Physics 215 - Experiment 15
Optics of the Eye

Fig. 15-1: Eye Model, Lenses, Light Source

Equipment
Cenco Eye Model
Set of Lenses
Object Box (Light Source)
Meter Stick
Eye Chart
Video Tape on the Eye
Flashlight

Fig. 15-2   Eye Model Schematic

_Lens Positions:_ (A) Corrective Lens  (B) Cornea  (C) Crystalline Lens

_Retina Positions:_ (D) Farsighted Eye  (E) Normal Eye  (F) Nearsighted Eye
Objective: The objective of this experiment is to study the optical properties of the human eye using an eye model.

Theory: The human eye can be thought of as a positive lens system that focuses a real image on a light-sensitive surface. Most of the refraction of light occurs at the cornea-air interface (at the surface of the eye).

The eye model (Fig. 15-1 and Fig. 15-2) depicts the function of the eye using a metal tank filled with water and various lenses. At the front of the tank is a lens which represents the cornea in a real eye. The retina can be moved into different positions to represent different conditions of the eye. The dark spot that appears on the retina represents the blind spot, the region where the optic nerve joins to the eye. This area has no rods or cones to perceive light.

The human eye can have conditions which affect vision. This can be caused by refractive parts (cornea, lens) having abnormal curvature, as well as an alteration in the length of the eyeball.

Myopia (nearsightedness) is a condition that causes the focused image of an object to occur in front of the retina. This condition is remedied by placing a diverging lens in front of the eye.

Hyperopia (farsightedness) is a condition that causes the focused image of an object to occur behind the retina. A converging lens is used to remedy this problem.

A third condition is astigmatism. In this case the cornea's curvature is asymmetric (different curvature in one direction than in another). A cylindrical lens (barrel shape) is used to correct for this problem (Fig 15-3).

The power of a lens, $P = \frac{1}{f}$, is referenced when discussing corrective lenses. The unit is diopter (D), or m$^{-1}$.

The first two parts of the experiment explores the concept of accommodation (i.e., ‘the automatic adjustment of the eye for seeing at distances effected chiefly by changes in the convexity of the crystalline lens’). You should observe the eye with the eye muscles in a ‘relaxed’ state.
Physics 215 - Experiment 15

Optics of the Eye

(resulting in a thin crystalline lens thin) and a contracted state (resulting in a fat or compressed crystalline lens.)

I. Normal

II. Myopic Eye

Diverging Lens

NoCorrection

III. Hyperopia

Converging Lens

Corrective Measures

Fig. 15-3

Procedure Notes:
Carefully study the Eye Model Schematic (Fig. 15-2) before beginning the procedure. A special data sheet is attached. Record your observations on this sheet for each step.

Procedure
1. Place the +7 D lens into the crystalline lens slot. Place the retina in the normal or middle position. Hold the eye model in a position so that it faces a brightly lighted object at least 20 meters away. (An object outside the window would be a good choice). Remove Lens.
2. Place the +20 D lens in the crystalline lens slot. Place the eye model so that it faces the object box. Approximately how far away must the object be for a sharp image to form on the retina?
3. Rotate the eye model so that a portion of the image falls on the blind spot. What happens to the portion of the image that falls on the blind spot?
4. Return the eye model to a clearly focused position. Move the object box closer to the eye model so that the image now falls behind the retina and the image on the retina is blurry. Place the diaphragm in front of the cornea. What happens to the image? This corresponds to the farsighted eye having adapted to stronger light or to a farsighted person squinting. Draw a ray diagram on the back of the data sheet to show how squinting improves poor vision. (If you are nearsighted, you might try the following exercise. Make a small hole with your fist and look through the hole without your corrective lenses on. The image of a distant object should appear much clearer.)
5. Move the object box so that the image falling on the retina is in focus again. Move the retina into the farsighted
Optics of the Eye

position, being careful not to move the object box or the eye model. What kind of corrective lens is needed to correct this condition? Explain why. Test your hypothesis. Which lens provided the clearest image?

6. Remove all corrective lenses from the eye. Move the retina into the nearsighted position. Which corrective lens is needed and why? Test your hypothesis. Which lens gives the clearest image?

Fig. 15-4a  Fig. 15-4b

Fig. 15-4c

1. Lens - Perpendicular Axes
2. Lens - Parallel Axes
3. Standard Cylinder Axis

Fig. 15-4

7. Remove all corrective lenses. Return the retina to the normal position. Leave the +20 D lens in the crystalline lens slot. Insert the -5.50 D cylindrical lens behind the cornea. This produces an astigmatic eye. Place the +1.75 D cylindrical lens in front of the cornea. Turn the +1.75 D lens until the image on the retina is in focus. How are the lenses aligned when this occurs? To determine this, look at each lens and find the axis. (Fig. 15-4)

8. Remove all lenses from the eye model. Keep the retina in the normal position. Try to form an image on the retina. Is this possible?

9. Place a +7 D lens in front of the eye. Adjust the eye model in front of the object box until an image forms on the retina. Measure the object distance.

10. Replace the +7 D lens with the +2 D lens. Measure the object distance when an image is clearly focused on the retina.

11. There is an eye chart at the front of the room. Twenty feet in front of the chart is a piece of tape on the floor. Stand with your toes on the tape while your partner is at the chart. Leave any corrective lenses you use in place. Cover your left eye with your hand; do not press on your covered eye. Read the smallest letters possible. Repeat for your right eye. (Don’t close one eye. This will effect the focusing of the other eye.) If you can read the line just above the red line on the eye...
chart, you have 20/20 vision. This means that you can see at 20 feet what a normal eye should be able to see at
20 feet. Record your vision number (e.g., 20/20 – right eye) on the back of
the data sheet.

12. Observe the pinwheel design chart as one eye is covered. Do any of the lines appear to be more distinct than others? Observe this chart with the other eye covered. If some of the lines are bolder than others (certain lines become dim and blurred), it could be a symptom of astigmatism.

13. Switch positions with your partner and repeat.

Questions

1. Why does most of the refraction occur at the cornea-air interface? (Hint: all the parts of the eye have an index of refraction close to that of water.)

2. Why can you not see clearly underwater without the aid of goggles? Why can you see with goggles?

3. Discuss the limitations of an eye that does not have a crystalline lens. What kind of lens is needed to compensate for this problem?