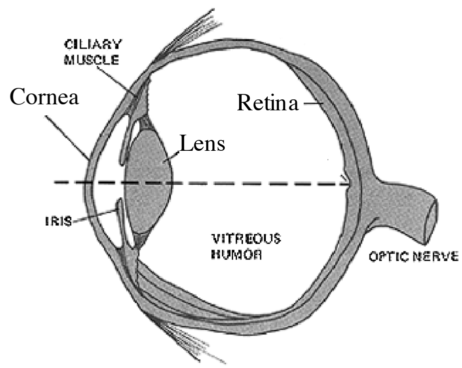
LABORATORY 3:
CORRECTING DISTANT VISION

A diagram of a human eye is shown below. In an eye with normal vision, the cornea and the lens can project a focused image of objects at a wide range of distances (not shown in the diagram) on the retina. To achieve such flexibility, the ciliary muscle in the eye can slightly change the shape of the lens to adjust its focal length.

Image of a Human Eye



As people age, their eyes may develop *cataracts*, in which metabolic changes in the material of the eye's lens cause it to become cloudy, leading to partial or complete loss of vision in that eye. Surgery to treat cataracts involves removing this lens and replacing it with an artificial lens of fixed focal length.[1] As a result, the patient's vision is only clear over a short range of distances. For example, a patient's vision may be clear at intermediate distances, but the patient needs glasses to focus on either nearby or distant objects.

In this lab you will build a model of such an eye with an artificial lens and find a corrective lens that brings distant objects into focus.

PREPARATION:

1. In your lab notebook, draw a ray diagram representing a surgically repaired eye viewing an object, placing the object at a distance of roughly 3 times the focal length of the repaired eye's artificial lens. Also indicate the location of the retina, assuming that the artificial lens can produce focused images on the retina for objects at this distance.

   Then sketch ray diagrams or use the thin lens equation to work out how the image location changes if the object is moved *much farther away* from the lens — is it still on the retina, or in front or behind it?

2. If a corrective lens is added to allow a clear image of the distant object to form on the retina, should that lens be converging or diverging, and why?

[1] In a remarkable feat of technology, implantable artificial lenses that can be attached to the eye's focusing muscles, allowing for variable focusing, were approved by the US FDA in 2003. However, they are quite a bit more expensive and often not covered by insurance, so it is still not uncommon for cataract patients to have fixed-focal length implanted lenses.

PART 2: VISION CORRECTION

MEASUREMENT: PLACING THE CORRECTIVE LENS

On the optical rail, construct a model of the eye that produces a focused image on the "retina," with the object located approximately 3 focal lengths from the eye's lens; then move the object to 8-10 focal lengths away and add a corrective lens[2] at a location that brings the new image into focus.
Draw a schematic in your lab notebook of the arrangement of the object, two lenses, and retina, with all distances labeled. Use these distances to calculate the focal length of the corrective lens.

Experimental tips:

- Use the 10 cm focal length convex lens as your eye lens and the screen as the retina.
- Set up the light source, lens and screen so that a focused image is formed when the light source is about three focal lengths away from the lens, **and** you have room to move the light source to much more distant (8-10 focal lengths). This will involve moving the light source away from the zero marking on the optical rail.
- Then move the source to 8-10 focal lengths from the lens and add a corrective lens between the source and the lens, so that you can focus the image of the source. Position the corrective lens by adjusting it until you see a focused image. Do NOT adjust the position of the eye's lens or the screen.
- If the image is very small, you can focus by making the outline of the bright square sharp, rather than by trying to focus the image of the crosshairs.

ANALYSIS: DETERMINING THE FOCAL LENGTH OF THE CORRECTIVE LENS

This analysis is challenging and may be time-consuming, but it's exactly like the kinds of problems you will need to solve with two lenses, so it's good practice! You may complete the analysis after lab and turn in your lab notebook next week.

Just as with the microscope, the image formed by the first lens (the corrective lens) serves as the object for the second lens (the eye lens). In this case that first image is virtual.

In this analysis, use your measurements to determine the focal length of the corrective lens.

1. To calculate the focal length of the corrective lens, work backward. Apply the thin lens equation to the "eye" lens, using your measured distances (including your measured focal length for the "eye" lens from before), to find the location of the object for the "eye" lens. This object is the image formed by the corrective lens.

2. Now that you know the location of the image formed by the corrective lens, you can apply the thin lens equation to the corrective lens and find the focal length of the corrective lens. (Be careful about signs! What is the sign of the image distance for a virtual image?)

3. You should find a negative focal length for your lens (if not, go back and correct your calculation). What does this mean?

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[2] If you were an opthalmologist treating a cataract patient, you would try different focal length lenses on the patient in order to identify the focal length that would allow the patient to see distant objects when that lens was worn in a pair of glasses — namely, when that lens is fixed at a particular distance from the patient's eye. However, in this lab all our diverging lenses have similar focal lengths. Therefore, in building your model, the focal length of the corrective lens is fixed, and you will adjust the distance from the corrective lens to the eye lens to produce a focused image.

CONCLUSIONS:

In your lab book, summarize your findings, including answering these questions

- What kind of lens was required to bring distant objects into focus?
- Does your measured value of the focal length agree with the value on the sticker on the lens within uncertainty? (The value on the sticker has an uncertainty of about 10%.)
- If there are discrepancies, what might be some of the sources of uncertainty in your measurement?