

Astronomy 101 Lab: Telescopes

This lab has a separate answer sheet from the procedure. Be prepared to make calculations in today's lab. Any calculator is acceptable, but make sure you know the order of operations (PEMDAS).

Pre-Lab Assignment: In this lab, you will be investigating the parts of a telescope individually (mirrors and lenses) and then bringing them together to see how a real telescope is constructed. Answer these questions before coming to lab.

You will be asked to calculate magnification in this lab. The equation is shown below, and **f** denotes the focal length.

$$\text{Magnification} = \frac{\text{focal length of objective}}{\text{focal length of eyepiece}}$$

A) *What is the main purpose of a telescope?*

B) *What is a "focal length?"*

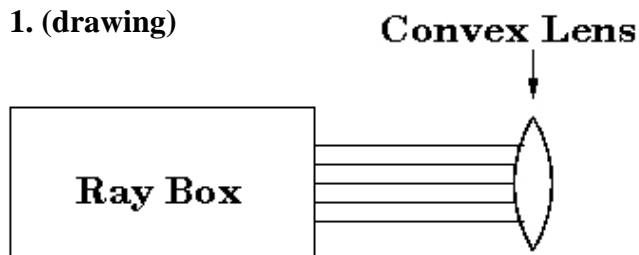
C) *If a telescope has an objective lens with a focal length of 200 mm and we use an eyepiece with a focal length of 10 mm, what magnification are we using?*

D) *If we change to a 5-mm eyepiece, does the magnification go up or down?*

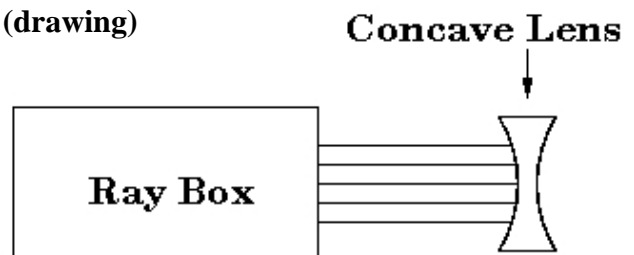
Telescopes Answer Sheet

Read the procedure to find the questions.

1. (drawing)



3. (drawing)



2.

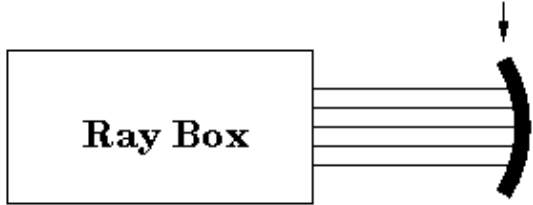
Telescopes Answer Sheet (continued)

Read the procedure to find the questions. Include units. Round all answers to one decimal place.

Part A (continued):

4. (drawing)

Concave Mirror



5.

Part B:

6.

7.

8.

9.

Part C:

10.

11.

12.

13.

14.

Part C (continued):

15.

16.

17.

18.

Part D:

d_o	d_i	f
80 cm	19.	23.
120 cm	20.	23.
200 cm	21.	23.
Far Away	22.	24.

25.

Part E:

Eyepiece	28 mm	15 mm	8 mm
26. Brightness			
27. Magnification			
28. Field of View			

29.

30.

31.

Analysis (complete Part D and E first):

32.

33.

34.

Telescopes Lab Procedure

Objectives: When you have completed this lab, you will be able to:

- Determine how different lenses and mirrors will affect the paths of incident light rays.
- Determine the properties of refracting and reflecting telescopes.

Procedure: You will be working in five stations to complete this lab. Since you'll be moving around, please move your personal items to a place so you won't forget about them.

Introduction: You will study different lenses and mirrors to determine their focal lengths. From what you learn, you will build a simple refracting telescope and you will analyze a simple reflecting telescope.

Write all your answers on the answer sheet. You don't need to submit the procedure.

Each group will start on a different part of the experiment. On the lab table at which you are seated, you will find a letter, denoting the part of the experiment on which you should start. Once you finish one part of the experiment, proceed to any part that is currently not in use. You may need to wait until another group finishes with the equipment. Please be patient.

Part A: There are three Light Blox with different colored lights. They will represent the "ray box" in the diagram on the answer sheet. Turn on each light. When the Light Blox are lined up, they produce parallel rays from the slits as shown in the figures on the answer sheet. Place a convex lens in the path of the light rays (See the first figure on the answer sheet, but note that only rays going from the ray box to the convex lens are shown.)

The focal length is the distance from the center of the convex lens to the point where the light rays are brought together. This point is called the focal point. You may notice that not all of the rays cross at the same point. To find the focal point, restrict your attention to rays that pass close to the center of the lens.

1. On the figure on the answer sheet, sketch the path of the light rays leaving the convex lens.

2. What is the focal length of the convex lens in cm?

Replace the convex lens with a concave lens.

3. On the figure on the answer sheet, sketch the path of the light rays leaving the concave lens.

Replace the concave lens with a concave mirror.

4. On the figure on the answer sheet, sketch the path of the light rays leaving the mirror.

5. What is the focal length of the concave mirror in cm?

Part B: For this experiment, you compare two seemingly identical black telescopes. While each telescope has the same objective lens, the eyepieces are constructed differently. The Galilean telescope uses essentially the same optical design as Galileo devised, including a double convex lens for the eyepiece. The Keplerian telescope incorporates Kepler's replacing the eyepiece with a double concave lens.

The two telescopes are mounted on a tripod and are pointed at the same distant object.

6. Describe two significant differences you observe between the images in the black telescopes.

Please move on to the largest telescope to make your final observation. The Dobsonian telescope obviously has the largest objective of any of these telescopes.

7. What are at least two advantages to using the Dobsonian telescope over any other telescope in the classroom?

The Dobsonian telescope is pointed at a green sign on the other side of the wing. Look through the telescope at the sign.

8. What does the green sign in the field of view say?

Take the black disk and hold it in front of the objective of the Keplerian telescope. Rotate the wheel so that you have the largest possible opening. While one student holds the disk in position, have each member of your group observe through the eyepiece. While observing, have a classmate slowly turn the wheel to allow less and less light to pass into the telescope.

9. How do the smaller openings affect the image?

This is the same effect that would be brought about by using a small diameter telescope rather than one with a larger diameter. This demonstrates a property of telescopes called "light gathering power".

Part C: On Table C, you will find three black tubes containing lenses. With these tubes, you will construct a telescope composed of two different lenses: a refracting telescope.

A wide lens with a long focal length is placed at the object end of the telescope. This is called the objective lens. A short focal length lens of smaller diameter is placed at the eye end of the telescope and is called the eyepiece.

You are provided with one objective lens and two eyepieces, enclosed in black cardboard tubes. You will need to determine the focal lengths of these lenses. There is a single flashlight mounted above the table. The light from this lamp will pass through each lens and project an image on the paper on the table.

Hold one of the lenses so that the side of the tube containing the lens is closer to the table. Move the lens up and down until you get a clear image on the paper. Once you get a clear image, use a ruler to measure the distance from the lens to the paper. **The lenses are not at the edge of the tube, so you must account for that additional distance.** Since the light source is far away relative to the focal length of the lens, this distance from the lens to the focused image is equal to the focal length of the lens.

Do this for all three lenses: the objective and the two eyepieces. All of the tubes are labeled. (Note: Both eyepieces have very short focal lengths.)

10. What is the focal length of the objective?

11. What is the focal length of the first eyepiece?

12. What is the focal length of the second eyepiece?

Gently insert the tube with the first eyepiece into the tube with the objective lens. Note that the tube containing the eyepiece will not fit snugly into the tube containing the objective. When you look through the telescope, you will have to hold both tubes.

Turn the tube so you can look directly through the eyepiece, with the objective lens at the far end of the telescope. Use this telescope to view an object in the classroom. As you will determine whether the resulting image is upright or inverted, you might want to try focusing on the periodic table or some other object with writing on it. The image is focused when the focal point for the objective is at the same position as the focal point for the eyepiece, so their distance from each other is equal to the sum of the focal lengths.

13. How far should the first eyepiece be from the objective when the image is focused?

14. Is the image upright or inverted?

Remove the tube with the first eyepiece and insert the tube with the second eyepiece. View the same object as before.

15. Which eyepiece provides a brighter image?

16. Which eyepiece gives a greater magnification?

$$\text{Magnification} = \frac{\text{focal length of objective}}{\text{focal length of eyepiece}}$$

17. Calculate the magnification using eyepiece 1.

18. Calculate the magnification using eyepiece 2.

Part D: In this part of the experiment, you will use an optical bench with a screen and a mirror. There will also be a light source. Be very careful when moving the light source and be careful not to touch the mirror.

Turn on the crossed arrows light source and direct it toward the mirror. The light source should be behind and off to the side of the white screen. You want the light from the source to reflect off the mirror and project an image on the screen.

Using the meter stick, place the light source at 80 cm from the surface of the mirror. This distance should be measured from the front of the light box. Move the screen back and forth until the crossed arrows image is as clear as you can make it.

The distance from the mirror to the light source is 80 cm. This is the object distance, d_o .

19. Using the meter stick, record the distance from the mirror to the image. This is the image distance, d_i .

20. Repeat this procedure with the light source at 120 cm.

21. Repeat this procedure with the light source at 200 cm.

We now want to view an object that is far away, specifically, outside of the window. Move the mirror and screen to a position such that light from the window will reflect off the mirror and project an image on the screen.

22. Move the screen back and forth until an image of an outdoor object is focused. Record the image distance.

Since this station takes the most time, please check with your instructor to see if you should move to another station before completing the following calculations.

For mirrors, the focal length (f), image distance, and object distance are related by the following equation:

$$f = (d_o \times d_i)/(d_o + d_i)$$

23. Determine the focal length of the mirror for the first three distances.

The objects you saw in the image were far beyond the window. As we've discussed in Part C, if the object being observed is far away, then the distance from the mirror to the focused image is equal to the focal length. (Using the equation, this is when d_o is much greater than d_i).

24. Based on the information in the preceding paragraph, record the last focal length in the table on your answer sheet.

25. You now have four focal length values. Calculate the average of these values by adding them together and dividing the sum by four.

This is the value you will use for the focal length of the primary mirror in the last part of the lab.

Part E: This part of the experiment involves the red reflecting telescope. Set up the telescope where you can see out the window.

The red telescope is a Newtonian reflector, a telescope composed of a primary concave mirror, a secondary flat mirror, and an eyepiece. The primary mirror is located at the back end of the tube. The secondary mirror is a small, flat mirror located in the converging beam coming from the primary mirror. This redirects the light rays toward the eyepiece located on the side of the telescope.

You are provided with 3 eyepieces of different focal lengths. The focal lengths are printed on the side of each lens. Put the eyepiece with the 28-mm focal length in the eyepiece holder on the side of the telescope. Point the open end of the telescope toward the window. Using the small, black knob near the eyepiece holder, move the eyepiece in and out until you can see a clear image. Repeat this with the eyepieces with 15-mm and 8-mm focal lengths. Be sure to refocus the image whenever you put in a new eyepiece.

Comparing the brightness of each image is not obvious. Consider how much light has been gathered by the telescope in each case.

26. Rank the eyepieces in terms of the brightness of the image, using a "1" for the brightest image.

27. Rank the eyepieces in terms of their magnification, using a "1" for the highest magnification.

28. Rank the eyepieces in terms of their field of view (the amount of the sky that you can see at one time), using a "1" for the largest field of view.

29. Look at your answers for the magnification and field of view. What is the relationship between the magnification and the field of view? Explain your answer.

Calculating percent errors:

Percent errors are calculated using the following equation:

$$\% \text{ error} = \left| \frac{\text{accepted value} - \text{measured value}}{\text{accepted value}} \right| \times 100$$

It's probably easiest to break it up into three steps. Follow these steps to calculate a percent error.

1. Take the accepted value and subtract the measured value.
2. Take the answer from step 1 and divide it by the accepted value.
3. Multiply the answer from step 2 by 100.

For example, let's say that a quantity has an accepted value of 320 and a measured value of 280. The percent error would be:

1. $320 - 280 = 40$
2. $40 / 320 = 0.125$
3. $0.125 \times 100 = 12.5\%$

The accepted value for the focal length of the mirror in the Newtonian telescope is 45 cm. Calculate a percent error between your measurement from Question 25 and the accepted value.

30. Percent error for the focal length of the mirror:

31. What do you think are some possible sources for the error in your measurements? (Please don't just write "human error". Explain what mistakes you could have made or the flaws in the procedure.)

The magnification of a reflecting telescope is calculated in the same way as the magnification for a refracting telescope. Use the equation from part C to calculate the magnification using the three different eyepieces; for the objective, use the average focal length that you calculated in Part D.

32. What is the magnification of the 28-mm eyepiece?

33. What is the magnification of the 15-mm eyepiece?

34. What is the magnification of the 8-mm eyepiece?