

*Note: This exercise assumes knowledge of the 3 types of telescopes.*

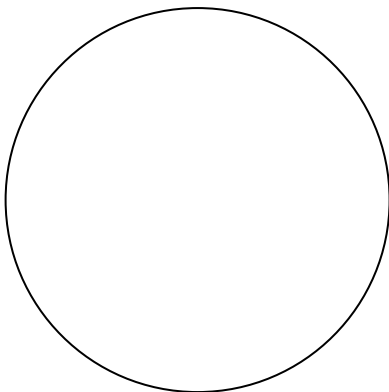
**PART I – The Telescope** - Become familiar with the parts of a telescope, including finder (or spotter), focuser and eyepieces

For this portion of the exercise, you'll be using an astronomical telescope. There are two telescopes making up the assembly, a main scope and a smaller scope. Draw a simple diagram illustrating both. What type of telescope is each one? Identify the primary optic, the focuser, and the eyepiece. Label these on your diagram.

**PART 2 – Practice Using the Telescope** - Find and focus on objects

Find an object across the room to look at. Look at the object through the small scope first. Record (write or draw) anything you notice.

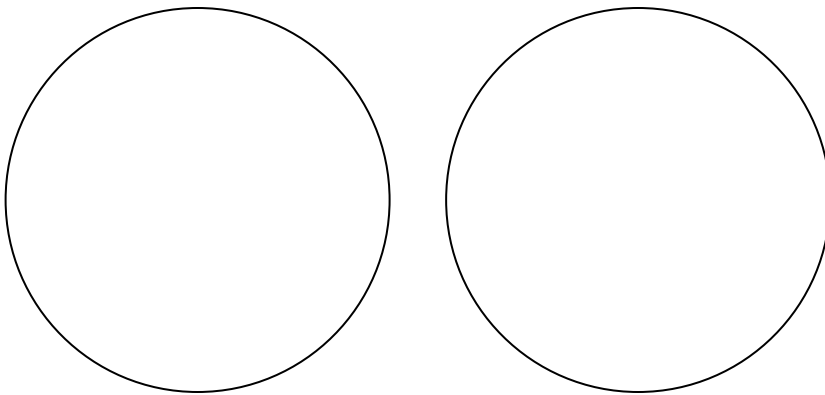
Now look at the same object through the larger scope. You might need to focus the image. Record (write or draw) anything you notice.



What differences did you notice between the view through the small scope and the larger telescope? The small scope is called a finder scope or a spotter scope. Why do you think that is? Explain your answer. Clearly describe the differences in the appearance of the object between the finding scope and the main telescope. From these observations, try to explain why the telescope has a finding scope.

Which has a higher magnification power, the larger telescope or the small scope? What is it about the object that you are looking at allows you to say that one has a higher magnification than the other? Recall that magnification is how large an object looks when compared to viewing it with the unaided eye.

Try to find, and focus on, a second object across the room or down the hall. Would you use the main scope or the smaller finder scope to find a second object? Try finding this second object using the main scope, and using the finder scope. Which made it easier to find the second object? Make a sketch of what you see of the second object. Try finding a third object. Make a sketch of what you see of the third object.

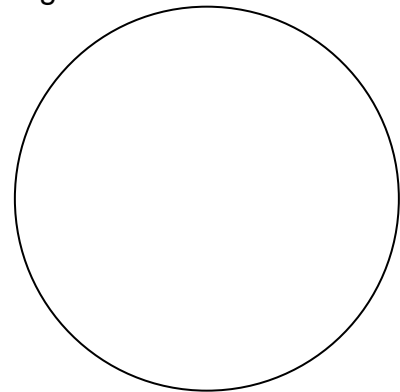


### **PART 3 – Estimate Magnification of Eyepieces and the Finder**

Looking at one object across the room, change out the eyepiece in the focuser. Now look through and re-focus. How does the view change?

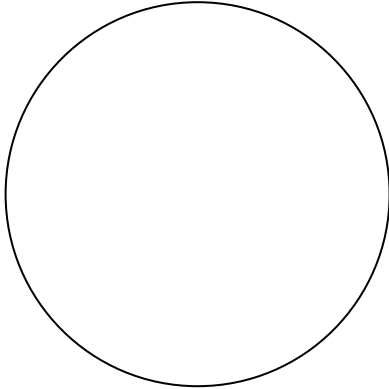
#### **PART 3 A –**

Have a group member stand across the room holding a meter stick. Look through the finder and make a reading of the meter stick. How much of the meter stick can you see through the finder scope? Write down the reading from the meter stick at one side of the field of view and the reading at the other. Sketch a drawing inside the circle below to help. How many centimeters are across the entire view as seen through the finder scope?



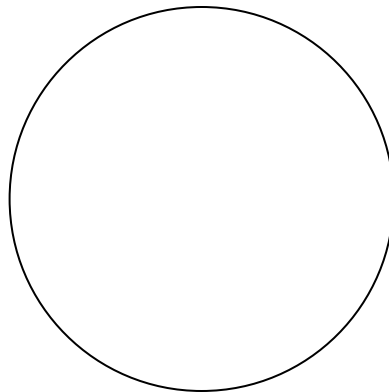
Now look through the telescope and make a reading of the meter stick using the one of the eyepieces. How much of the meter stick can you see through the eyepiece? Write down the reading from the meter stick at one side of the field of view and the reading at the other. Sketch a drawing inside the circle below to help. How many centimeters are across the entire field of view?

Total of meter stick as seen through eyepiece #1 \_\_\_\_\_ (in mm)



Now replace the eyepiece in the focuser with the other eyepiece. Focus the view. Make another reading (and sketch) of the meter stick and indicate your results. How many centimeters in the field of view with the second eyepiece?

Total of meter stick as seen through eyepiece #2 \_\_\_\_\_ (in mm)



Now look at your data. Which has a greater magnification, the finder, eyepiece #1 or eyepiece #2? Why? How many times more magnification does the one eyepiece have over the other? Explain how you determined this.

### **PART 3 B – Calculate Magnification of Eyepieces**

*(Note: The finder scope probably indicates somewhere on it what the magnification factor is, so it will not be included in the following calculations.)*

The magnification ( $M$ ), or power, is how large an object looks when compared to viewing it with the unaided eye. This can be determined mathematically by comparing the ratio of the focal length of the telescope to the focal length of the eyepiece. The focal length is the distance from the primary optic to the point where the image comes into focus. So, magnification is the focal length of the telescope ( $f_l$ ) divided by the focal length of the eyepiece ( $f_e$ ).

The focal length of telescopes and eyepieces is given in millimeters, and is usually found printed somewhere on the telescope or eyepiece. Find the focal length of the telescope ( $F = \text{???? mm}$ ) and record it below. The focal length of the eyepiece(s) is written on the eyepiece. Find this number and note it also.

Focal length of telescope ( $f_l$ ) \_\_\_\_\_ (in mm)

Focal length of eyepiece #1 ( $f_{e1}$ ) \_\_\_\_\_ (in mm)

Focal length of eyepiece #2 ( $f_{e2}$ ) \_\_\_\_\_ (in mm)

Calculate the magnification of the two eyepieces you are using:

magnification ( $M$ ) of eyepiece #1 =  $(f_l) / (f_{e1}) =$  \_\_\_\_\_

magnification ( $M$ ) of eyepiece #2 =  $(f_l) / (f_{e2}) =$  \_\_\_\_\_

If you use an eyepiece with a small focal length, will you get a smaller or larger magnification?

### **PART 3C – Error Estimations for Magnification of Eyepieces**

Compare your results from the calculation above to the results of your measurements of the field size through each eyepiece. Which do you think is more accurate, your estimate through the eyepiece in **PART 3-A** or your calculations from **PART 3-B**? Explain where you might find error. (Go beyond the answer “Human error.”) Make a best guess estimate as to how far off your measurement might have been. Would this account for the difference between the observed and calculated difference in magnification?

Now try to quantify the difference in magnification between the two eyepieces. In other words, by what factor does one eyepieces magnify compared to the other (eg. 3 times more magnification). From your calculations in **PART 3-B**, by what magnification factor are the two eyepieces different? Compare this to your estimated factor in **PART 3-A** above. How do they compare? Can you account for the difference by measurement error?

You can quantify your measurement error by estimating how well you could read the meter stick. Are you confident in your measurement to within 1cm? How about to within 1mm? Look through the telescope at the meter stick again. Use your best judgment on how precisely you can read the meter stick through the telescope. What is your estimate?

Using your estimate, devise a way to quantify the error in your magnification factor between the two eyepieces. Write out clearly what you have done in order to find your error. You should end up with a final magnification factor that you can place uncertainty values on. (For instance, the factor is 2.5 plus or minus 0.2). Does your measurement uncertainty account for the difference in magnification from **PART 3-C**?

#### **PART 4 – Determine field of view of each of the eyepieces and the finder**

(Note: This section uses data from PART 3-A and PART 3-B.)

[http://users.zoominternet.net/~matto/M.C.A.S/aparent\\_vs\\_true\\_field.htm](http://users.zoominternet.net/~matto/M.C.A.S/aparent_vs_true_field.htm)

Astronomers use the degree ( $^{\circ}$ ) to measure distance between objects on the sky. The eastern horizon is 180 degrees away from the western horizon. The point straight over your head on the sky is  $90^{\circ}$  from the horizon. Your fist held at arm's length is approximately  $10^{\circ}$ . How many fists would it take to cross the sky between East and West? How many would it take to go from the point over your head to your horizon? If you notice the Moon above your horizon, and measure  $2\frac{1}{2}$  fists between it and the horizon, how many degrees above the horizon is it?

Now let's figure the field of view, in degrees, of each of the eyepieces. Hold your fist out at arm's length in front of you. Look through each eyepiece without using the telescope and try to determine how much of your fist you can see through it. This is just an estimate. Write down approximately how much of your fist you can see with each eyepiece, in degrees (eg, 2 degrees, 5.5 degrees, etc).

Now we'll compute the actual angular field of view ( $\theta$ ) "theta" of each of the eyepieces.

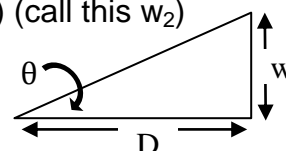
Recall the data from **PART 3A**:

Total of meter stick as seen through eyepiece #1 \_\_\_\_\_ (in mm) (call this  $w_1$ )

Total of meter stick as seen through eyepiece #2 \_\_\_\_\_ (in mm) (call this  $w_2$ )

Recall the data from **PART 3B**:

Focal length of eyepiece #1 ( $f_{e1}$ ) \_\_\_\_\_ (in mm)



Focal length of eyepiece #2 ( $fl_{e2}$ ) \_\_\_\_\_ (in mm)

Next, accurately measure the distance from the telescope focuser to the meter stick at the far end of the room. Record that number:

Distance (D) to meter stick \_\_\_\_\_ (in mm)

Using a scientific calculator, figure the field of view angular ( $\theta$ ) from the following equation:

$$\tan \theta = w / D$$

*The tangent of the field of view angle equals the part of the meter stick seen through the eyepiece divided by the distance from the focuser of the scope to the meter stick.*

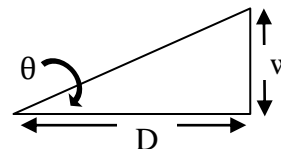
Re-arranging the above equation:

$$\theta = (\tan^{-1}) (w / D)$$

*The field of view angle equals the inverse tangent of the part of the meter stick seen through the eyepiece divided by the distance from the focuser of the scope to the meter stick.*

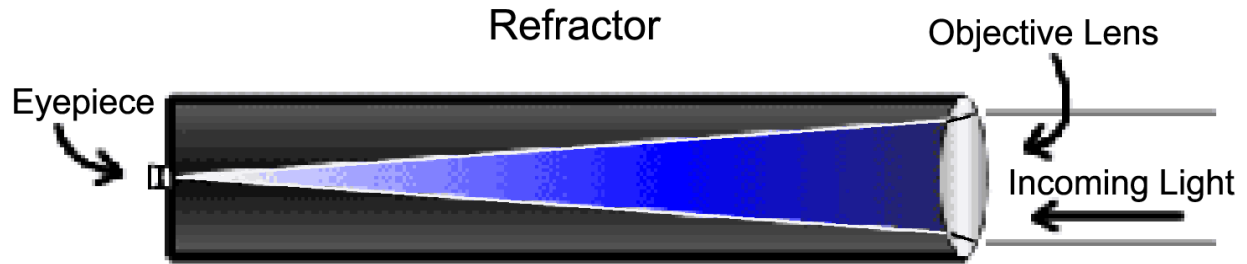
field of view angle of eyepiece #1 \_\_\_\_\_

field of view angle of eyepiece #2 \_\_\_\_\_



The full moon is approximately 0.5 degrees. Which one would show the best view of the entire moon? Which view would show the best view of a close-up of a crater? Which would show the Moon and a nearby bright star or planet? What kind of eyepiece focal length would you need if you wanted to really zoom in on one of the craters of the moon?

**Final questions:** Which is better to use when first finding an object on the night sky: eyepiece #1, eyepiece #1, or the spotter scope? Why?



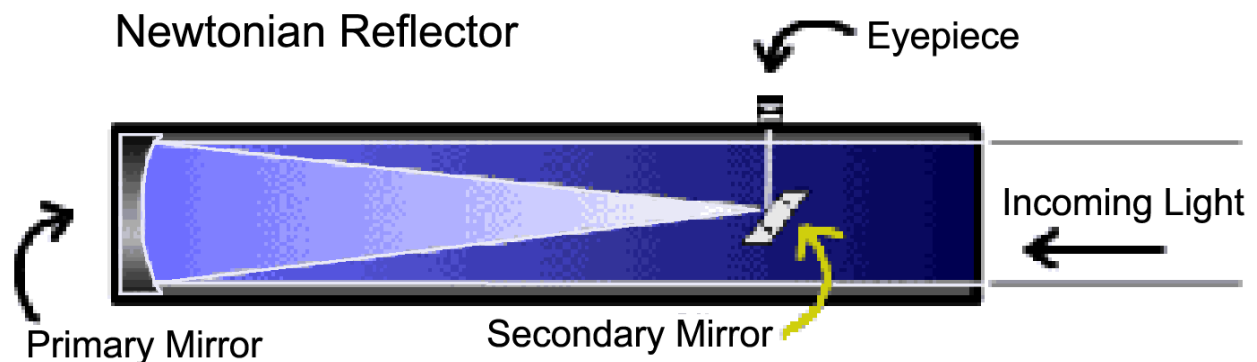
**REFRACTOR (lens system)**

*Advantages*

- No light-path obstruction
- Potentially provides the best images

*Disadvantages*

- Some show “chromatic aberration” - colored halos around objects
- Large ones are BIG
- Can be expensive



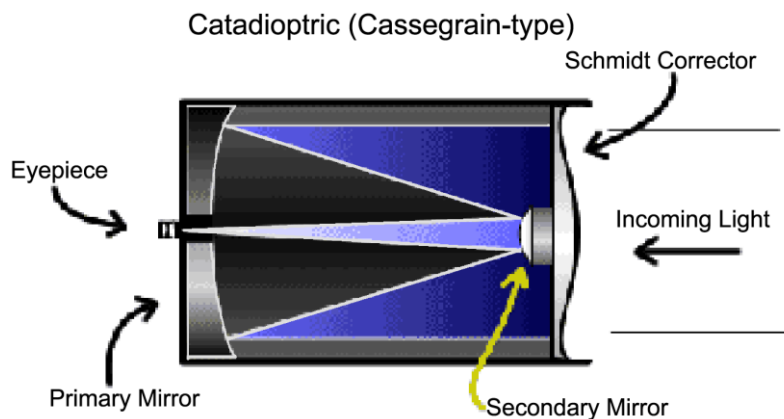
**REFLECTOR (mirror system)**

*Advantages*

- Least expensive
- High portability
- No chromatic aberration (colored halos around images)

*Disadvantages*

- Some light block by secondary mirror
- Can require frequent collimation (alignment of optics)
- Larger than Cassegrain-types



**CASSEGRAIN-TYPE (mirror/lens)**

*Advantages*

- Compact design
- High portability
- Can be computer-driven
- Middle of price range

*Disadvantages*

- Potential for least clarity of image
- Subject to dew problems

### HOW TELESCOPES WORK

- Telescopes gather light, like a “light bucket”
- Curved optic bends parallel light rays into “light cone”, forming tiny, intensified image of object at tip of light cone
- Length of “light cone” called focal length (fIT); determined by shape of optic curve; mm (millimeters)
- Eyepieces are mini refractors
- Eyepiece focal length (fIE) measured in mm (millimeters)
- Focal length of scope in conjunction with focal length of eyepiece determines magnification.

### MAGNIFICATION (POWER)

- Size of object when viewed through telescope compared to viewing with un-aided eye
  - Object viewed through telescope looks 48 times bigger than viewed with un-aided eye = 48 power or 48 times magnified(48x)
- Defined by relationship between focal length of telescope (fIT) and focal length of eyepiece(s) (fIE)

### LIMITS OF POWER

- Under ideal conditions
  - Approximately 50 to 60 power per inch of aperture (primary optic diameter)
  - 8-inch telescope = 8”x50 to 8”x60 = 400 to 480 power
- Many night-sky objects need low magnification because they are dim, faint, fuzzy: nebulae, galaxies

### TECHNICAL DETAILS OF MAGNIFICATION OR POWER

- Defined by relationship between focal length of telescope (fIT) and focal length of eyepieces (fIE)
- The Equation:
  - $fIT / fIE = \text{magnification of eyepiece}$
- Magnification can change on same telescope when different eyepieces are used

### USING MAGNIFICATION

- Higher magnification
  - Reduces image brightness, sharpness and detail
  - Shows blurrier, fuzzier, poorer quality images
  - Only 1/4 the brightness and 1/2 the sharpness coming through eyepiece
  - Sees a smaller field of view (fov) in eyepiece
- Lower powers
  - Give clearest images
  - Show larger portion of sky (fov)

### FIGURE MAGNIFICATION

- A telescope has focal length (fIT) of 2000mm, with two eyepieces at:
  - Focal length #1 (fIE1) = 26mm
  - Focal length #2 (fIE2) = 40mm
- Divide focal length of scope (fIT) by focal length of each eyepiece (fIE)

### FIELD OF VIEW (fov)

- Describes how much of sky is seen through eyepiece
- Lower magnification = larger field of view (fIT / fIE1)
  - $2000\text{mm} / 40\text{mm} = 50$  times magnified
- Higher magnification = smaller field of view (fIT / fIE2)
  - $2000\text{mm} / 26\text{mm} = 76.92$  times magnified
- Which would you use to begin your observing session?

