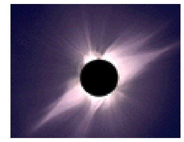
Spring 2001

Telescope workshop

Astronomy & Cosmologies



Adapted from Grinnell College optics workshops, Phil Pearl's thin lens workshop, and Dale Ferguson's telescope workshop.

This workshop is designed to let you see how lenses affect light. By bending light rays, lenses can focus light (onto camera film...), form images (on your retina...), defocus light (useful in some corrective lenses), and change the sizes of images (telescopes, microscopes...) Lenses let us more clearly see objects that are too distant or too small for naked eyes. They bring the stars to earth.

Do parts A and B below; leave C for the very end in case you have extra time, maybe design some investigations of your own... and (D) turn in the survey before you leave. Have fun!

Astronomy home
Syllabus
Research
Groups
Workshops
Web-X
InQsit
Links
Evergreen Library
Evergreen home

Learning GOALS:

A. To experience image formation by lenses.
B. To build a simple refracting telescope.
C. To better understand the behavior of light and lenses.
D. To develop your teamwork skills and reflect on your learning.

EQUIPMENT:

- *assorted lenses and/or magnifying glasses*
- *blank 3x5 cards (or other opaque white screens)*
- *rulers and meter sticks*
- *a lamp to shine on a clock on the wall*
- *illuminated arrows, lens holders, optical benches*

ACTIVITIES:

A. Make a real image *By holding a lens at the window, and placing a screen behind the lens at the focal distance, you can see that a real image appears on the screen.*	B. Make a telescope *If you remove the screen, the real image is still there in space, and it can be examined with a magnifying glass. That is a telescope. Make one.*
C. Further investigations *Play with different lenses. If you have time, investigate how the relative positions (and focal lengths) of lenses affect image locations and sizes, more carefully and quantitatively.*	D. Reflect on your individual and team work. Fill out a workshop feedback form with your team.

A. Real image forms at the focal point of a convex lens.

Light bounces off a tree (for example) in all directions, The few light rays that reach you from a distant tree are traveling nearly parallel to each other. When those parallel rays come through your lens, the lens will focus them at some point in space. If you move a card to that point, you can see that the focused rays form an image (on the card) of your object (the tree). ***The focal length is*** *the point at which the lens will focus distant light (parallel rays) into an image. The focal length (f, or focal point) of a lens turns out to be half the radius of curvature R of the lens.*

Measure the focal lengths of several lenses: Choose convex lenses. You can feel that they curve out, not in (concave), on both sides, even if you can't see the curvature.

- Go to the window or stand outside in the shade. Choose a distant, sunlit object such as a tree.
- Hold a lens in one hand and a 3x5 card in the other, and vary the distance between them until a clear image forms on the card. Is the image upright or inverted? What else do you notice about the image? Light rays actually converge in space at the position of this image, so we call it a 'real' image. The screen reflects these light rays into your eyes.
- Have a partner measure the distance between the card and the (center of) the lens. Write down which lens has which focal length.
- Discuss what you see and write down your observations.

Imagine putting camera film or your retina in place of the card. The light of the image elicits an electromagnetic or chemical response from the surface it falls on. Notice that the point where objects focus appears independent of their color or size.

(B): A simple refracting telescope has an eyepiece focused on the focal point of the objective lens.

Get at least two convex lenses, one highly curved (small f: the eyepiece) and a flatter one, with a very slight curve (large f: the objective lens).
You might use a magnifying glass for one of your convex lenses. You might even find a concave lens that works.
What are your focal lengths? Be sure to measure them with a very distant light source!

Fix the **flatter** (objective) **lens** (longest f) on the optical bench and use your 3x5 card to **find the image of a distant object** (e.g. an illuminated wall clock inside, if the trees outside are too dim). If you don't have an optical bench, have one partner hold the lens still at the 0 end of a meter stick, and the other partner measure the location of its image.
Then put your highly curved **eyepiece lens** (shortest f) in place of the card, at the original image location.
Look straight through the eyepiece and objective **at your distant object**. The eyepiece directs the image light into your eyes as parallel rays when it is properly located. How far back do you have to move it to see a clear, magnified image?

Does it look like the object is closer or further?

.

Larger or smaller?

.

Move the lens and your eye around until you can see the effect clearly. Help your partner see it. Discuss what you see and write down your observations.

.

.

Magnification: Try to see the clock itself in the same field of view as your magnified image of the clock, one with each eye.
Estimate how much bigger the image appears than the object.

.

The ratio M= (-image size/ object size) is the magnification. How does M compare to the ratio of your lenses' focal lengths?

.

.

Look through your neighbors' telescopes. How does their magnification compare with yours?

.

.

Find out the ratio of the focal lengths of their lenses. What does this have to do with your different magnifications?
.

(C): More advanced investigations

(1) Object at p, image at q: *You have seen that images of distant objects form at the focal point of a lens.* ***Images of close objects*** *form not at the focal point, but at a point that depends on the distance between the object and the lens. The lighted arrows are convenient objects for investigating this.*

- Mount a lighted arrow on one end of the optical bench, and a card on the other (no lens yet).
- Move the card back and forth; can you get an image of the arrow to focus clearly on the card?
- Now choose a lens to mount between the card and the lighted arrow, at some arbitrary distance.

(a) Move the lens and/or the card around until you get a clear image of the arrow on the card.
Measure the object distance, p, between the object and the lens, and the image distance, q, between the image and the lens, and keep track of them.

	first trial	second trial	third trial
p	.	.	.
q	.	.	.
f	.	.	.

(b) Move the lens away from the light (increase p). Where do you have to move the card to find the image?
Does q increase or decrease? Does the image get bigger or smaller?

(c) Remember to record the focal length f of your lens for each trial.

(d) Discuss your observations and write down a sentence that summarizes - in words - how the object distance depends on the image distance.

(2) Thin lens equation: $(1/f) = (1/p) + (1/q)$

Check this relation by calculating $(1/p) + (1/q)$ for (a) and (b) above.
How do your results compare to the focal length f of your lens? The results may not match perfectly. Why not?

(3) Magnification *$M=(-q/p)$ = relative size of image, compared to object, as you may have discovered above. Since the image and the object subtend the same angle from the lens, the larger of the two is further away. An object close (small p) to the lens (but not inside the focal length...) yields a large image (large q) far from the lens (consider a magnifying glass). An object far from the lens (large p) yields a small image close to the lens (small q).*

Calculate the magnification M for your setup above.
How does it compare to your observations about the relative size of the image and object, and their respective distances from the lens?

(4) Signs: *Your p and q (and f) are positive numbers (for real objects and images, and converging lenses), so your M is negative.*
Does negative M correspond to an upright or inverted image?

(5) Predictions and tests: Pick a different lens whose f you know. Mount it a fixed distance p (greater than f) from your lighted arrow. Use the simple equation above to predict where the image will be (calculate q). Check your prediction by moving the card around until you find the image, to measure q. How do your results compare? How does the magnification change? What could contribute to a slight mismatch between your calculations and your observations?

(D): Reflect on your individual and collaborative work.

(1) What did you learn, and how? Reflect about your own questions, participation, and ideas. **Write a reflective paragraph** in your notebook about your work today. Be specific.

(2) What did you learn about working in your **small group**? Discuss with teammates what went well and what you'd like to do differently next time. Tell me about it on your blue workshop feedback form.

(3) What did you learn from sharing information with nearby tables and the **rest of the class**?

(4) Help your small team fill out a blue workshop feedback form.

Maintained by: E.J. Zita