

Refracting Telescopes

Adapted from <http://www.astro.lsa.umich.edu/Academics/Undergrad/labs.php>

Introduction

There are two basic types of telescopes: reflectors and refractors. The type is determined by what collects the light: reflectors have a primary mirror, while refractors have an objective lens. If the image is to be viewed directly, a lens called an eyepiece is also used. Otherwise, an astronomer may place a camera (film or CCD), spectroscope or other device on the telescope.

The focal length of a lens or mirror is given by:

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \quad (7)$$

where f is the focal length, d_o is the distance to the object (e.g. a star) and d_i is the distance to the image. Note this is for a single lens or mirror: you'll explore what happens when you add an eyepiece later. The magnification by definition is simply the ratio of the size of the image h_i to the size of the object h_o :

$$M = \frac{h_i}{h_o} \quad (8)$$

Simple Lenses

- Note the lenses are in holders and the holders are labeled with a colored sticker with a number and letter on it. Record the color and number of your set.
- Begin by solving the equation for the focal length for f if d_o is at infinity.
- Set up the optics bench with lens B in the middle and the screen. Point the bench toward the light source. Make a table as follows:

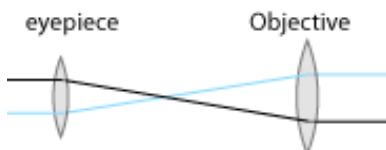
Label	d_i (cm)
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- Slide the screen back and forth until the image is in focus. Record the distance between the screen and the lens as d_i in the row labeled B in your table. Repeat the same procedure for the other 4 lenses.
- Rank your lenses in order from shortest to longest focal length.
- Measure the “height” of the object. In this case, the height will be the longest dimension, even if the source is at an angle. Check with your GSI if you're unsure what to measure. Don't forget to estimate your uncertainty.
- Place your longest focal length lens on the optics bench. Measure the “height” of the image and record it as h_i . If the image is upside down, make h_i negative. Estimate your uncertainty.
- Calculate the magnification of this lens. Also, calculate your uncertainty in the magnification using error propagation methods.

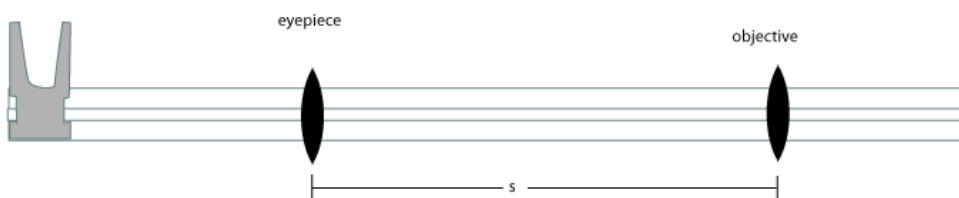
1. What does a negative magnification mean?
2. What does it mean if the absolute value of the magnification is less than 1?

Refracting Telescopes

Refractors usually have a large lens to collect the light at the front (objective), then an eyepiece to focus the light for your eye. They are designed to work for objects far enough away that the incoming light rays are parallel.



In this section you'll build a couple refractors and determine the characteristics. In order to test your telescope, you'll need to have as long a view as possible, such as down the hallway, out a window or into the next room. Your telescope should look something like this:



1. Unplug the light source from the power supply and wrap up the cord so it's out of the way. Find a comfortable place to set up where you can see a long distance and you aren't likely to lose a lens or hit one of your lab partners.
2. Choose a lens at random and slide it onto the bench. Leave just enough space between it and the light source to get your head in there to look through it: this will be the eyepiece. Record its label and focal length in your table under the eyepiece section.
3. Slide another lens onto the bench. Record its label and focal length under the objective lens.
4. For steps 5 - 7, each person will record his or her own observations. Your measurements should all be close, but small variations are expected.
5. Look through your telescope. Bring the eyepiece close to your eye, then adjust the objective to focus the image. Record the distance between the two lenses as s in your table.
6. Estimate the magnification and field of view (FofV). To estimate the magnification, keep both eyes open and try to align the two images side-by-side. For the field of view, compare it to what you could see if you didn't have the lens in the lens holder: 1 = same, 2 = twice as much, $1/2$ = half as much. Record your estimates in your table. If the image is upside down, record M as negative.
7. Repeat steps 2 - 7 using the same 2 lenses, but switch their positions (the eyepiece lens becomes the objective, the objective becomes the eyepiece for telescope number 2).
8. Repeat steps 2 - 7 with a different set of lenses.

Make a table with your measurements as follows:

eyepiece		objective		telescope properties		
Label	f (cm)	Label	f (cm)	s (cm)	M	F of V

Use the data in your table to determine the relationship between the focal lengths of the lenses and their separation and the telescope's magnification. Write those relationships as equations. Get them checked by your GSI before you continue.

Design Your Own Telescope

1. Based on your observations and relationships from Part 2, describe the properties of a telescope (s , M and F of V) with lenses of equal focal length, f :
2. Design a telescope to get the widest possible field of view. Enter the labels and focal lengths of your chosen lenses in your table.
3. Calculate the predicted separation and magnification of your telescope and enter those values in your table.
4. Test your 'scope: place the lenses on the optics bench in the correct order and look through it. Move the eyepiece to focus, and record the observed separation in your table. Estimate the magnification and record it in your table.
5. Design a second telescope to get the highest magnification possible. Repeat the steps above to fill in the bottom row of your table.

	eyepiece		objective		telescope properties		
goal	Label	f (cm)	Label	f (cm)	s (cm)	M	F of V
Widest F of V							
Highest M							

6. Look through your highest magnification telescope again and describe the view: is the image right side up or upside down, forwards or backwards, brighter or dimmer than looking directly at the source, is the entire field in focus, is there any distortion, extra or missing colors or anything else different about the source?
7. How did you decide what lenses to use and which one to make the objective and which one the eyepiece?

Thinking Questions

1. The brightness of an object generally changes the same way the field of view changes. What happens to the field of view as the magnification is increased? If you wanted to observe a faint diffuse object would you want a high or low magnification? Why?
2. These "telescopes" had identical diameter objectives and eyepieces on carriers that you could move and even change. In a real telescope, which one can you change?
3. Why is magnification not important, either to astronomers or if you were going to buy a telescope?