more easily seen if the glass is placed on a dark surface and what might the pencil be for?

b Why is the reflection of the ceiling light double?

c Complete the ray diagram to show how the less bright image of the pair is formed.



A stereo pair of similar images is here for those who can cross-view …
https://www.flickr.com/photos/jacobs_ian/6919422603/in/photostream

3 On a quiet afternoon we decided to amuse the children by putting ‘eyes’ in a leaf. We punched little holes and in the leaf and filled them with drops of water.

The figure shows the leaf with detail in the inset.

a Sketch what you believe to be the shape of the water lens.

b Sketching a ray diagram and describe both the object and the image.

c Holes have now been made close to the centre of the leaf. The ‘pupils’ have been enlarged. How could that have been most easily done?

d Moving the head to the side rolls the eyes but all the eyes appear not to follow you but to look away. Explain why.

4 The image below shows to reflections of a ceiling light in two identical lenses.

Large real images are 10 cm above each lens and smaller virtual images are below.

a Describe in general terms the curvature of the lens surfaces.

b Write down an estimate of the radius of curvature of the upper surface.

c Estimate the focal length if the lenses are *symmetrical* and made of glass (refractive index 1.50). *Show your working* and write down the power of the lens.

e In a word: what eye defect would these spectacles correct?

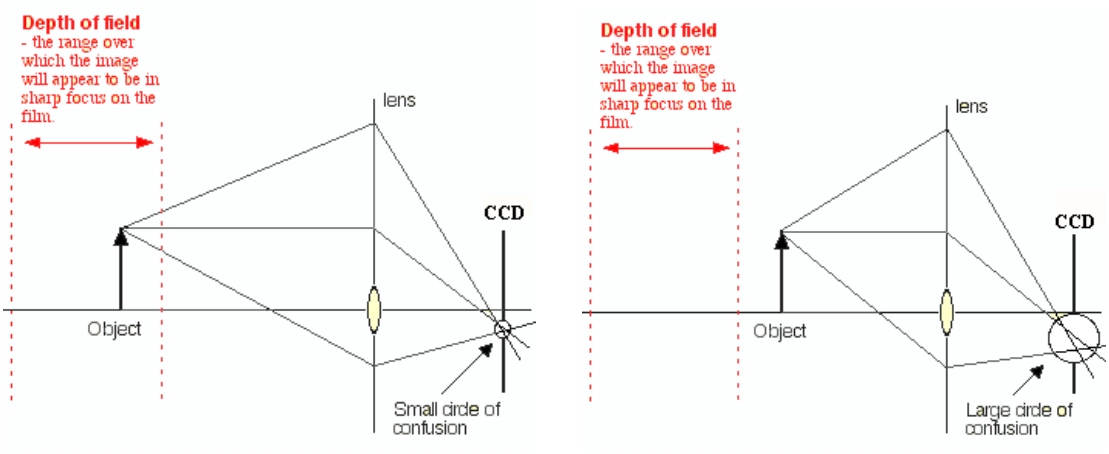
f Sketch a *detailed ray diagram* to locate the images if the ceiling light is regarded as a distant object.

g A series of images are formed below the lens by additional partial reflections and refractions.

i Add the approximate positions of the second and third images in the series on your diagram for part (**f**) and describe the images in general terms. [*You may, if you choose, redraw the diagram*]. Explain why additional images are not seen in the figure above.

ii Locate the first three images of the series in terms of *r* (the radius of surface curvature) by using the reciprocal formula for the combined focal length of thin lenses and/or mirrors in contact. *Show your working*.

5 Depth of field refers to the range (distance from the camera) over which an image on the CCD appears to be in relatively sharp focus.

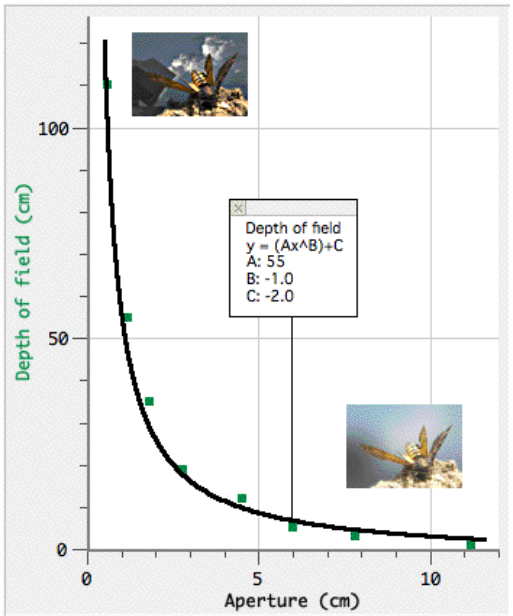


When an object is within the depth of field, rays are brought to an approximate focus on the CCD. Out of that range the *circle of confusion* increases beyond an acceptable limit. The diagrams above show this in schematic form.

A student is asked to do a benchtop experiment to determine the depth of field of a simple biconvex lens (a ten cm diameter magnifying glass) as a function of aperture diameter.

> **a** Describe a possible procedure, specifying the equipment needed and the measurements to be made.

A data plot from such an experiment is shown below.



> **b** Describe the relationship between aperture diameter and depth of field.

Question 5 continued …

c Explain briefly why reducing the diameter of the aperture increases the depth of field for a given lens.

d Why is limited depth of field often an issue when photographing insects, but not when photographing clouds?

6 The usual way to increase the limited depth of field in macro photography is by image stacking, but there are occasional instances of images with unusually extended depths of field. Pinhole cameras require very long exposures and resolution is diffraction limited so pinhole images are never as sharp as conventional images, but they do have an infinite depth of field.

a Explain what is meant by *resolution* and *diffraction limited*.

The pinhole images below are of the sun. The images were photographed on tiles under a tree. The gaps in the leaves acted as pinholes.

The diameter of the Sun in the sky is 0.5 degrees and nine tiles have an area of one square metre.

b Estimate the average height of the leaves above the tiles.

c How do you know that not all the holes in the leaves were at exactly the same height?

d *Look very carefully at the image above*. How many pinholes contributed to the pattern?

The writer was surprised on one occasion to see this dappled pattern on the road under a tree.

e What did he see when he looked in the sky?

The single image below is another example of depth of field extension. It was made by photographing the refection in a hemispherical mirror placed on the ground under the tree.

f Explain why in this case the depth of field is from 5 cm to 25 m.