Optics of the Eye

Goal: To investigate some of the principles of the human eye.

Lab Preparation

We see objects because light bounces off of them and into our eyes. For normal vision light enters our eye and is focused on our retina. This forms an image of the object, much like your convex lenses formed images on screens in the previous labs.

Some of the basic relationships that will be used in this lab are:

a. Power of a lens (in diopters): $\mathcal{D} = \frac{1}{f}$ where f is the focal length in meters.

b. Thin lens equation: $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

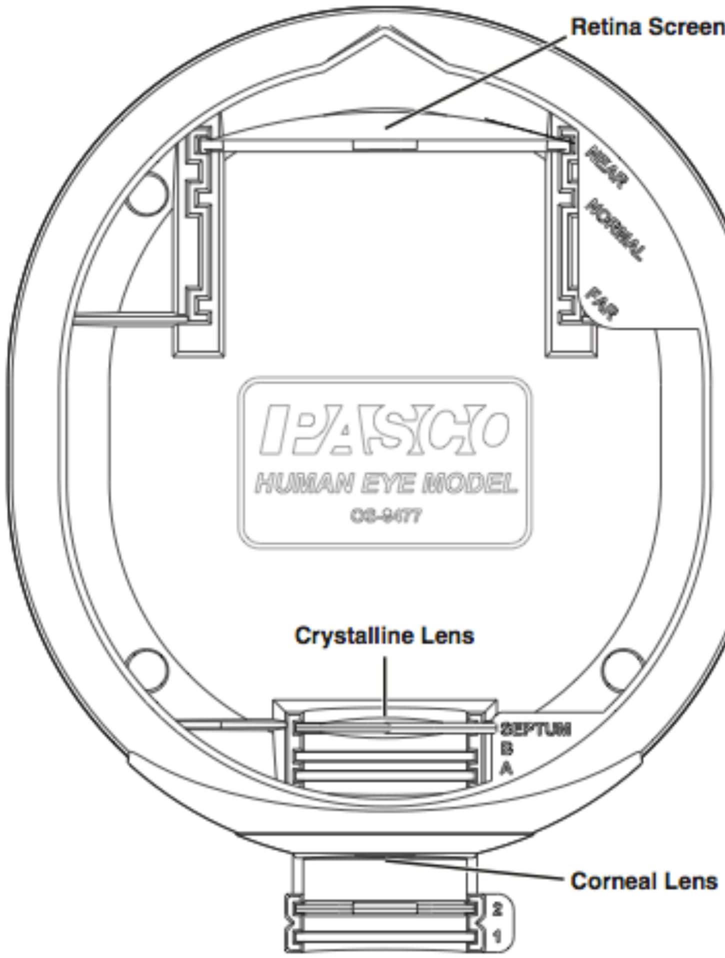
c. Magnification equation: $M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$

During this lab we will investigate accommodation, normal vision, and some defects of the eye using the eye model provided.

Equipment

The Human Eye Model consists of a sealed plastic tank shaped roughly like a horizontal cross section of an eyeball. A permanently mounted convex lens on the front of the eye model acts as the cornea. The tank is filled with water, which models the aqueous and vitreous humors. The lens of the eye is modeled by a changeable lends behind the cornea. A moveable screen at the back of the model represents the retina. A picture of the eye model is below.

Tops View



Procedure

I. Introduction to the Eye Model

Your eye model consists of a cornea and the following:
*Slots 1 and 2 are outside the cornea and will be used for vision correction.
*Slots A, B, and SEPTUM are just inside the cornea and are used to simulate the lens of the eye.
*Slots FAR, NORMAL, and NEAR are back where the retina screen is placed.

You also have a set of lenses that can be used in various locations.

Do not wipe off or dry the lenses during this lab

A. To start with, place the +400 mm lens in the SEPTUM position and the retina screen in the NORMAL position in your eye model (the eye model should not have any water in it at this point). Put your hand about 50 cm in front of the eye model and illuminate your hand with a desk lamp. Describe the image you see on the retina.

B. What happens to the image when you move your hand up and down?

II. Normal Vision and Accommodation

In this part we will explore accommodation – the ability of the eye to change the shape of the lens to focus both close and far objects.

A. Normal vision. Fill the eye model with water to within 2 cm of the top. Place your object (light source) at 0 cm. Place the eye model about 35 cm from your object and replace the +400 mm lens in the SEPTUM slot with the +62 mm lens. This will be our setup for normal vision throughout the lab.

B. Effective focal length. Slide the eye model as close as you can while keeping a clear image on the retina and record the position of the eye model (measure from the front of the bracket).

   The corneal surface and lens (the +62 mm lens) combination can be thought of as a "single lens."

   1. Make the appropriate measurements to determine the effective focal length of the "single lens" and find this focal length. To simplify, treat the top of the front rim (which is at the same location as the front of the bracket) as the location of your "single lens."

   2. Measure the object height and image height (use the optics caliper) and determine the magnification of your eye by using these heights. Also, determine the magnification using the object and image distances.

C. Accommodation for close objects. When the eye focuses on objects that are close, the lens becomes thicker, thus changing the effective focal length. To simulate this, place the +400 mm lens in slot B and focus the image on the retina of the eye by sliding the eye model. Record the position of the eye model and compare (in words) to the original position of the eye model.

D. Accommodation for far objects. When the eye focuses on objects that are further away the lens becomes thinner, thus changing the effective focal length. To simulate this, replace the lens in the SEPTUM with a +120 mm lens and find the closest focused image on the retina of the eye by sliding the eye model. Record the position of the eye model and compare (in words) to the original position of the eye model.

III. Farsightedness

Set the eye model back to normal vision (+62 mm lens in SEPTUM, screen in NORMAL position) and put the eye model back to the closest focused image.

When a person is farsighted the light rays from closer objects do not converge soon enough to put the image on the retina, thus the image on the retina is blurred. This could be due to the cornea being too flat or a person having a shorter-than-normal eyeball. We will simulate this by moving the screen forward to the FAR position. Note how the image is no longer clear when we do this.

A. Pupil size. People will often try to squint to put blurry objects into focus. Try this with the eye model by placing the rounded pupil in slot A. What happens to the clarity of the image? Explain why this change occurs. When done remove the rounded pupil.

B. Correcting for farsightedness. We will now try to correct the farsighted vision of your eye model. Will you need a convex or concave lens to fix the vision? Find a lens that brings the image into focus when you place it in front of the eye in slot 1. Record the focal length of this lens. What is the power of this lens?

IV. Nearsightedness

Set the eye model back to normal vision (+62 mm lens in SEPTUM, screen in NORMAL position) and put the eye model back to the closest focused image.

When a person is nearsighted the light rays from distant objects converge too soon, thus the image on the retina is blurred. This could be due to the cornea being too curved or a person having a longer-than-normal eyeball. We will simulate this by moving the screen backward to the NEAR position. Note how the image is no longer clear when we do this.

A. Pupil size. People will often try to squint to put blurry objects into focus. Try this with the eye model by placing the rounded pupil in slot A. What happens to the clarity of the image? When done remove the rounded pupil.

B. Correcting for nearsightedness. We will now try to correct the nearsighted vision of your eye model. Will you need a convex or concave lens to fix the vision? Find a lens that brings the image into focus when you place it in front of the eye in slot 1. Record the focal length of this lens. What is the power of this lens?

C. Remove the "eyeglasses" and adjust the eye model to get a clear image on the retina. Record the position of the eye model and compare (in words) to the original position of the eye model. What has happened to the near point of the eye?

V. Astigmatism

In a normal eye, the lens surfaces are spherical and rotationally symmetrical; but an eye with astigmatism has lens surfaces that are not rotationally symmetrical. This makes the eye able to focus sharply only on lines of certain orientations, and all other lines look blurred. Astigmatism can be corrected with a cylindrical eyeglasses lens that is orientated to cancel out the defect in the eye. The cylindrical lenses included here have their cylindrical axis marked by two notches in the edge.

Once again set the eye model back to normal vision (+62 mm lens in SEPTUM, screen in NORMAL position) and put the eye model back to the closest focused image.

A. Astigmatism. Place the -128 mm cylindrical lens in slot A. The side of the lens handle marked with the focal length should be towards the light source. Describe the image formed by the eye with astigmatism. Rotate the cylindrical lens and describe what happens to the image.

B. Correcting for astigmatism. Place the +307 mm cylindrical lens in slot 1. Once again, the side of the lens handle marked with the focal length should be towards the light source. Rotate the corrective lens until the image is sharpest. What is the angle between the cylindrical axes of the crystalline lens and the corrective lens?

C. More than one defect. An eye can have more than one defect. Make the eye model have both astigmatism and farsightedness by moving the retina screen forward to the FAR slot. What additional eyeglasses lens do you have to put in slot 2 to bring the image back in focus (or as close to focus as you can get it)?

VI. Blind Spot

The blind spot is the small area on the retina where the optic nerve is attached. There are no rods or cones in the blind spot so it is insensitive to light.

Cover your left eye and hold this sheet at arms length. Look continuously at the plus sign with your right eye and move the page slowly toward the eye, keeping your gaze fixed on the plus sign. At some distance the dot will disappear. When this position is found you are focusing the image on your blind spot. What is the approximate distance from your eye to the paper when this happens? Flip the paper upside down and do this for you other eye as well.

***When finished with your lab <u>please empty the water</u> out of the eye model and clean up your lab station.**