Introduction to Astronomy	Laboratory Exercise #4
Name ___________________________	Date _______________
Partners _________________________	Section _____________

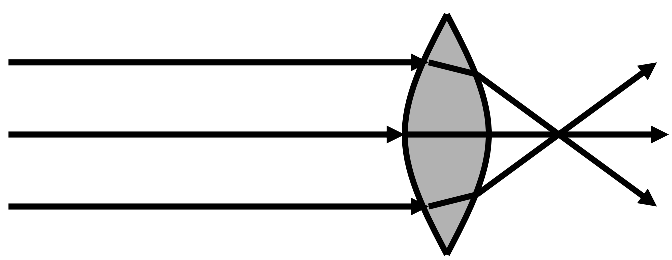
Optics and Telescopes

Purpose:
To understand the basics of thin lens optics and its application to the operation of a telescope.

Equipment:

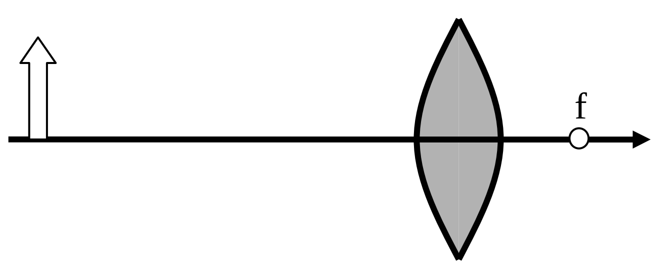
150 mm lens	Optics Track	Meter Stick
75 mm lens	2 Component Holders	Viewing Screen

Background:
Lenses use the principle of refraction to redirect light that passes through them. Parallel light rays traveling through a converging lens is directed to a single point called the focus of the lense.



If a ray of light travels through the center of a lens, the direction of travel for the light will be unaffected. Using these two principles it is possible to determine the location of an image formed by a converging lens.

Exercise:
Part 1: Determine the image point using ray optics.
On graph paper draw an upright arrow, lens, and a line going through the axis of the lens as illustrated below. This diagram should be located in the upper half of the graph paper as it in placed in a landscape orientation. Place the lens at the center of the diagram, the arrow at a distance of 8 cm to the left of the lens. Make the arrow 2 cm tall. Place the focal point 3 cm to the right of the lens.



From your graph determine the location of the arrow's image by drawing a parallel ray from the tip of the arrow to the lens. At the lens continue the ray from the lens through the focal point and beyond. Next draw a ray from the tip of the arrow to the center of the lens. Continue this line through the lens. The location where the two rays intersect corresponds to the image of the arrow's tip.

Repeat this process for the middle of the arrow. From the image point of the arrow's tip and middle point, draw an image of the arrow at the image point.

Mathematically this image point can be calculated with the formula

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \qquad \text{or} \qquad d_i = \frac{d_o f}{d_o - f}$$

where f is the distance to the focal point, d_o is the distance to the arrow and d_i is the distance to the image of the arrow.

The size of the arrow is equal to $h_i = -\frac{d_i}{d_o} h_o$

	Focal Length	Object Point	Object Height	Image Point	Image Height
Graph	3 cm	8 cm	2 cm		
Calc	3 cm	8 cm	2 cm		

Draw a second diagram on the bottom half of the graph paper and repeat the process with an object height of 2 cm, object point of 4 cm and an focal length of 5 cm.

	Focal Length	Object Point	Object Height	Image Point	Image Height
Graph	5 cm	4 cm	2 cm		
Calc	5 cm	4 cm	2 cm		

If the lines do not cross, then extend the lines backwards through the lens to see if they intersect on the same side of the lens as the object is.

Question #1: Does the calculated values of the image height and location match the values obtained from the graph paper?

Question #2: Which of the two arrangements would be affective as a magnifying glass? Why?

Part 2: Optics bench

Place on the optics bench a light source, an arrow target, a 75 mm focal length convex lens and a image screen. Place the arrow target next to the light source and place the convex lens at a distance of 300 mm from the the arrow target. Next slide the image screen from the far end of the optics bench toward the convex lens until you get an image to form on the screen. Record the distance between the lens and the screen as well as the height of the image. Use the diameter of the circle around the arrow as the image height.

Repeat this process for several different object distances. Verify the results by using the mathematical formulas for image location and image height.

	Focal Length	Object Point	Object Height	Image Point	Image Height
Bench	75 mm	300 mm	10 mm		
Calc	75 mm	300 mm	10 mm		

	Focal Length	Object Point	Object Height	Image Point	Image Height
Bench	75 mm	200 mm	10 mm		
Calc	75 mm	200 mm	10 mm		

	Focal Length	Object Point	Object Height	Image Point	Image Height
Bench	75 mm	100 mm	10 mm		
Calc	75 mm	100 mm	10 mm		

	Focal Length	Object Point	Object Height	Image Point	Image Height
Bench	75 mm	50 mm	10 mm		
Calc	75 mm	50 mm	10 mm		

Question #3: Is there agreement between the experimental results from the optics bench and the calculated values?

Question#4: Did all possible object distances give an image? If not, what condition must be true for you to get an image with a convex lens?

Part 3: The Telescope

A telescope uses a combination of two converging lenses to provide magnification. The magnification arises from the ability to increase the angle at which light enters the eye.

Normally the eye can not focus on objects closer than the "near point" of the eye. For most people it is around 25 cm. Place your eye at the end of the optical bench and slide the arrow target away from your eye until you can clearly see the arrow. Write down the location of the target. This should be at the "near point" of your eye.

Near Point = ______________

Next place the 150 mm focal length lens at the end of the optics bench and place the arrow target on the far side of the lens. Slide the arrow target until you get a clear view of the arrow through the 150 mm lens. Write down the distance of the arrow target with respect to the end of the optics bench. Repeat the procedure with the 75 mm lens.

Target with 150 mm lens = _____________

Target with 75 mm lens = _____________

The magnification of the target is based on the proximity of the target and the ability of the lens to provide additional convergence so your eye can bring the target into focus. The angular magnification is given by the following formula.

$$\frac{\theta_{mag}}{\theta_{eye-\max}} = \frac{\text{Near Point}}{\text{Lens Focal Length}}$$

Question #5: Which lense gave you the largest magnification of the arrow target? What was its magnification?

Question #6: How could you measure the magnification of the arrow target directly?

The telescope uses the first lense to form an image of a far away object. This image will be fairly close to the focal point of the first lens, f_1. The second lens with focal length of f_2 is then used as a magnifier, which is placed a distance f_2 from the image point of the first lens. Therefore, for a telescope the two lenses will be close to $f_1 + f_2$ apart. This combination of lenses will provide an angular magnification of

$$\frac{\theta_{tele}}{\theta_{w/\,out\ tele}} = \frac{\mathrm{f}_1}{\mathrm{f}_2}$$

Place the two lenses 225 mm apart on the optics bench. Use your telescope to look at a distant object by placing your eye next to the 150 mm lens (eyepiece) and looking towards the 75 mm lens (objective lens). Adjust the distance between the two lenses until you get a clear image. Repeat the same procedure with the 75 mm lens closest to your eye.

Question #7: Which lens being closest to your eye, gave you a magnified object?

Question #8: The Dobsonian telescope used for class has an objective focal length of 1200 mm. What kind of magnification do you get with a 25 mm eyepiece and with a 10 mm eyepiece?