<u>Measuring the focal length of a Refractor Telescope</u>

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It seems probably not very useful for most Hobby Astronomers to determine the focal length of a refractor. Normally everybody who buys a new telescope should know its focal length from its manufacturer.
However there are some old or prototype telescopes out there from where the focal length may be unknown.

There are several methods how to determine experimentally the focal length of an lens system and the most intuitive may be the use of a bright object in infinity (e.g. the sun). The focal length is simply the distance between the rear principal plane of the lens system and the plane where the sunlight is focused. For single thin biconvex lenses both principal planes are at the centre of the lens.

Unfortunately the things are not that simple for most telescopes. An astronomical telescope lens system typically contains of at least 2 single lenses. The position of the principal planes of these lens systems is most of the time not known to the user. Not knowing these positions makes the exact measurement of its focal length with the above mentioned, simple method impossible.

A very elegant and surprisingly accurate method, that does not need the information about principal planes, neither a parallel light source, is the “Bessel-Method”.
The principle behind the Bessel method is the fact, that for a given distance “a” (>4f) between object and screen there are two lens positions (P1,P2) where a sharp image is formed on the screen (see figure 2). At both positions there are real, reverse images (I1 and I2), but the size is different – magnified at P1 and smaller at P2.

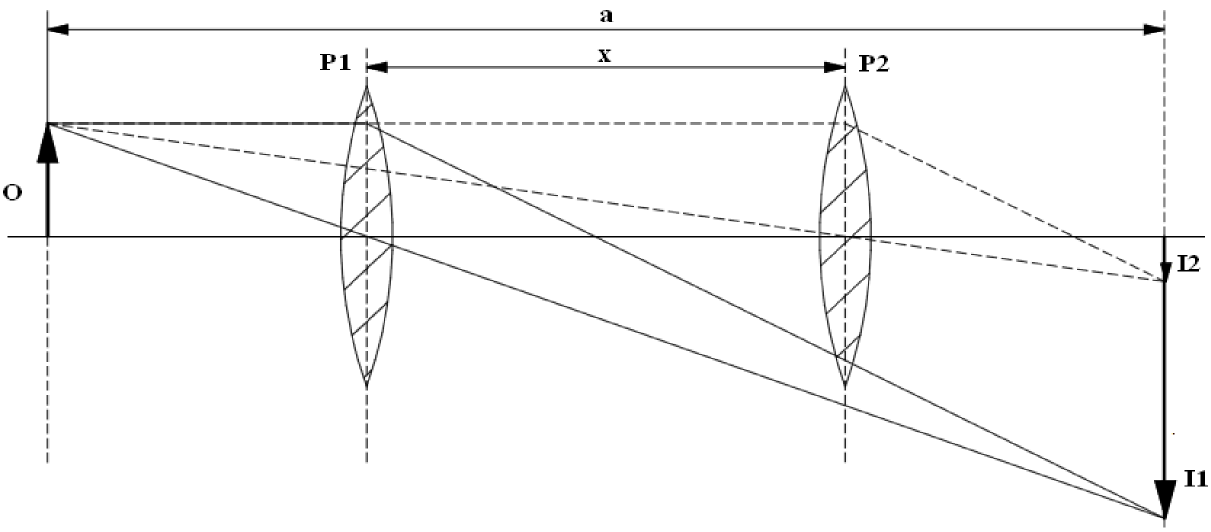


Figure 1: Image formation at Position 1 and 2

So much for theory, let us start the measurement:

The object (light source) can be any sufficiently bright object (e.g. torch). And the screen can be a white wall. Important is that the distance between object and screen is at least four times the focal length of the lens - so make the distance long enough!

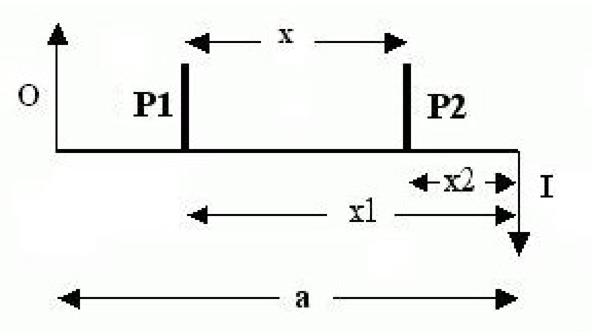
At first remove the dew shield and the diagonal from the telescope and bring it in a position close to the screen. The light from the object should enter from the focuser, so the front of the scope points towards the screen. Make sure that object, center of focuser tube and center of lens are in line and that this line is vertical to the screen.
Move the scope along this virtual line and watch the screen. Stop the movement when a sharp image of the object is formed on the screen and measure the distance “x2” from the screen to the front of the lens cell.
Now move the scope along our virtual line further towards the object and watch carefully the screen. At some point a sharp, but much dimmer and much larger image of your object will be formed on the screen (see figure1). It may be necessary to darken the environment depending on the brightness of the image. A second person can be helpful to move the scope or watch the screen closely. Measure again the distance “x1” from the screen to the front of the lens cell.

If you subtract “x2” from “x1” you will get the distance “x” and together with the object-screen distance you can calculate the focal length with:

$$f = \frac{(a^2 - x^2)}{4a}, \qquad a \geq 4f$$

where “a” is the distance between light source and screen and “x” the distance between lens Position 1 and 2.

The following schematic shows the experimental set up for the Bessel method:



O: Object (light source)
I: Image (screen)
P1: Lens Position 1 (real image 1)
P2: Lens Position 2 (real image 2)
x1: Distance 1
x2: Distance 2
x: x2-x1
a: Distance object-screen

Figure 2: Bessel method set up

If the work was done carefully, the result will match the real focal length by a few Millimeters.