PHY385H1F – "Introductory Optics"
Practicals Day 6 – Telescopes and Microscopes
October 31, 2011

Group Number (number on Intro Optics Kit): ____.

Facilitator Name:________________________________.

Record-Keeper Name:__________________________________. [Turn this sheet in for marks]

Time-keeper:______________________________.

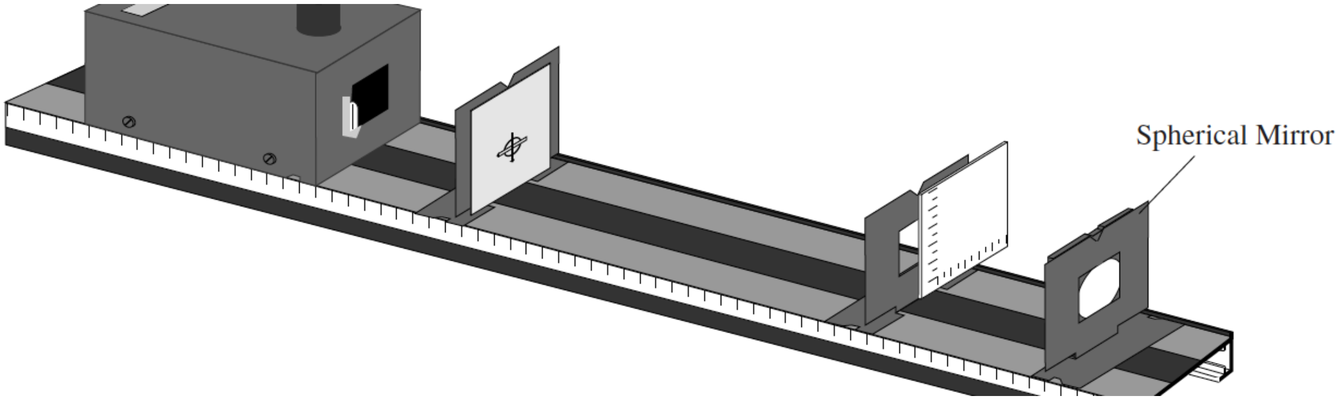
Computer/Wiki-master:________________________________.

Activity 6.1 – Image Formation from Spherical Mirrors

EQUIPMENT NEEDED:

- -Optics Bench, Light Source
- -50 mm F. L. Spherical Mirror
- -Crossed Arrow Target.
- -Component Holder (3)
- -Viewing Screen

Parallel rays can be brought to a focus by a reflective parabaloid of revolution. In this sense, a parabaloid reflector plays the same role as a lens in an optical system. It has a focal length and can be used to form an image of an object. For rays close to the optical axis, a parabaloid of revolution can be *approximated* by a spherical surface. In this activity, we will investigate a concave spherical mirror and apply the thin lens equation to its use in image formation.



Set up the equipment as shown in the figure above, with the concave side of the mirror facing the Light Source. The Viewing Screen should cover only half the hole in the Component Holder so that light from the filament reaches the mirror.

Adjust the position of the mirror until there is a well focused image of the crossed arrow target on the viewing screen. Make measurements of s_o and s_i for four or five values of s_o. In the table on the next page, fill in your measurements s_o, s_i , $1/s_o$ and $1/s_i$. Plot $1/s_o$ versus $1/s_i$ and find the best fit line (linear fit). This should give a straight line with a slope of -1 and a y-intercept equal to $1/f$. What is the measured value of f for this mirror?

Concave Mirror

s_o (with some suggested values)	$1/s_o$	s_i	$1/s_i$
400 mm			
300 mm			
200 mm			
150 mm			

Inferred value of f:______________________.

From this, what do you expect is the radius of curvature of this mirror? R = ________________________.

Activity 6.2 – The Telescope

EQUIPMENT NEEDED:

- -Optics Bench
- -150 mm Focal Length Convex Lens
- -75 mm Focal Length Convex Lens
- -Component Holders (2)

Telescopes are used to obtain magnified images of distant objects. The image of a distant object when viewed through a single converging lens will be focused nearly at the focal point of the lens. This image will be real, inverted, and reduced in size. In fact, the greater the distance of the object (with respect to focal point **f**), the smaller the size of the image.

However, this reduced image is useful. By viewing this image through a second converging lens—used as a magnifier—an enlarged image can be seen.

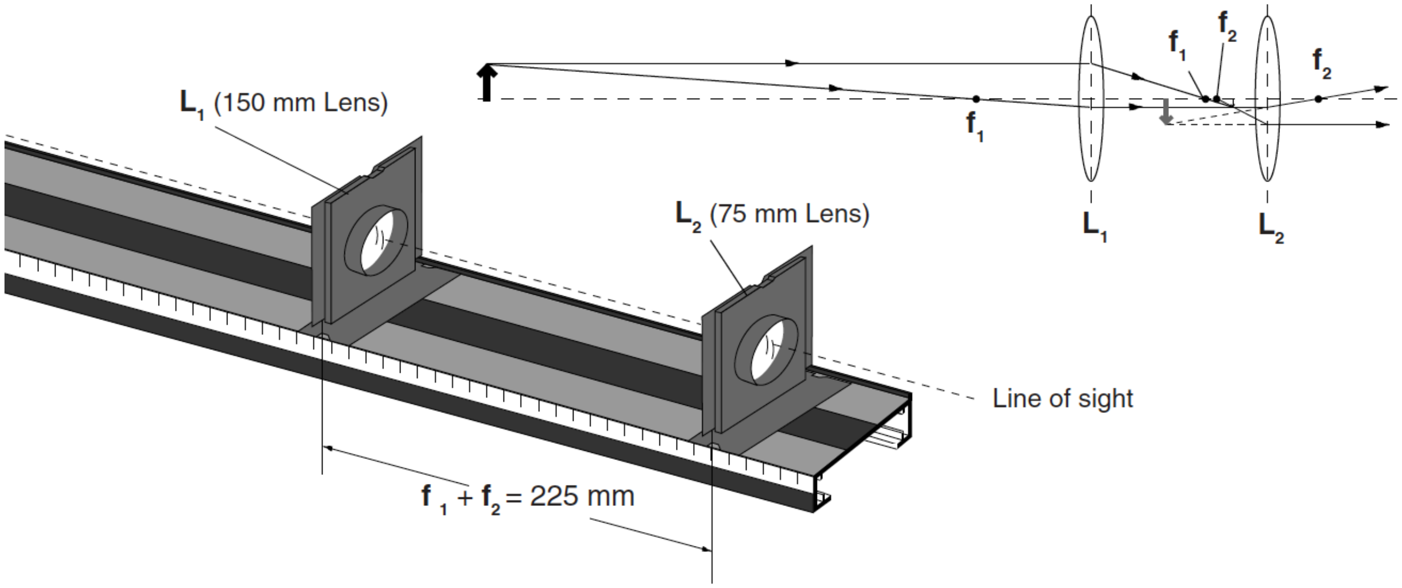


Figure 1. The Telescope

Figure 1 shows the setup for a simple telescope. The objective lens, **L$_1$**, creates a real, inverted image. (You can barely see this image in the diagram. It's very small, just inside the focal point of lens **L$_2$**.) If the object is sufficiently far away, this image will be located approximately at **f$_1$**, the focal point of **L$_1$**. The eyepiece, **L$_2$**, then acts as a magnifier, creating a magnified, virtual image which can be viewed by the observer. For maximum magnification, **L$_2$** is positioned so the virtual image is just slightly closer than its focal point, **f$_2$**. Therefore, the distance between the objective lens and the eyepiece of a telescope, when viewing distant objects, is approximately $f_1 + f_2$.

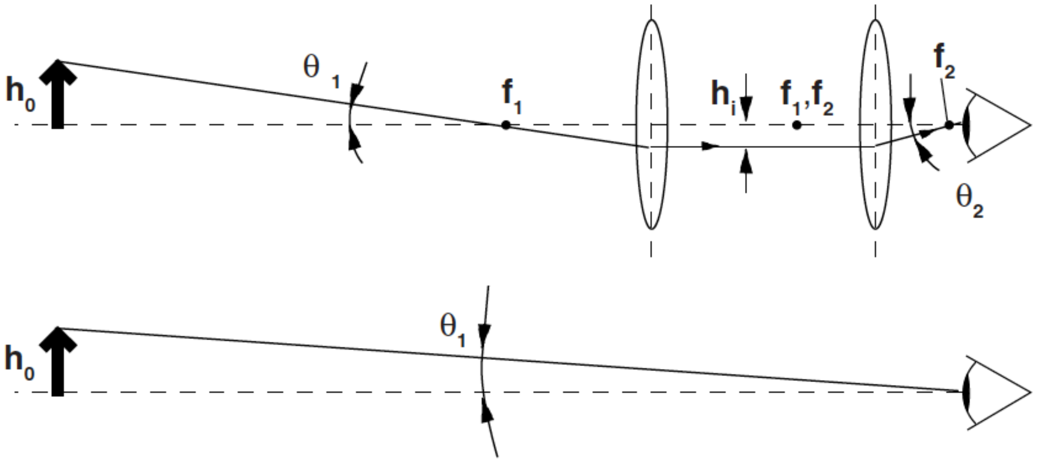


Figure 2. Telescope Magnification

The angular magnification for a telescope can be approximated by assuming the lenses are exactly $f_1 + f_2$ apart, as shown in Figure 2. The height of the object as seen with the naked eye is proportional to the angle θ_1 in the lower diagram. If the distance from the object to the telescope is large, much larger than is shown in the diagram, then θ_1 is the same in both diagrams, to a good approximation. The ray shown in the upper diagram passes through the focal point of the objective lens, comes out parallel to the optical axis of the telescope, and is therefore refracted by the eyepiece through the focal point of the eyepiece. The angle θ_2 is therefore proportional to h_i, the height of the image seen by the observer.

PROCEDURE:

A. Using Figure 2, calculate tan θ_1 and tan θ_2 as a function of the height of the image, h_i, and the focal lengths of the two lenses, f_1 and f_2.

Assume that θ_1 and θ_2 are very small, and therefore equal to tan θ_1 and tan θ_2, respectively.

B. Calculate the angular magnification of the telescope, MP = θ_2/θ_1.

Set up a telescope using the 75 mm and 150 mm focal length lenses; the distance between the lenses should be approximately 225 mm. Using the 75 mm lens as the eyepiece, look at some reasonably distant object. Adjust the distance between the lenses as needed to bring the object into sharp focus.

To measure the magnification, look with one eye through the telescope, and with the other eye look directly at the object. Compare the size of the two images. (If a repeating object is used, such as venetian blinds or bricks in a wall, you should be able to estimate the magnifying power fairly accurately: if 3.5 bricks viewed without the telescope overlap with one brick viewed with the telescope, then MP = 3.5×.)

C. What do you measure as the magnification of the telescope when using the 75 mm lens as the eyepiece? Compare with the prediction of Part B.

D. What is the magnification of the telescope when using the 150 mm lens as the eyepiece and the 75 mm lens as the objective lens? Compare with the prediction of Part B.

Activity 6.3 – The Compound Microscope [Parts D, E, F if you have time]

EQUIPMENT NEEDED:

- Optics Bench
- 150 mm Focal Length Convex Lens
- Variable Aperture
- 75 mm Focal Length Convex Lens
- Component Holders (3)
- Viewing Screen

A compound microscope uses two lenses to provide greater magnification of near objects than is possible using a single lens as a magnifier. The setup is shown in Figure 3.

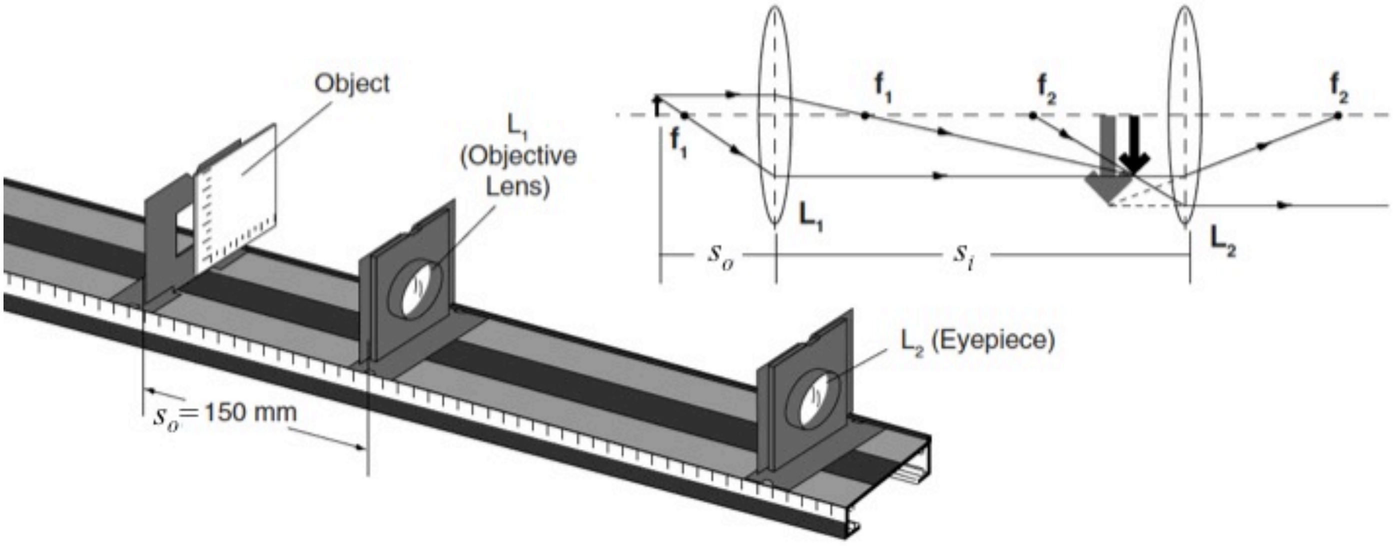


Figure 3. The Compound Microscope

The objective lens, L_1, functions as a projector. The object is placed just beyond the focal point of L_1 so a real, magnified, inverted image is formed. The eyepiece, L_2, functions as a magnifying glass. It forms an enlarged virtual image of the real image projected by L_1.

The real image that is projected by L_1 is magnified by an amount $M_{T1} = -s_i/s_o$, as indicated by the Thin Lens Equation. That image is in turn magnified by the eyepiece by a factor of MP = (25 cm)/f_2 (see Hecht Section 5.7.3 The Magnifying Glass). The combined magnification is, therefore:

$$\text{MP} = \left(-\frac{s_i}{s_o}\right)\left(\frac{25\text{cm}}{f_2}\right).$$

Set up the microscope as shown in Figure 3. Use the 75 mm focal length lens as the objective lens and the 150 mm focal length lens as the eyepiece. Begin with the objective lens approximately 150 mm away from the object (the Viewing Screen). Adjust the position of the eyepiece until you see a clearly focused image of the Viewing Screen scale.

A. Is the image magnified? How does the magnification compare to using the 75 mm focal length lens alone, as a simple magnifier?

While looking through the eyepiece, slowly move the objective lens closer to the Viewing Screen. Adjust the position of the eyepiece as needed to retain the best possible focus.

B. Why does the magnification increase as the objective lens is moved closer to the object?

C. What focusing problems develop as the magnification increases?

Use the Variable Aperture to restrict the path of light to the central regions of the objective lens. Vary the size of the aperture and observe the effects on focusing.

D. What effect does the aperture have on focusing?

E. What effect does the aperture have on the brightness of the image?

F. What advantage would there be in using a 75 mm focal length lens as the eyepiece?