

The Human Eye Lab

Introduction:

In this experiment you will examine images formed by a PASCO model of the human eye. Eye defects, such as near-sightedness, far-sightedness, and astigmatism will be observed in the model eye. They will also be corrected with exterior lenses, which represent the eye with glasses or contacts.

Some helpful tips are below:

- ♦ The word “object” refers to the pictures that are used (1.6” and 6.25” high images)
- ♦ Let f be the focal length of a lens, n be the index of refraction of the lens material, and n_m the index of refraction of the medium in which the lens is immersed. Then it can be shown that $1/f$ is proportional to $(n-n_m)$. The shorter the focal length (stronger the lens), the greater difference between n and n_m . Except for the outer surface of the cornea the lens surfaces of the human are in material whose index of refraction is close to that of water. As a result these lenses are weaker than they would be in air.
- ♦ The focal lengths f marked on the lenses are for the lenses in air. The index of refraction of air is about 1.0003 ~ 1.000. The focal length f_l of one of these lenses in a liquid of index of refraction n_l is given by
$$f_l = \left[\frac{n_l(n-1)}{n-n_l} \right] f$$
where n is the index of refraction of the lens material. For example, the polycarbonate lens ($n=1.586$) marked as having a focal length of 62 mm will have a focal length of 191 mm in water ($n_l = 1.333$).
- ♦ To change the eye-object distance, move the object.
- ♦ The longer the focal length of a lens, the weaker the lens. If the focal length is given in meters, the inverse of the focal length is the strength of the lens in *diopters*.

Equipment:

PASCO human eye model with accessories (eye model placed on end of bench away from wall), goose neck lamp, 2 meter ruler, 3”x5” card with “Picture” (can be creative) about 1.6” high (for close objects), 8 ½” x 8 ½” card with “Picture” about 6.25” high (for distant objects), 3”x5” card with thick astigmatism lines, 2 ½” x 5” card for observing focus of distant object, clean water to fill lens model, paper towels to lay wet lenses down on, 1inch strip to allow observation of a “blind spot”. The room should be fairly dark for this lab.

The plastic eye model can be filled with water. The water serves as the aqueous and vitreous humors of the eye. A plano-convex lens rigidly attached to the model (+400 mm Lens) serves as the corneal lens. Outside slots marked 1 and 2 are for the insertion of corrective lenses (glasses or contacts). A slot inside the model marked ‘septum’ is for the insertion of a lens that serves as the crystalline lens. Adjacent to the septum slots are labeled ‘A’ and ‘B’. These two slots are for the insertion of lenses that change the focal

length of our model crystalline lens and can also introduce astigmatism. Across from these slots are some additional slots labeled 'normal', 'near', and 'far'. These are for a screen that serves as the retina. It is on this screen that you observe images of the "object". To mimic the normal, far-sighted and near-sighted eye, the screen can be moved to the respective slots. The screen also has a hole in it to simulate the blind spot of the retina.

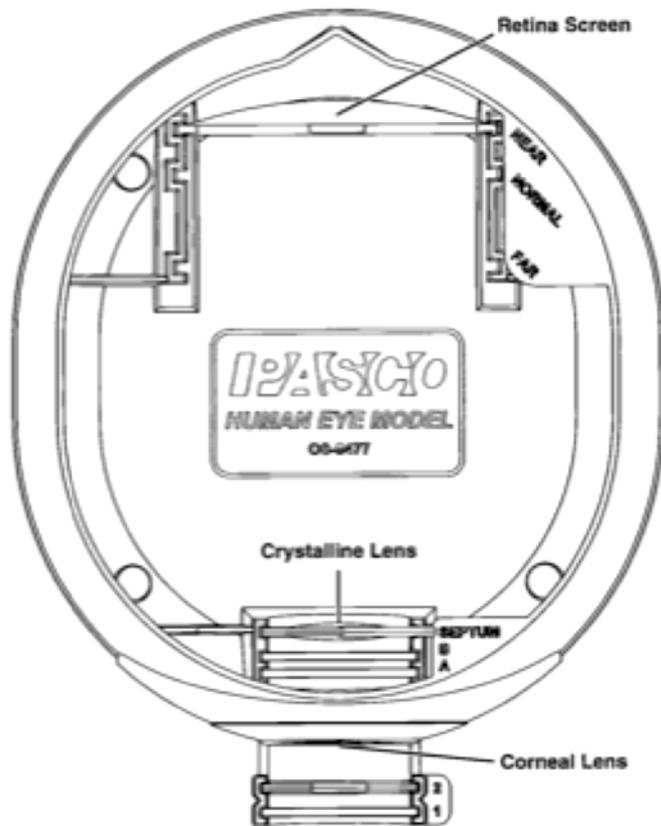
The lenses for the Eye Model are plastic and fairly soft. Some of these lenses will be used in water. Please do not rub or wipe them dry, as this will ultimately scratch them. Just lay them down on soft paper towels. The lenses are held by plastic holders that have handles for easy handling and insertion into the various slots in the eye model. The lens holders allow for about 90° rotation when a lens is in a slot of the eye model. On each lens holder is printed the focal length of the lens *in air* (as mentioned previously) with a plus sign for a *converging* lens and a minus sign for a *diverging* lens. When a lens is called for these numbers will be referred to, for example, a converging lens with a focal length of 120 mm in air will be referred to as a +120 mm lens.

Each cylindrical lens has two notches in its frame that denote the axis of the lens. All the lenses have handles for easy insertion into the slots and for easy removal from the slots. Note that the index of refraction depends slightly on wavelength

(Specific lens information is provided at the end.)

Measuring "Objects"

Two objects supplied should be a large picture and small picture on cards. The image gets small as the object distance increases, so use the small picture for the small object distances and the larger picture for the large object distances. Illuminate the card with a lamp placed fairly close to the card and off to the side a bit. The *center* of the eye model's two lens system is approximately the top rim of the model. Measure object distances from this point unless otherwise advised. To measure image sizes, use the calipers provided. Change the object distance by moving the card. Use the meter stick to measure object distances. To detect astigmatism, use the card with a "star" on it.



Part 1 - Images Formed in the Eye

Using an empty eye (no water) with no additional lenses present, we will investigate the focal length and image properties of the model's corneal lens in air.

With the eye model at one end of the bench and the large "object" at the other end of the bench, use the 2 ½" x 5" card in the region of the retina screen slots to form a clean image on the card.

1. Measure the object and image distances from the corneal lens (not the top rim of the eye model as there is no crystalline lens present).
2. Use the thin lens formula to calculate the focal length of the corneal lens in air and compare to that given by the lens specification sheet.

Thin lens formula: (where f is the total effective focal length, i is the image distance and o is the object distance)

$$\frac{1}{f} = \frac{1}{i} + \frac{1}{o}$$

(do not fill with water, but answer the following)

3. If you were to fill the model with water, do you think an image could be formed by the corneal lens within the body of the eye model? Why or why not?

Examine the “object”

4. Explain how the image of the “object” differs from the object itself. In particular, have up and down been interchanged? How about left and right? What happens to left and right when you turn your head to look from the object to the image or vice versa? Would an object, such as the letter “I” provide as much information as the “object” you have?

5. Measure the image size using the caliper and a ruler and measure the object size using a ruler. From these quantities, calculate the magnification, providing the correct sign. Also calculate the magnification from the object and image distances and compare with your measured value.

Part 2 - The Normal Eye

Background: The lens of the human eye has the longest focal length when the ciliary muscles are relaxed. Under these circumstances, a human eye with good vision focuses a distant object on the retina. For the eye model, this corresponds to a crystalline lens with a focal length of $\sim +120\text{mm}$.

The eye model should be empty for the first part of Experiment 1.2. Insert the converging lens with a focal length of 120 mm in air in the septum. Put the retinal screen at ‘normal’. Using the small “object”, determine the object distance that produces a focus. Move the object up and down and horizontally.

6. How does the image move when you make these motions?

Fill the eye model with water (Approx 1 liter) to within 1 or 2 cm of the rim. With the eye model at one end of the bench, put the large “object” at the other end of the bench.

7. Is there a reasonable focus on the retinal screen? Do you get a better focus if you put the retinal screen in the near slot or the far slot?

Background: Suppose a normal vision eye wants to focus on a nearby object. That person will tighten the ciliary muscles to squeeze the crystalline lens and make it more curved. The crystalline lens becomes stronger with a shorter focal length and enables the person to focus on nearby objects. We can't squeeze the model lenses but we can replace them with a stronger lens to mimic the effect.

Remove the +120 lens and replace it with the strong +62 mm lens.

8. At what distance does the model eye now focus?

Background: The ability of the human eye to focus at different object distance is called accommodation. The nearest distance that can be focused is called the near point. This is about 7 cm for a rather young person, but recedes with age. At age 60, it might be 200 cm. This decrease of accommodation with age is called presbyopia.

Normal Near Vision

You will be asked several times to set the model eye for “**normal near vision.**” This means that

- A. The eye model is filled with water
- B. The +62 mm lens is in the septum slot
- C. The screen is in the normal position

Part 3 - Near Sightedness (Myopia)

Background: An eye that is near-sighted focuses an image in front of the retina. This can be interpreted in one of two ways:

- A. The crystalline lens is too strong*
 - B. The crystalline lens – retina distance is too long*
- We will use the second in our eye model.*

Set the eye model up for normal near vision. Get the small object in focus on the screen. Now move the screen to the near slot

9. Describe the image.

See if among the spherical lenses provided you can find a lens that when inserted in slot 2 makes the image sharp. This lens is an “eye glass.”

10. Describe how the eye glass works and which, if any, lenses improved the image quality.

Part 4 - Far Sightedness (Hyperopia)

Background: An eye with hyperopia focuses an image in back of the retina. This can be interpreted in one of two ways:

- A. The crystalline lens is too weak*
- B. The crystalline lens – retina distance is too short*

As with the near-sightedness, we will use the second interpretation with our eye model.

Set the model up for normal near vision. Get the small object in focus on the screen. Now move the retina screen to the far slot.

11. Describe the image.

See if any of the spherical lenses provided when inserted in slot 2 will make the image sharp.

12. Describe how the eye glass works and which, if any, lenses improved the image quality.

Part 5 - Astigmatism

Background: A normal eye has spherical lenses. If one of the lenses is not purely spherical, but is partly cylindrical then the eye is said to have an astigmatism. The result is a blurred image.

Take a look at the astigmatism chart. (You cannot wear contacts or glasses to do this tests). Cover one eye and look at the chart. If you have astigmatism some of the lines will appear darker than others. If you removed your glasses, put them on and look at the chart again. Is there any improvement?

In the eye model, the astigmatism is created by using a lens that is purely cylindrical and has no spherical component. The corrective lens that will be used is also purely cylindrical. Look at the spherical and cylindrical lenses provided edge on and observe the difference.

Set up the eye model for normal near vision. Adjust the position of the small object so the image is in focus on the screen. Leave the object in this position. Insert the -128 mm cylindrical lens in slot A with the side of the lens handle marked with the focal length facing the light source.

13. Describe the image. Rotate the lens with the handle as much as possible. Does the image change?

Correct for the astigmatism by inserting the +307 mm cylindrical lens in slot 1. Rotate the handles of the two cylindrical with respect to one another until you get the best focus.

14. Describe when you get the best focus.

It is helpful to leave the astigmatism lens and object where they are for this next section. (you can remove the corrective lens)

Part 6 - Far sightedness AND Astigmatism

*Background: A human eye often is near-sighted or far-sighted (sometimes both) **and** has an astigmatism at the same time.*

Insert lenses into the model to create an eye that is both far-sighted **and** has an astigmatism.

15. Find the two lenses that when inserted into slots 1 and 2 correct for these conditions.

Note that you have corrected this dual condition by using two lenses, while an optometrist would correct with one lens that has both spherical and cylindrical curvature.

Part 7 - The Blind Spot

Background: The nerves that carry the electrical signals from the light sensitive cells on the surface of the retina all go through the retina at the same spot. Therefore, there are

no light sensitive cells at this point. This spot is called the blind spot and in the eye model is depicted by a hole in the retina screen.

Experiment on yourself by observing your blind spot. Use the figure that has a plus sign on the left and a black dot on the right. Hold the figure arm's length from your eye. Cover your left eye and look at the plus sign with your right eye. Bring the figure closer to you. At some point (still focusing on the plus sign), you should see the black dot disappear! If you bring the figure closer still, you should see it reappear!

16. Why?

Try the same experiment using your human eye model. Use the strip of the black dot and + sign. Set up the eye model for normal near vision. Use a copy of the figure and see if you can get an image with the plus sign at the center of the retina screen and the dot at the position of the hole in the screen.

17. Is the eye model for a left or right eye?

Specifications of the Human Eye Model and Accompanying Lenses

Model Eye

Dimensions	15 cm x 17 cm x 10 cm
Water Capacity	1 liter
Retina Diameter	7 cm

Movable Lenses

Material	Polycarbonate Plastic
Diameter	3 cm

Focal lengths (In Air)

Spherical Convergent	+120 mm
Spherical Convergent	+62 mm
Spherical Convergent	+400 mm
Spherical Divergent	-1000 mm
Cylindrical Convergent	+307 mm
Cylindrical Divergent	-128 mm

Index of Refraction (Polycarbonate Plastic)

<u>Color</u>	<u>Wavelength</u>	<u>Index of Refraction</u>
Blue	486 nm	1.593
Yellow	589 nm	1.586
Red	651 nm	1.576

Plano-convex Corneal Lens

Material	B270 Glass
Diameter	3 cm
Thickness	4 mm
Radius of Curvature	71 mm
Focal Length (in air)	140 mm

Index of Refraction (Glass)

<u>Color</u>	<u>Wavelength</u>	<u>Index of Refraction</u>
Blue	486 nm	1.529
Green	546 nm	1.525
Yellow	589 nm	1.523
Red	656 nm	1.520