Lab 5 – Simple Lenses and Telescope Design

ASTR 1010

Name:

Overview

In this activity you will explore the geometric properties of simple lenses and how the aperture size and focal length influences telescope properties.

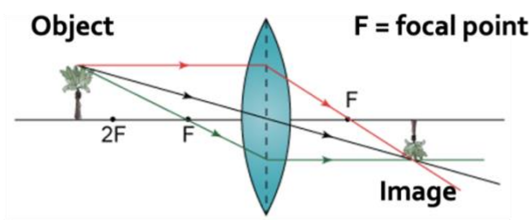
Objectives

After completing this activity students will be able to:

- Describe how object distance affects the location of the image formed by a simple double convex lens.
- Describe how the radius of curvature of a lens affects the properties of the image.
- Describe how telescopes aperture and focal length affect the properties of light gathering ability, angular resolution, magnification, and field of view.
- Select a personal telescope based on how they intend to use the telescope, for example viewing planets or view star clusters and nebulae.

Definitions

Here are some terms from lecture that we will be using today in lab:



- **Focal point** – the location where parallel light rays from a very distant location such as a star are brought to a focus
- **Virtual image** – image formed at the ›position where the paths of the principal rays cross when projected backward from their paths beyond the lens. Although a virtual image does not form a visible projection on a screen, it is no sense "imaginary", i.e., it has a definite position and size and can be "seen" or imaged by the eye, camera, or other optical instrument. (from GSU Hyperphysics)
- **Light Gathering Power (LGP)** – a measure of a telescope's ability to collect light. It is proportional to the area of the primary mirror or lens. The greater the LGP, the fainter objects the telescope can detect.
- **Angular resolution** – how clearly a telescope can resolve small details. The smaller the angular resolution, the smaller the details that can be observed.
- **Magnification** – the process of enlarging the apparent size of an object. In astronomy, magnification depends of the focal length of the objective lens of the telescope (F_o) and the focal length of the eyepiece (F_e). Mathematically, $\text{Magnification} = {}^{F_o}/_{F_e}$

- **Refracting telescope** – telescopes that use lenses to collect and focus light. The simplest form of this telescope consists of a tube with an objective lens at one end and an eyepiece lens at the other.
- **Reflecting telescope** – telescopes that use mirrors to collect and focus light. The common form of this telescope consists of a primary mirror at the base of the tube which reflects the light to a secondary mirror which reflects the light out to the eyepiece.

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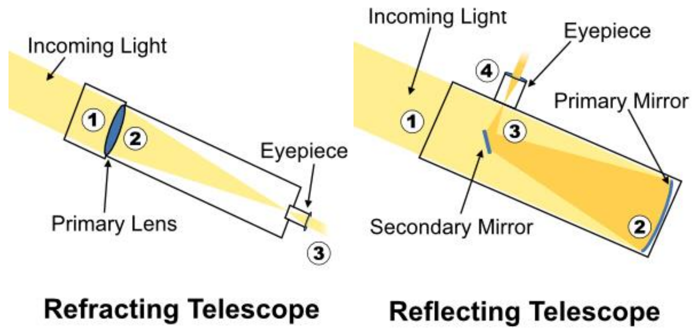
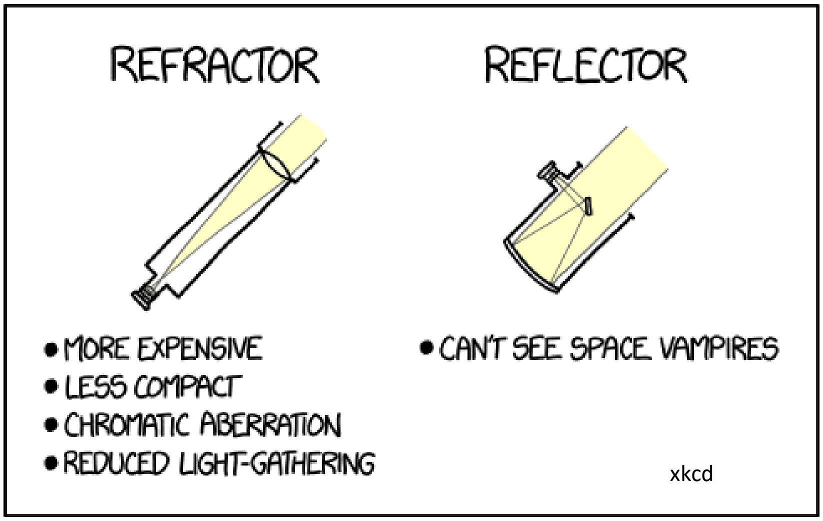




Part 1: Geometric Properties of Simple Lenses

For Part 1 of this activity you will use the Geometric Optics simulator from the University of Colorado – Boulder to investigate image formation and properties of simple lenses. You may need to allow flash (see video in the 'Extra Info' module). The applet can be found here:

https://phet.colorado.edu/sims/geometric-optics/geometric-optics_en.html

At the top of the simulation window you will see a green box that allows you to investigate the basic optical properties of lenses. To move the object, click and drag the left image to move it closer and farther from the lens. The two x's are located at the lens focal point. The **focal point** is the location where parallel light rays from a very distant location such as a star are brought to a focus.

1. How does the image change when the object is moved farther away from the lens?

2. How does the image change when the object gets closer to the lens?

3. When the object is placed at the x representing the lens focal point where is the image formed?

4. When the object is placed between the focal point and the lens what happens to the image? Hint: click on virtual image.

5. Use the slide switch to increase and the diameter of the lens and describe what happens to the image as the lens diameter in increased.

6. What happens to the image when the lens diameter is deceased?

7. Use the slide switch to adjust the curvature (thickness) of the lens. As the lens gets thinner what happens to the image?

8. As the lens gets thinner what happens to the position of the focal points?

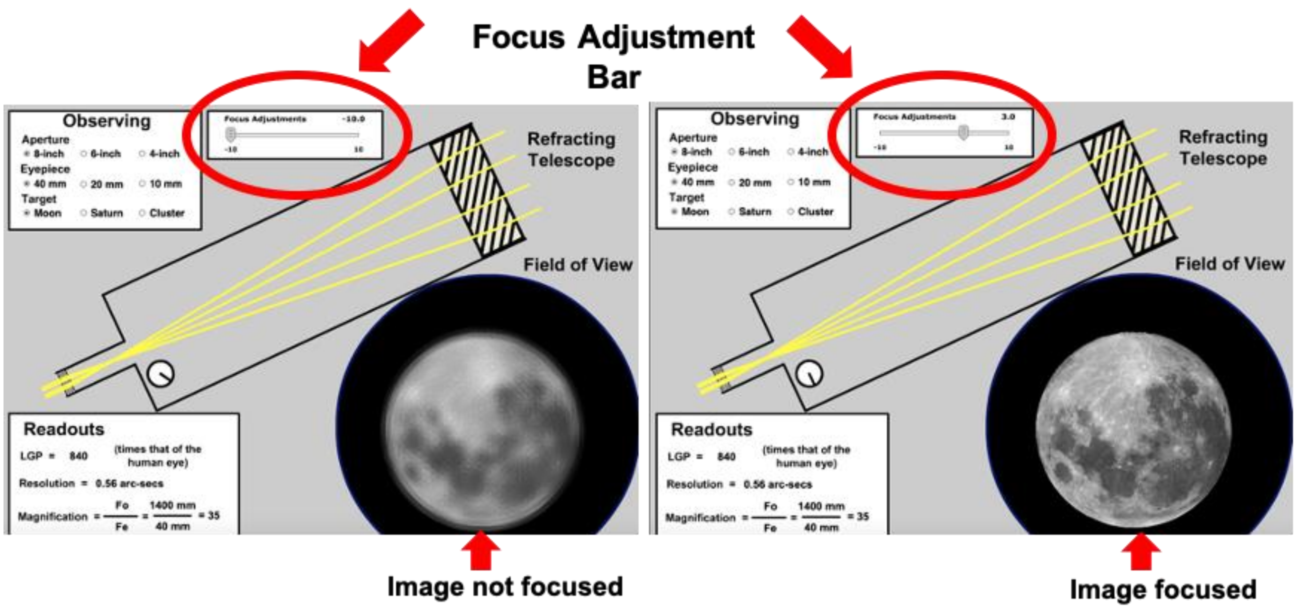
9. Why do you think astronomers build large diameter telescopes?

Part 2: Properties of Telescopes

For Part 2 of the activity you will use a virtual telescope simulator from the University of Nebraska - Lincoln. Be sure the flash setting is set to 'Allow'. The applet can be found here:

http://astro.unl.edu/classaction/animations/telescopes/telescope10.html

Note. After the simulator opens you may need to use the slide the 'Focus Adjustments' bar at the top center to focus the image. Move the bar until the image in your field of view becomes clear and sharp. See example below!



Light Gathering Power (LGP)

As you may know a large bucket catches more rain than a smaller bucket. Telescopes can be thought of light buckets and so a larger diameter telescope catches more light than a smaller diameter telescope.

Start with the 8-inch diameter (aperture) telescope using a 40mm eyepiece and record the number of light rays entering the telescope and the LGP. Repeat for both the 6-inch and the 4-inch telescopes. Record your answers in Table 1.

Table 1. Light Gathering Power of simulated telescopes

Telescope	8-inch	6-inch	4-inch
Number of rays			
LGP			

10. Describe how the light gathering ability of these telescope change as the aperture decreases.

11. Again, start with the 8-inch telescope and describe how the brightness of the image changes as the telescope aperture gets smaller.

Angular Resolution

Angular resolution refers to how clearly a telescope will show tiny details such as planetary features and stars that are very close together.

Starting with the 8-inch telescope record the angular resolution in arcseconds and record your answers in Table 2.

Table 2. Angular resolution of the simulated telescopes

Telescope	8-inch	6-inch	4-inch
Angular resolution (arcsec)			

In the 'Observing' box in the upper left corner of the applet, switch target from 'Moon' to 'Star Cluster'. You will need to refocus using the 'Focus Adjustments' bar.

12. Starting with the 8-inch telescope using a 40mm eyepiece, describe how the clarity of detail visible and the magnification of the image change as you switch to the 6-inch and then the 4-inch telescopes.

13. Which telescope allows you to see the smallest details in its image?

Magnification

The magnification of a telescope depends on the focal length of the objective lens, or mirror, and the focal length of the eyepiece being used to view the image. The magnification of a telescope is calculated using the equation:

$$\text{Magnification} = {}^{F_o}/_{F_e}$$

where F_o is the focal length the objective lens and F_e is the focal length of the eyepiece.

In the 'Observing' box in the upper left corner of the applet, switch target back to 'Moon'. Be sure to refocus the telescope. Starting with the 8-inch telescope and the 40mm eyepiece record the magnification for each of the telescope and eyepiece combinations listed in Table 3.

Table 3. List of magnifications for the telescopes in the simulation

Telescope	Eyepiece focal length (mm)	8-inch	6-inch	4-inch
Magnification	40			
	20			
	10			

14. Which of these telescope and eyepiece combinations provides the highest and lowest magnifications?

    Highest:

    Lowest:

View the Moon and Saturn with each telescope and eyepiece combination, focusing as you switch between telescope and eyepiece combinations.

15. In your opinion, which telescope/eyepiece combination provides the best viewing image of planetary detail?

16. Using the information previously learned about light gathering ability, angular resolution, and magnification justify your selection for the best planetary telescope.

Field of View (FOV)

Every telescope/eyepiece combination has a field of view. This basically means that some combinations provide the ability to see the entire moon or only a piece of the moon. The field of view tells you how much of the sky is viewable in the telescope. Usually the field of view is expressed as an angle such as degrees.

In the 'Observing' box make sure the target is set to 'Moon'. Starting with the 8-inch telescope and the 40mm eyepiece record the field of view for each of the telescope/eyepiece combination listed in Table 4.

Table IV: Field of view for the telescopes and eyepieces in the simulation

Telescope	Eyepiece focal length (mm)	8-inch	6-inch	4-inch
Field of View (degrees)	40			
	20			
	10			

17. Which of these telescope and eyepiece combinations provides the widest and smallest field of view?

Widest:

Smallest:

View the star cluster with each telescope and eyepiece combination to confirm which telescope provides the widest and smallest field of view. Don't forget to focus the telescope as needed.

18. Using the information from Tables 3 and 4, how does magnification affect the field of view?

To complete this assignment for grading:

- File → Save As… → Rename the file 'YourLastName – LensTellLab'
- Upload to the file to the 'Lab 6 –Simple Lenses and Telescope Design' assignment in iCollege (click Add Attachments → Upload → upload renamed saved file → Update).
- Complete the Reflection activity on iCollege