

<b>SIERRA COLLEGE OBSERVATIONAL ASTRONOMY LABORATORY EXERCISE</b>		
<b>NUMBER II.D.    TITLE: THE MAKING OF A TELESCOPE</b>		
<b>DATE-</b>	<b>PRINT NAME/S AND INITIAL BELOW:</b>	<b>GROUP</b> <input style="width: 40px; height: 20px;" type="text"/>
<b>DAY-</b>		
<b>LOCATION</b>		

**OBJECTIVE:**

Be able to:

- Measure the optical properties of lenses and mirrors.
- Assemble several simple telescopes and evaluate their magnification power.
- Calculate and analyze Magnification Power, Light Gathering Power, Resolving Power, and f-ratio for a variety of telescopes.

**DESCRIPTON:**

The operation of all optical instruments such as binoculars, small telescopes, and more sophisticated astronomical instruments such as the Hubble Space Telescope are governed by the basic laws of refraction and reflection. This laboratory exercise will offer the opportunity to measure the optical properties of lenses or mirrors and construct a simple telescope.

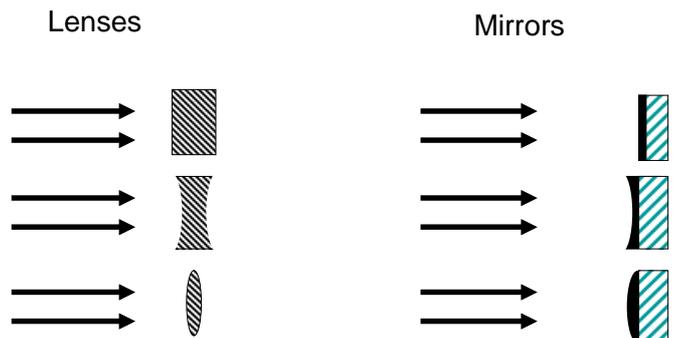
**PROCEDURE:**

- Each group should use the following materials:
- optical bench, large L-shaped projection screen, meterstick
  - tubes containing 'objective' lenses A, B, and C
  - tubes containing 'eyepiece' lenses I, II, and III
  - one telescope tripod (may have to share)

The instructor will perform an optical demonstration to describe refraction and reflection and how lenses and mirrors form images. The necessary measurements to complete the following tables will also be explained.

**STEP 1:**

Predict the reflected or refracted light path for the following lenses and mirrors. Assume the light is coming from the left from a very distant object (as indicated by the arrows)



**LENSMAKERS EQUATION:**

Eq. #1

$$1/F = 1/I + 1/O$$

or

$$F = \frac{I \times O}{I + O}$$

where F is the focal length of the objective lens, I the image distance and O the object distance.

**STEP 2: DISTANT OBJECT METHOD TO DETERMINE FOCAL LENGTH:**

In equation #1, as O gets larger, 1/F gets closer in value to 1/I or the image distance approaches the value of the focal length (F = I). If one can use the sun as a distant target then F=I, since O is essentially infinity. **DO NOT LOOK DIRECTLY AT THE SUN THROUGH THE TELESCOPE.**

If the sun is not available, then focus on a **DISTANT** white light bulb for each lens. Measure the image distance (I) three separate times and object distance (O). Use equation #1 to calculate 'F' to determine the focal lengths for optics A thru C and I thru III. Finally, from the measured diameter (D) of the optics A thru C and I thru III, calculate the focal ratio (f/ratio) as determined by equation #5.

**TABLE A – OBJECTIVE LENS FOCAL LENGTHS**

Obj. lens (letter & # of dots)	I <sub>1</sub>	I <sub>2</sub>	I <sub>3</sub>	I <sub>ave</sub>	O	I <sub>ave</sub> +O	F <sub>o</sub>	D <sub>o</sub>	F ratio
<b>A</b>									
<b>B</b>									
<b>C</b>									

**STEP 3: TELESCOPE MAKING:**

Use the optical tubes to determine the focal lengths (F) of the combination of objective and eyepiece lenses provided. For each objective lens selected, use the three eyepieces and measure the separation between the lenses when a focused image can be seen through the eyepiece. Do this for a distant (> 100 m) object. One can then find the focal length of the eyepiece (F<sub>e</sub>) by subtracting the focal length of the objective lens (F<sub>o</sub>) from the distance between the lenses (L) when looking at the distant target. Since the eyepieces are concave lenses the focal lengths you obtain for F<sub>e</sub> should be negative. These data should be placed in Table B.

Eq. #2

$$F_e = L - F_o$$

Focal length of objective when focused on distant target

One can also determine the Field of View (**FOV**) of each of the combinations of objectives and eyepieces by direct measurement. The details will be described by the instructor. Place the results in Table B.

**TABLE B – TELESCOPE MAKING RESULTS**

Objective lens	Eyepiece lens # (and number of dots)		F <sub>o</sub> Focal length of objective (from Table A) mm	L Distance between lenses when looking at <u>distant</u> target mm	F <sub>e</sub> Focal length of eyepiece (L – F <sub>o</sub> ) mm	Visual Estimate of M	Calculate M using Eq. #3 with average F <sub>e</sub>	FOV Field-of-view	
								meters	deg
A	I								
A	II								
A	III								
B	I								
B	II								
B	III								
C	I								
C	II								
C	III								

**AVERAGE FOCAL LENGTH OF EYEPIECE:**

Average focal length of eyepiece I \_\_\_\_\_.

Average focal length of eyepiece II \_\_\_\_\_.

Average focal length of eyepiece III \_\_\_\_\_.

**MAGNIFICATION OF TELESCOPE ON DISTANT OBJECT:**

Eq. #3

$M =  F_o/F_e $ <p>Magnification has no units.</p>
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Estimate the magnification power of each telescope combination by a method described by instructor. Enter these results in the above table for comparison with computed values. Also, in the table above, show the calculations to arrive at the computed magnification.

## LIGHT GATHERING POWER AND F/RATIO (IMAGE BRIGHTNESS):

The light gathering power (LGP) is a 'unitless' number indicating the relative amount of light or radiation a telescope objective can gather in comparison to a smaller (or larger) telescope objective. For example, by equation #4, a 10 inch telescope (telescope with 10 inch diameter objective) will gather 25 times more light than a 2-inch telescope.

Eq. #4

$$\text{L.G.P.} = (D_1/D_2)^2$$

The bigger objective or larger aperture, however, does not always produce the brighter image. The image brightness is dependent upon the objective diameter and focal length combined. **The focal ratio (f/ratio) is determined by dividing the focal length of a lens or mirror by its diameter.**

Eq. #5

$$\text{f/ratio} = F/D$$

It too, is a unitless number and useful for determining the length of exposure necessary for photographing an object. **As mentioned before, measure the diameters of the optics in Table A and determine the f/ratios for each. Enter results in Table A.**

## RESOLUTION:

The ability of a lens or mirror to separate or distinguish two or more closely spaced points of light in an image plane is limited by diffraction. As a result, the smallest angular separation of two points that can potentially be resolved is given by  $\alpha = 2.1 \times 10^5 \times \lambda/D$  where  $\alpha$  is given in arc seconds,  $\lambda$  is the wavelength (color) of transmitted light from the object, and D is the aperture diameter. Any linear units can be used for  $\lambda$  and D as long as they are the same.

If  $\lambda$  is chosen to be 550nm (middle of the visible spectrum) then the simplified formula (#6) may be applied.

Eq. #6

$$\alpha = 116/D$$

'D' is in millimeters

## SUMMARY QUESTIONS: (Place answers in the 'Blue Book')

1. Which telescope combination (e.g A-I, II or III) had the largest field-of-view? The smallest field-of-view? How is this related to the calculated (or measured) magnification?
2. For a **Meade telescope** equipped with a **6 mm eyepiece**: a. Calculate 'M'. b. Calculate L.G.P. compared with the human eye (D=5mm). c. Calculate 'α'. d. Calculate the f-ratio.
3. What would limit the resolving power of a larger ground based telescopes?
4. Would the above answer also limit light gathering and magnification power as well?