Physics 208
Lenses and the eye

Your TA will use this sheet to score your lab. It is to be turned in at the end of lab. You must use complete sentences and clearly explain your reasoning to receive full credit.

What are we doing this time?
You will complete three related investigations.

PART A:
Use a single lens on the optical track to understand focus and the lens equation, and the difference between real and virtual images.

PART B:
Build a microscope and a telescope on the optical track to understand how the image formed by the objective lens acts as an object for the eyepiece lens.

PART C:
Investigate near-sightedness and far-sightedness using an eye model filled with water.

Why are we doing this?
Refraction of light is an unusual phenomenon, and the way lenses use this effect to bend and reform light rays to make an image has myriads of applications. Understanding this will help you get the most out of research instruments such as microscopes.

What should I be thinking about before I start this lab?
You should be thinking about images produced by lenses, and how either a real image or virtual image can act as an object for another lens, such as the one in your eye.

Any safety issues?
If you aim your telescope across the street at the windows in the chemistry building, just keep an open mind and remember that chemists are different.
A. Lenses

Aim Firefox at the course web site laboratories page (not the lab manual web site) and click on the “Virtual Optics Bench” for Lab 1. Click the top button for ‘Converging Lens’, and scroll the page to look at the lens system.

A1. Move the lens around to see the locations at which an image forms on the screen. Then move the screen closer and try again. Is there always the same number of lens positions at which a sharp image forms on the screen? Explain what you found.

Now you will use the Pasco track and light source, three color-coded converging lenses, and a white screen to view images. Position the light source accurately at 0 cm on the track, and the white screen at 30 cm. Put one of the red lenses on the track between the screen and the light source.

A2. Find all the positions of one of the red lenses that give a sharp image on the screen (there is more than one position, but there may not be four)

<table>
<thead>
<tr>
<th>Lens position (cm)</th>
<th>Image distance (cm)</th>
<th>Object distance (cm)</th>
<th>Magnification</th>
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A3. From the data of A2, use the lens equation to calculate the red lens focal length. The two red lenses have nominally the same focal length, but may differ by several mm.

A4. Now move the screen to 100 cm, and write down the positions of the green lens that give a sharp image on the screen.

A5. Calculate the focal length of the green lens.
Magnifying glass (simple magnifier)

Go back to the “Virtual Optics Bench” from the course web site and click the button for “Magnifier w/Eye Lens”. Move the magnifying glass and eye around, and look at the rays. Use the simulation to answer the following question.

A6. The eye can focus only on objects more than 25 cm away. Put the eye about 6 cm behind the magnifying glass. Move the object around to change object distance. About what is the smallest object distance that will give a sharp image on the retina?

A7. Now use a Pasco red lens as a magnifying glass. That is, hold the lens in your hand close to the words on this page so that they appear larger when you look through the magnifying glass.

Move the magnifying glass and your eye until the words are as big as possible, but still in focus. The image may be distorted due to imperfections in the lens.

To answer these questions, it may help to refer back to the simulation.

i) Are the words on the page closer to or farther from the lens than the focal length?

ii) Is the image formed by the magnifying glass upright, or inverted?

iii) Is the image formed by the magnifying glass real or virtual? Explain.

iv) Now try the green lens as a simple magnifier, then answer this question: which lens was able to magnify the most when used as a magnifying glass, long focal length or short focal length?
B. Microscopes and Telescopes

This section involves two-lens systems. These will make a lot more sense if you remember these things:
1. The first lens (objective) forms a real image.
2. The image formed by the objective is used as the object for the (eyepiece) lens
3. A real image will appear on a screen placed at the image location. A virtual image will not, but your eye can focus the rays from a virtual image on your retina.

Compound Microscope

Go back to the “Virtual Optics Bench” from the course web site and click the “Microscope” button. Move the objective with respect to the object and watch the image locations change.

B1. How does the position of the image formed by the objective move when you change the objective position?

B2. Is the image formed by the objective real or virtual?

B3. How does the position of the image formed by the eyepiece move when you change the objective position?

B4. Does the eyepiece form a real or virtual image?

B5. Why does changing the distance between the objective and the object (moving the stage in a microscope) focus the microscope?
Now use the two red lenses to make a compound microscope, an instrument that makes a nearby sample appear larger. Use the light source on the track as a sample. The objective (lens closest to sample) is used to make a larger, real image of the sample. The eyepiece (lens closest to your eye) is used as a magnifying glass to look more closely at the image from the objective.

B6. Use one of the red lenses as the microscope objective to form an image of the light source on your white screen somewhere on the track. Measure the positions of the objective and image and fill in the following table:

<table>
<thead>
<tr>
<th>Distance of objective from light source</th>
<th>Distance of image from objective</th>
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B7. Approximately at what location on the track should you position the other red lens (as the eyepiece) so that you can look through the eyepiece and see a magnified image of the light source?

B8. Complete your microscope by putting the eyepiece at the approximate location, then moving the eyepiece (and possibly the objective) slightly until you see a magnified image of the light source when you look through the eyepiece. Experimentally estimate the magnification of your microscope using any method you can think of.

Remember that the objective lens will form a real image that you can see on a screen. The eyepiece is used as a magnifying glass to look at this real image.

\textit{a}: Draw a diagram of your microscope at right, drawing each lens at the position you have it on the track. Also indicate the focal points of each lens.

\textit{b}: Label the point on the diagram at right where the image is formed by the objective, as you found in B6 using the white screen.

Use the lens equation to find the position of the image formed by the eyepiece. Also label this point on the diagram at right.
Telescope
A telescope is an optical instrument that uses two lenses to make a distant object appear closer. The objective lens points toward the distant object (such as the building across the street) and forms an image on the opposite side of the objective lens. The eyepiece is used as a simple magnifier to look more closely at this image.

Go back to the “Virtual Optics Bench” from the course web site and click the “Telescope” button. Change the location of the eyepiece and watch how the image locations change in order to answer the following question.

B10. A telescope is focused by changing the position of the eyepiece. Explain why this works.

Now use a green lens and a red lens to build a telescope. Remove the light source from your track, and arrange the lenses on the track to make a telescope. Since a telescope is used to view objects far away, you should aim the telescope out the window, or at a light board at the other end of the lab room. (You can prop up one end of the track on the eye-model light source)

B11. Use the green lens as the telescope objective to form an image of the distant object on your white screen somewhere on the track. What is the distance of the image from the objective?

B12. Show that this image location is consistent with the lens equation.

B13. At what location should you position the red lens (as the eyepiece) so that you can look through the eyepiece and see a magnified image of the distant object?

B14. Complete your telescope by putting the eyepiece at the appropriate location and look at various objects.

B15. List two differences between a microscope and a telescope.
C. The eye
Your eye also has multiple “lenses”, although they are referred to as the “cornea” and the “crystalline lens”. Both of them do some refracting – these are two closely-spaced lenses. If you wear eyeglasses, that is a third lens!

The image formed by the cornea is used as an object for the crystalline lens, just as in the microscope and telescope. But because the lenses are closely spaced, the image formed by the cornea is on the other side of the crystalline lens (the same side as the image formed by the crystalline lens).

This means that the object distance for the crystalline lens will be negative in the lens equation.

This lab closely follows lab L-4 in the Physics 208 printed/online lab manual. Do parts 1, 2, and 5 of the lab.

Accommodation. Do part 1 as in lab manual.
C1. What are the focal lengths in air of the two lenses you used? (The power in diopters is stamped on the lens holders)

C2. How are the focal lengths of these lenses different when in water in the eye model (are they longer or shorter than for the lens in air?). Explain

C3. Both the cornea and eye lens refract the rays to produce an image on the retina. But it can be easier to talk about this pair as a single lens with an 'effective' focal length (just as multi-element camera lens are labeled with a focal length). Assuming that this lens is halfway between the cornea and eye lens, what range of focal length was necessary to focus on objects at infinity and at 30 cm?

C4. Don’t do the reduced aperture part of part 2, but do the rest.

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<tr>
<th></th>
<th>Nearsighted</th>
<th>Farsighted</th>
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<tbody>
<tr>
<td>Lens power required</td>
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Explain in words the sign (+ or -) of the lens required in each case.

Nearsighted:

Farsighted:

C5. Cataracts. A cataract is a cloudy crystalline lens, which usually requires surgical removal. Once the lens is removed, light rays are bent only by the cornea, which alone does not have enough refracting power to form a sharp image on the retina.

Put the retina back in the middle (normal vision) position, and carefully remove the eye lens using your best surgical technique. Verify that without the eye lens a sharp image never forms on the retina, regardless of the light source location. Historically the eye lens was not replaced, and eyeglasses provided the additional refracting power.

In this case you need to determine the power (hence focal length) of the cornea alone.

a. Put in the +7 diopter lens (outside the eye, as glasses) and adjust the light source distance so that a sharp image is formed on the retina. Draw your setup below, indicating positions of the object, image, eyeglass lens, and cornea.

b. In the human eye, roughly 2/3 of the focusing 'power' comes from the (fixed-power) cornea, and 1/3 from the (variable power) eye lens. This sharing may be different in your eye model. In this part, you determine how the cornea and lens share the focusing duties in your eye model. Use the results of part a to calculate the power of the cornea alone.

How does the power of the cornea alone compare to the power of the ‘effective’ lens-cornea combination?