

Introduction

In this lab, you will make your own telescope and measure its performance (Experiment A). You will study your own eye as an optical instrument and measure the distance on your retina from the fovea to the “blind spot” (Experiment B). Lastly, you will study a model of the eye, and examine the ability of the lens to bring an object into focus at different distances. You will study how an abnormal eyeball causes blurred vision and how to correct this (Experiment C). There is only one station with the model of the human eye. Whenever that station becomes available, take a few minutes at that station to perform Experiment C.

Experiment A: Building a Telescope

Pre-Lab Homework:

1. Starting with the definition of magnification (Eqs. 24.8–24.9), derive the equation below for the magnification of a telescope (Hecht, pg. 976).

$$M_A = -\frac{f_O}{f_E}$$

What is the significance of the negative sign?

2. List as many similarities and differences as you can between half of a pair of binoculars and the telescope you will build in this lab. Compare the function of the objective of a telescope with the objective of a microscope. Compare the function of the eyepiece in both instruments.

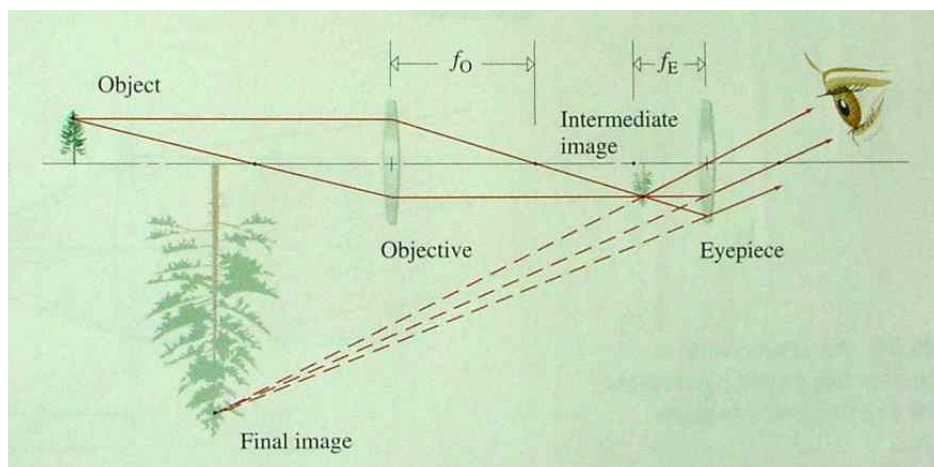


Figure 24.30 from Hecht, pg. 975.

Materials:

The following materials are included in the telescope kit for each person:

- Two cardboard tubes (a smaller one that slides inside the larger one)
- A 4-cm-diameter positive lens
- A 1.7-cm-diameter positive lens
- Additional support materials (foam, red piece to hold the lens, cardboard spacer, etc.)

*Experiment A (continued):**Procedure and Questions:*

Determine which lens is the objective and which is the eyepiece.

The procedure for measuring focal lengths (as in the previous lab) is briefly repeated here: Hold the lens in front of a white board or wall, and – by moving the lens – focus a distant light source on the wall. The distance from the lens to the wall is the focal length.

- A1. Measure and record the focal lengths of the objective lens and *both orientations* of the eyepiece lens (flat side vs. curved side facing the light source). (Note that the eyepiece has two different orientations, and so cannot be considered a thin lens. Its focal length and the image quality it can create depend on how it is used.)
- A2. Based on the focal lengths of the lenses, calculate the magnification you expect your telescope to achieve.

Now, attach the objective to the larger tube and the eyepiece to the smaller tube. Slide one tube inside the other and look through the telescope towards a distant object. Adjust the distance between the lenses by sliding the smaller tube inside the larger one until you can see a focused image. Ask your TA for help if you cannot get an image into focus.

- A3. Once the image is in focus, measure the distance between the lenses. How does that length compare to the sum, $f_O + f_E$?
- A4. Is the image you see erect or inverted? Can you think of applications where an inverted image would not matter?
- A5. Try using the telescope with the both flat and curved sides of the eyepiece facing your eye. If you can see a difference, describe which configuration makes the “better” images and leave the telescope in this configuration.

Use the following procedure to measure the magnification of your telescope:

1. If the image is too wobbly, brace the telescope against a rigid support or set it on a stool.
 2. Point the telescope at the brick wall of the building opposite the lab (outdoors).
 3. Look through the telescope with one eye, and look straight at the brick wall with the other eye. This is often very tricky! If you are having trouble, just open one eye at a time to examine each image in turn. (Your brain is receiving different information from each eye. Your brain is not used to this and will struggle to sort out what to do. In fact, this is also an exercise that will help you understand how your brain processes visual information.)
 4. Now, open both eyes at the same time and “superimpose” the two images. One image is magnified with respect to the other and the normal-sized bricks are “inside” the magnified brick.
 5. Count how many of the non-magnified bricks (seen with the naked eye) fit vertically “inside” of the magnified brick. This number is the magnification.
- A6. What is the actual magnification of your telescope? How does this compare to the magnification you predicted in A2?

Experiment A (continued):

- A7. Comment on the image formed by the telescope. Is it sharp at the center and at the edges? Are there any distortions? Does it gather and deliver more light to your retina than your unaided eye? Would that be of any practical use? Are there things that you can see better with it than without it?

Experiment B: Determining Your Blind Spot**Pre-Lab Homework:**

- Measure your own “near point” and “far point.” If you wear corrective lenses, do this twice, once with them on and once with them removed. Comment on the type of lenses you wear (are they positive or negative?). If you have perfect vision try to convince an optically challenged friend to perform this for you and comment on their vision with and without lenses.
- An optometrist measures the power of a lens in diopters (D). The formula defining diopters is:

$$\text{lens power (in diopters)} = 1 / \text{focal length (in meters)}$$

For example, if $f = -50$ cm, lens power = -2.0 D. Assume that the distance from the lens of your eye to the retina is 1 inch (in effect, the image distance). Calculate the power of the lens in your eye (in diopters) for both your far point and near point. The difference between these two lens powers is called the “power of accommodation” and it decreases with age, as shown in the table below:

Age (years)	10	15	20	25	30	35	40	45	50	55	60	65
Accommodation (D)	14	12	10	8.5	7	5.5	4.5	3.5	2.5	1.7	1.0	0.5

Does your power of accommodation agree with the table?

Procedure:

At least one person in each group must measure his/her blind spot. Keep your eyeglasses or contacts on if you wear them.

- Stand about 2-3 meters from the white board.
- Have your lab partner make a 1-inch solid dot in the middle of the white board.
- Cover your left eye with your hand and stare at the spot on the board with your right eye. (This puts the image of this point on the fovea where vision is most acute.)
- Have another lab partner point the laser beam at the spot on the board. (Do not point the laser beam at anyone’s eyes, ever!)
- While continually staring straight ahead at the dot on the board, have the other lab partner slowly move the laser beam horizontally to the right. Do not move your eye to follow the laser beam. (This is cheating and will not help you find your blind spot.)
- At a certain point, the laser beam will disappear from your field of vision. When this happens, have your lab partner mark this spot on the white board. This is because the image of laser beam falls on the blind spot of your eye. (The blind spot is where the optic nerve reaches the retina and so, there are no receptor cells.)
- Have your partner continue to move the laser to the right and, eventually, the laser beam will reappear in your field of vision. Mark this spot on the white board as well.

Experiment B (continued):*Questions:*

- B1. Measure the distance from your eye to the board and the distance from the spot you were staring at and the beginning of your blind spot.
- B2. Assuming the focal length of your relaxed eye is 25 mm and the distance from the retina to the fovea is also 25 mm. Using this model of the eye and similar triangles, calculate the distance on the retina between the fovea and the optic nerve.

Experiment C: The Human Eye Model*Pre-Lab Question:*

- 5. When your eyes are relaxed do the lenses have their largest or their shortest focal lengths? In this state can you see more clearly at a distance or up close? Is the lens at its fattest or thinnest?

The eyeball model allows you to simulate and observe many of the functions of the eye on a large scale. The human eye varies the lens shape (and hence the focal length) to sharply focus the image on the fovea. The model has a flexible water-filled lens that can be made thicker or thinner by adding or removing water using the syringe at the base. A card at the back of the eye is marked with a circle for the fovea and a black spot for the blind spot. The total length of the eye can be changed to simulate myopia and hyperopia.

Procedure and Questions:

The eyeball should be setup for a normal shaped eye. Check that the slot is set at the midpoint at the top of the model. Adjust the focus of the lens so that a distant object (the table lamp) is focused on the fovea. Now, move the object to be about 20 cm from the model.

- C1. Is the image still in focus? How do you have to change the shape of the lens to bring it into focus again? Measure the near point for the model.

Put the object back at a large distance and refocus the lens. Suppose you could not adjust the lens. (e.g., In an aging human, the power of accommodation decreases resulting in the need for reading glasses.) Bring the object close to the eye model but do not change the lens power.

- C2. What type of external lens do you need to make a close-up image appear sharp? Try some of the lenses you tested in the previous experiment to see if you can find a lens that helps to make a sharper image.

The model can also be used to show the effects of myopia and hyperopia by changing the shape of the eyeball. Lengthening the distance between the lens and the fovea makes a myopic (nearsighted) eye. This is corrected by negative external lenses. Decreasing the distance between the lens and the fovea creates a hyperopic (farsighted) eye, which is corrected by positive external lenses. If you have time, change the model eye to simulate (and correct) for nearsighted and farsighted eyes.