Observational Astronomy | **First Name:**__________________
Lab: I-4FS | **Last Name:**__________________

Building a telescope

Today we will make a simple telescope using some lenses. We will begin by examining the properties of a lens, and learn how to measure focal lengths. We will then use the lenses to make a telescope, and examine its magnification.

Equipment: optical bench, magnetic stands, light source, 1 mm aperture mask, plane mirror, concave mirror, glass, imaging screen, and several lenses.

1. Properties of a single lens

Set up the optical bench as follows, with the 1 mm aperture attached to the light source, a 70 mm lens and the screen, as shown below. Position the source so the front face corresponds to the zero position on the bench — this makes measuring distances easier.

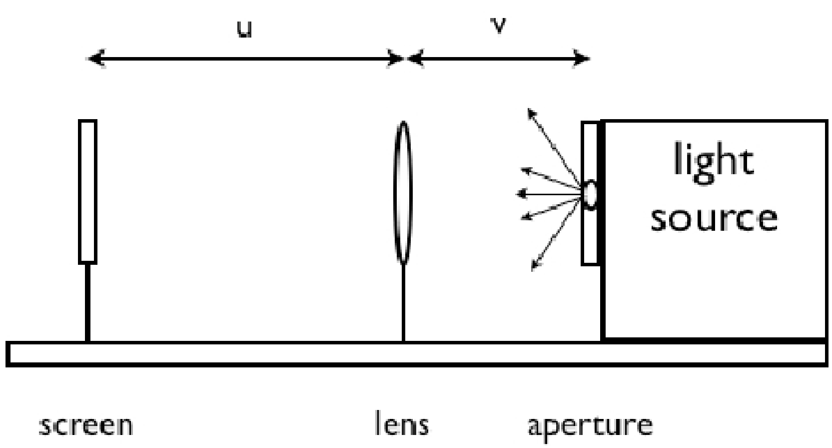

Figure 1:

In what follows, we shall refer to the distance between the source and the lens as v (the object distance), and the distance between the lens and the screen (when the image is in focus on the screen) as u (the image distance).

Move the lens so that $v = 60$ cm. Then move the screen until the image of the light source is in focus. Determine the corresponding value for u and enter the result in the table below. Repeat the procedure for the other values of u given in the table. Note as you proceed the relative brightness of the focused light at each configuration — mark whether the image is brightest for $v = 20$ or $v = 60$ cm. Plot the results on the attached sheet of graph paper, and join the points with a neat, smooth curve.

v (cm)	u (cm)
60	
50	
40	
30	
25	
20	

On the schematic of the optics above, draw the path the light takes from the center point of the aperture, assuming that the light is in focus. Start at the arrows shown and continue the lines until the light hits the screen. Remember the light goes straight when going through the air and bends when it goes through the lens! Note of course that not *all* of the light ends up going through the lens.
Mathematically, the relation between u, v and the focal length f is given by the equation:

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \tag{1}$$

A special case occurs when $u = v$. Then:

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{u} + \frac{1}{u} = \frac{2}{u} = \frac{1}{f} \tag{2}$$

In other words: $f = u/2$ when $u = v$. From your plotted curve find the point when $u = v$ and deduce f:

Examine your graph and comment:

1. What happens to u as v gets very large?

2. What happens to u as v gets very close to f?

These special cases can be investigated with the above equation. When v is very large (at infinity) then $1/v = 0$. What then is the value of u?

When $v = f$ (i.e. the source is at the focus of the lens, what then is the value of u?

2. Parallel light and focal lengths

We can use the results from part (1) in two ways: first, to simulate on the optical bench a very distant light source, and then to use this to directly measure focal lengths.

First, set up the optical bench as follows, with the light source at one end as before, but now with the 48 mm focal length lens and the plane mirror:

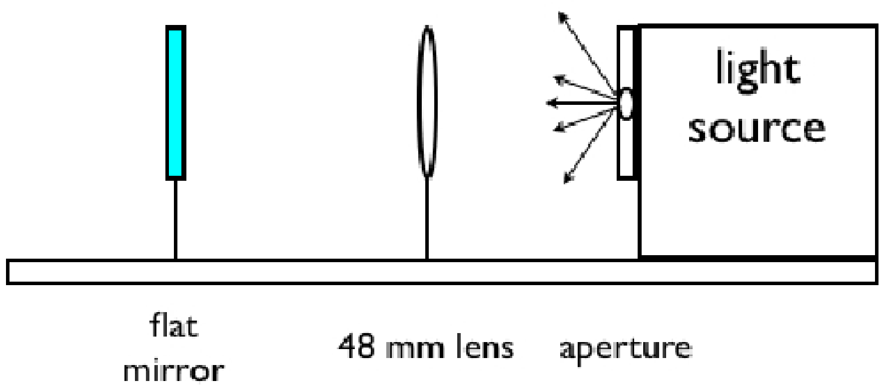

Figure 2:

Adjust the position of the lens (keeping the mirror close to it) so that the light from the source is reflected back off the mirror and through the lens again, and is in sharp focus on the front face of the source. This may require some fiddling so you can actually see the image on the source screen (if things are aligned too well, the image will form on the aperture itself, where you won't be able to see it).

Some thought should convince you that (a) the source-lens distance is equal to the focal length of the lens, and (b) on removing the mirror, the beam emerging from the lens will be equivalent to that coming from a very distant object (that is, the rays will be essentially parallel). Draw the light paths in the above diagram.

With a parallel ("collimated") beam, we can directly measure focal lengths of lenses. Simply mount a lens on the bench in the parallel beam close to the 48 mm lens, as follows:

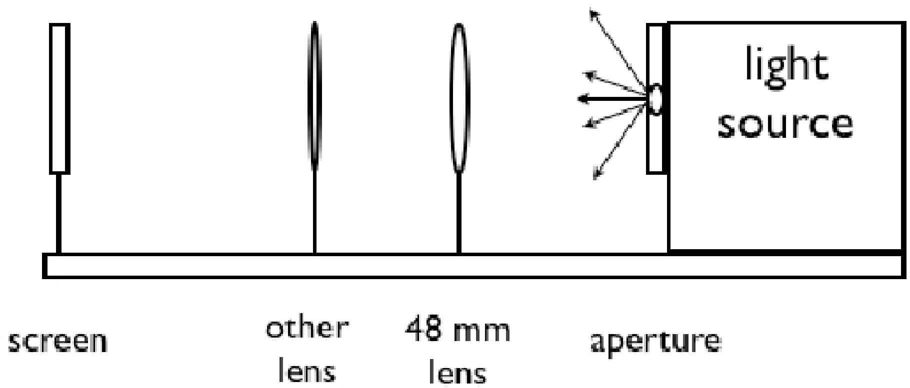

Figure 3:

Adjust the position of the screen from the lens until a sharp image is obtained. From part (1) it should be clear hat this distance equals the focal length of the lens. Compare your measurement with the label on the lens itself:

Again, draw the light paths for an in-focus configuration in the above diagram.
While we have a parallel beam set up, let us look at how a mirror focuses a beam. Install the concave mirror and a piece of straight, clear glass, as shown below:

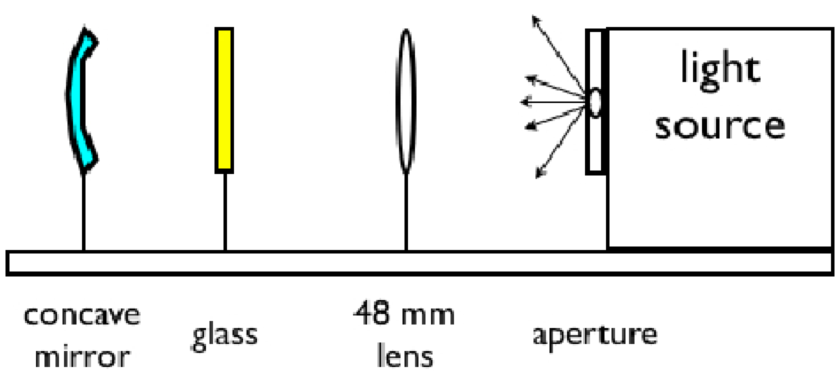

Figure 4:

Configure the mirror so that you can see the image form on the *glass*. The distance between the concave mirror and the image it forms from a parallel beam is its focal length. Compare your measured focal length to that stated on the mirror:

Draw the paths of the rays in the figure above.

3. A simple telescope

Clear the optical bench of everything including the light source, and mount two lenses: an "objective" lens O with focal length f_O and an "eyepiece" lens with focal length f_e. To begin, put the eyepiece at one end, and position the objective length a length f_O from it. Try to look at a source on the far end of the room; you will see that the telescope is not in focus. Move the objective back until the distant object is clearly in focus.

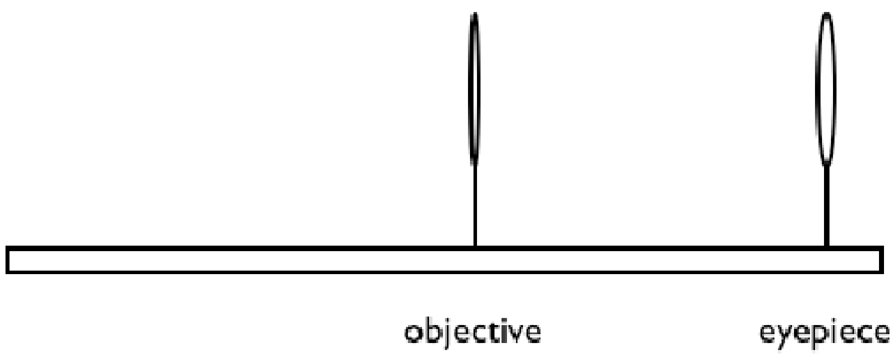

Figure 5:

Draw the light paths in the diagram above.

If properly configured, this set up should produce a magnified image of distant objects — if you find that the images are *demagnified* how do you have to change the configuration?

Measure the distance from lens O to lens E. How does that compare with the number you expect?

We now have a telescope that magnifies distant objects. According to the theory, the angular magnification of the telescope is given by $M = f_O/f_e$. Using the labeled values of f_O and f_e on your lenses, calculate the theoretical magnification of the telescope.

Now pick a different lens for the objective, and report if the magnification changes in the expected manner:

4. Extra credit

Notice that the image in the telescope we have built is reversed. Suggest and implement a change in the design to make the images upright.