PHSC 2105 **Lenses and Image Formation** **Name:**______________________

Object: (1) To use a converging lens to form images and to compare the measured position of each image with theory, and (2) construct some optical instruments and note their magnification.

Theory: The focal point of a converging lens is defined as that point where a beam of incoming parallel light rays will be brought to a focus. For a diverging lens, a beam of parallel light rays will be spread out such that it will appear to diverge from a focal point located in front of the lens.

Since lenses can bend light rays as stated above, it is therefore possible to form images using lenses. The location and nature of an image formed by a lens can be predicted either from a ray tracing diagram or by means of a lens equation.

To locate the image by diagram, three rays (known as the principal rays) are drawn:

- A parallel ray is drawn from the top of the object parallel to the optic axis of the lens. When this ray passes through the lens it is bent so as to pass through the primary focal point.
- A central ray is drawn from the top of the object toward the center of the lens. It passes through the lens undeviated.
- A focal point ray is drawn from the top of the object through the secondary focal point. When it passes though the lens it will emerge traveling parallel to the lens axis.

The three principal rays are not the only rays coming from the object, but they are sufficient to determine the location and nature (magnification, orientation, real/virtual) of the image.

The location and nature of the image can also be found using the *thin-lens equation*, which relates together the object distance s, the image distance s', and the lens focal length f:

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}. \tag{1}$$

If the image is on the opposite side of the lens from the object, s' is considered to be positive (real image); if on the same side, then negative (virtual image). Also, f is positive for a converging lens and negative for a diverging lens.

The magnification of the image is calculated from the ratio of the image distance to the object distance or from the ratio of the image height h' to the object height h:

$$M = -\frac{s'}{s} = \frac{h'}{h} \tag{2}$$

M will be positive if the image is erect and negative if the image is inverted.

Note: we use s for the object distance, but there are other notations, such as d_o or just o; likewise, we use s' for the image distance, but you might see d_i or just i by other authors.

Care of Equipment: Try to touch the lenses only on the edges to avoid fingerprints on the refracting surfaces. Please also make sure each lens is returned to its proper paper slip cover and back in the bag or box it came from. The ground glass screens are also delicate and expensive.

Procedure for the Single Converging Lens:

1. Measure the focal length of your converging lens by placing a lighted object on one side of the lens, and a viewing screen on the other. Adjust the positions of the lens and screen until the object and the focused image are the same distance from the lens. Record s and s' (they should be the same number). Under these conditions the focal length will be one-half the object distance (or one-half the image distance since they are the same in this case). Measure f carefully for your upcoming predictions to be good.
2. Use equation 1 to calculate the image distance s' when $s = 50.0\,\text{cm}$ and when $s = 25.0\,\text{cm}$.
3. Position a lighted object on the optical bench at each of the distances specified in procedure 2. Locate the image on a viewing screen and measure the image distance in each case. Compare your measured results with the results predicted in procedure 2. Find the percent difference for each case.
4. Use your calculated s' and s (from procedure 2 and equation 2) to calculate the image magnification when $s = 50.0\,\text{cm}$ and when $s = 25.0\,\text{cm}$.
5. Use a ruler to measure the height of the object and image; record the measured magnification. Find the percent difference for each case.
6. Predict (*pre* means before you do the experiment) what will happen to the image if you use a piece of opaque paper to cover the bottom half of the lens when $s = 25.0\,\text{cm}$, and also if you cover the lens with an opaque paper with a 2 cm diameter hole cut in the center. Record your predictions. Then do the experiment and record what really happened.
7. Calculate the image distance when $s = 10.0\,\text{cm}$. What will be the nature of this image?
8. Position the lighted object and lens on the optical bench with $s = 10.0\,\text{cm}$. Can you locate the image on a viewing screen? Explain. How did you eventually see this image?

Procedure for Multi-Lens Optical Instruments:

1. Construct a *compound microscope* on a meter stick using a converging lens with $f = 5\,\text{cm}$ for the objective lens and a converging lens with $f = 10\,\text{cm}$ for the eyepiece. First observe the magnifying power of the eyepiece alone by using it as a magnifying glass near a printed page. Note any difference between looking through the center of the lens and its periphery.

   Then mount the eyepiece about 25 cm from the end of the meter stick and mount the objective lens just more than its focal length away from the end of the meter stick. Tip the meter stick so it is vertical and look down through your microscope on a printed page and adjust the position of both lenses until you get a sharp focus. Note the magnification.

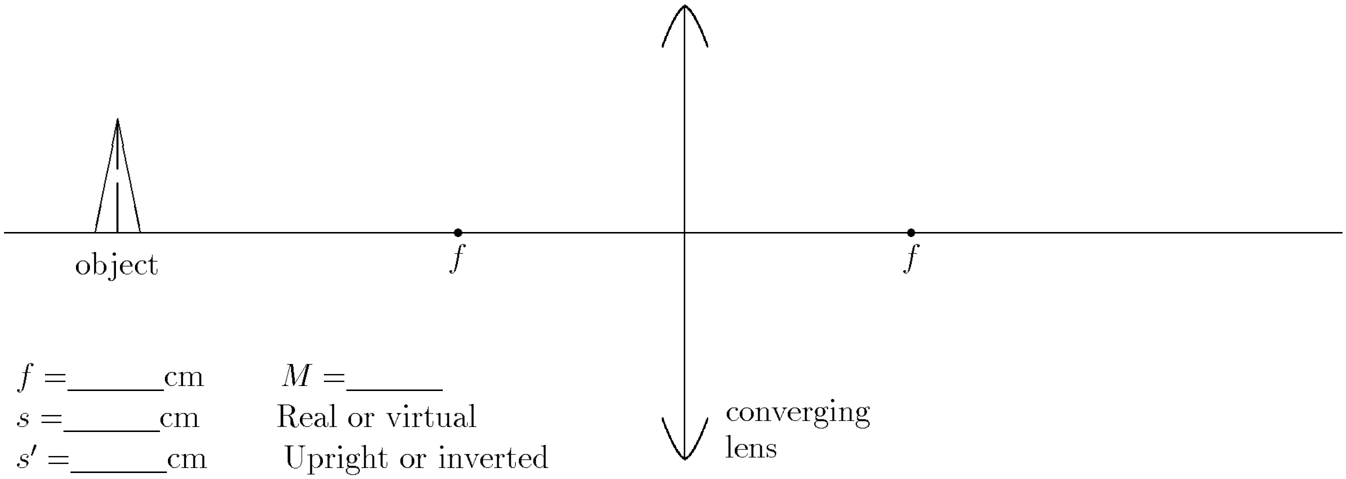
2. Construct a *simple (or astronomical) telescope* on a meter stick using a converging lens with $f = 5\,\text{cm}$ for the eyepiece and a converging lens with $f = 30\,\text{cm}$ for the objective lens. Look

through the combination at a distant object and adjust the position of both lenses until you get a sharp focus. What do you notice about the image, its magnification, and your field of view?

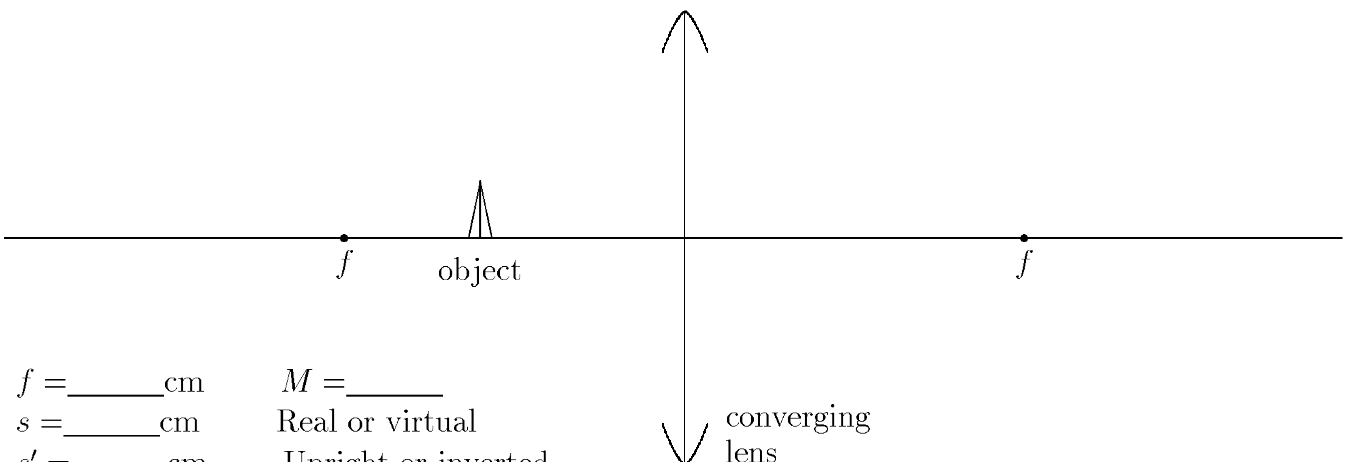
3. Construct a *Galilean telescope (or opera glass)* on a meter stick using a diverging lens with $f = -10\,\text{cm}$ for the eyepiece and a converging lens with $f = 30\,\text{cm}$ as the objective lens. Look through the combination at a distant object and adjust the position of both lenses until you get a sharp focus. What do you notice about the image, its magnification, and your field of view?

Conclusions: Comment on your success with today's lab. Were your predictions correct? How important have lenses been in the advancement of science throghout history?

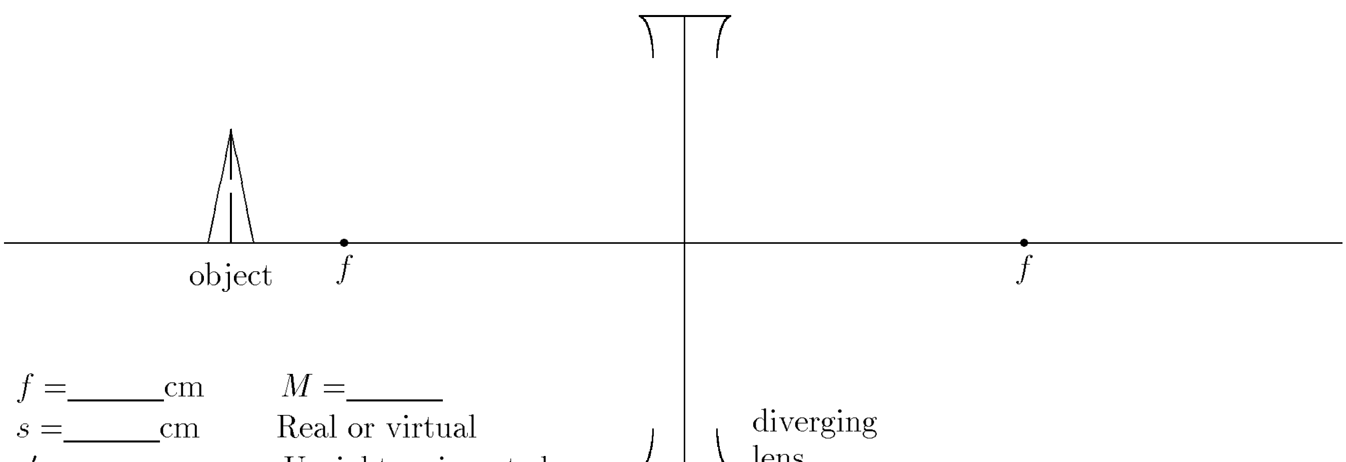
Practice: For each of the lenses shown below, use a straight edge to draw the three principal rays and locate and label the image. Measure the distances with a ruler. Verify the thin-lens equation.



$f =$______cm $M =$______
$s =$______cm Real or virtual
$s' =$______cm Upright or inverted



$f =$______cm $M =$______
$s =$______cm Real or virtual
$s' =$______cm Upright or inverted



$f =$______cm $M =$______
$s =$______cm Real or virtual
$s' =$______cm Upright or inverted