Optical Principles of the Eye

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Date______________________________________ Section____________________________________

The object lamp might be hot. Exercise caution while using.

Introduction

A model, built to conform roughly with the shape of the eye, consists of a tank of water containing a movable white screen which serves as the retina. A window in the tank is covered with a meniscus lens which performs the function of the cornea. One of a series of interchangeable lenses takes the place of the crystalline lens of the eye. The image of an illuminated object is projected on the retina and its appearance observed. The accommodation of the eye to different object distances is demonstrated by interchanging lenses. A movable retina is used to show farsightedness and nearsightedness. Astigmatism is produced by the use of a cylindrical lens. The correction of optical defects is accomplished by the use of auxiliary lenses.

- **The mechanism of human eye**

The human eye is a most ingenious optical mechanism. A schematic sketch of the eye is shown in figure 1. The eye consists of a lightproof chamber into which light from an object enters through the cornea and the crystalline lens. This lens forms an inverted image of the object upon the retina at the back part of the black-coated chamber. The optic nerve receives an impression of this image and transmits it to the brain, where the sensation of sight is obtained.

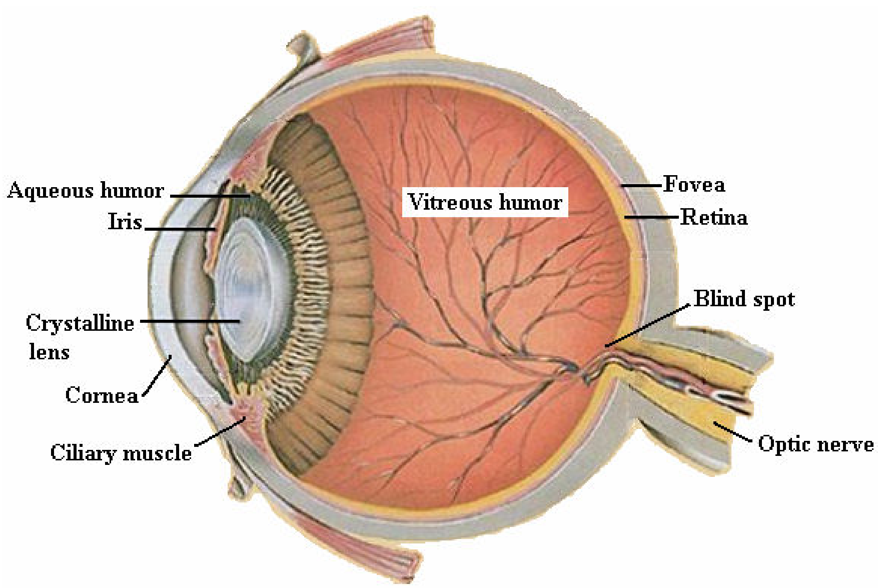

Figure 1: Anatomy of the Eye

- **Iris**

The amount of light admitted to the eye is controlled by an opening known as the iris. Its aperture is adjusted to varying light intensities by muscular action. The major portion of the eye is filled with transparent fluids, that portion behind the lens being called the vitreous humor and the part in front of the lens being designated the aqueous humor.

- **Blind spot**

At the place where the optic nerve leaves the eye there is an insensitive region known as the blind spot. The region of the retina of greatest sensitivity is the fovea centralis. As the eye scans an object, it rotates in its socket to bring successive parts of the image onto the fovea.

- **Accommodation**

In order that images of all objects at varying distances may focus at the same place, the crystalline lens changes its curvature by unconscious muscular control. This action is known as accommodation.

- **Nearsightedness**

An optical defect known as nearsightedness or myopia is caused by the lens not being sufficiently flattened, so that images are formed in front of the retina. Such a person unconsciously brings an object near his eye, so that the image recedes from the lens as near the retina as possible. This defect is remedied by spectacles having diverging lenses.

- **Farsightedness**

A common optical defect, especially among older people, is the inability of the crystalline lens to contract sufficiently properly to focus light from nearby objects. This is known as farsightedness or hyperopia and is corrected by wearing spectacles with positive (converging) lenses.

- **Astigmatism**

Another very common optical defect is astigmatism. This is the phenomenon whereby the rays of light from different planes in an object do not all focus at the same point on the retina. Because of the effect, lines in some directions are seen clearly while those in other directions are blurred. Astigmatism is caused by differences in the curvature of the cornea or crystalline lens at different diameters. It is corrected by the use of cylindrical spectacle lenses, with the axis of the cylinder properly chosen so as just to neutralize the cylindrical curvature of the cornea or crystalline lens. The corrective cylindrical lenses are also combined in the spectacles with the proper spherical lenses to correct for nearsightedness or farsightedness.

- **Power of lenses**

The power of a lens is a term used by opticians to designate the ability of the lens to change the curvature of a wave incident upon it. Since a lens changes the curvature of a wave by an amount 1/f, this is the measure of its power. The common unit of lens power is the diopter, which is defined as the power of a lens having a focal length of 1 m. Hence a +3- diopter lens would be a converging lens of 1/3 m focal length; a diverging lens of focal length 50 cm would have a power of –1/.5=-2 diopters. These two lenses in contact would have a combined power of 3-2 or 1 diopter; their equivalent focal length would be 1 m.

- **The experimental setup**

The model eye consists of a metal tank, Fig. 2, shaped roughly like a horizontal section of the eyeball. A window in one side of the tank is covered with a meniscus lens C which serves as the cornea. The tank is filled with water which takes the place of the aqueous and vitreous humors. The interchangeable crystalline lens L is mounted in a septum which marks the boundary between the humors. Two supports, $G_1$and G_2 are provided for the insertion of additional lenses and a diaphragm. In front of the cornea are two additional supports, S_1 and S_2, for spectacle lenses. The retina is represented by a circular white area on a removable curved screen R which may be located also at R_m for a myopic eye and at R_b to simulate a hyperopic eye. The blind spot is represented by a black spot is represented by a black spot painted on the retina.

A diaphragm and the following set of six lenses are mounted individually in a metal holder.

1. Spherical convergent	(+7.00 d)
2. Spherical convergent	(+20.00 d)
3. Spherical convergent	(+2.00 d)
4. Spherical divergent	(-1.75 d)
5. Cylindrical divergent	(-5.50 d)
6. Cylindrical convergent	(+1.75 d)

Table 1

In the case of the cylindrical lenses the axis of the cylinder is indicated on the mount. Numbers 1 and 2 of these lenses serve in turn mostly as crystalline lenses. The others are used to simulate defects of vision or as correcting eyeglass lenses in front of the cornea.

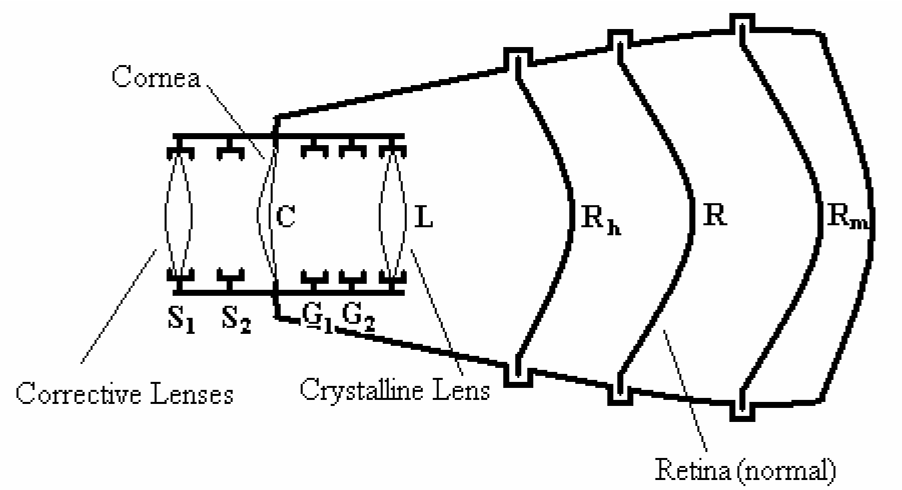

Figure 2: Eye Model

The study of the optical principles of the eye by the aid of the eye model depends upon the examination of the images formed on the retina, whether the image is upright or inverted, distinct or blurred, and larger or smaller than the object. Also to be noted is how the image moves as the object is moved up or down and from side to side.

Experiment 1: Understand the process of accommodation

1. Fill the tank with water to within 2 cm of the top
2. Direct the eye model toward a window or other bright object (human or fluorescent lights) 4 to 5 m (12-15 ft) away.
3. Place the retina in the normal eye position (the middle one in the eye model).
4. Insert the weaker (+ 7.00) crystalline lens in groove L in the water just below the partition

The image should now be in focus on the retina.

5. What is the character of the image i.e.
    a. Erect or inverted?
    b. Size compared to the object size?

♦ This is optional. (Ask your TA)

The blind spot in the eye is a small area of the retina that is not sensitive.
⅄ What is the probable effect on one's perception of that part of the image which falls on the blind spot?
⅄ Use as the object the lamp box with the radially slotted pattern
⅄ Place the lamp 35 cm from the cornea

6. Replace the weak crystalline lens with the +20.00 lens in groove L. **Important!**

This illustrates the process of accommodation or focusing which in the eye is automatically accomplished by a set of muscles which change the curvature of the crystalline lens. <u>This +20.00 lens is to be used hereafter in all of the experiments with a "normal" eye.</u>

Experiment 2: Understand the cause of farsightedness and nearsightedness

In the case of farsightedness,

1. Make the eye farsighted by moving the retina forward to the R_h position.
2. Adjust the position of the object box (lamp) until the image is sharp. What is the distance?
3. Now move the image box until it is 35 cm from the eye.
4. What is the appearance of the image?
5. Try the two lenses +2.00 and –1.75 for each time. Which lens is necessary to correct this defect? Is it converging or diverging?

You will repeat the above steps for nearsightedness.

6. Now make the eye nearsighted by moving the retina to the R_m position.
7. Adjust the position of the object box until the image is sharp. What is the distance?
8. Now move the box until it is 35 cm from the eye.
9. Try the two lenses +2.00 and –1.75 for each time. Which lens is necessary to correct this defect? Is it converging or diverging?

Experiment 3: Understand the effect of varying pupil size.

1. Select any case in which the image is not clear.
2. Insert the diaphragm with the 13 mm hole either just in front of or just behind the cornea.
3. How is the image changed?

Persons who have minor eye defects may, by looking at objects through a small hole in a card, or by squinting, see them distinctly. Why is this?

4. What is the intensity of the image with that of the normal eye?

Experiment 4: Understand the cause of astigmatism.

1. Place the lamp box at 35 cm and the retina in the R (normal eye) position
2. Insert immediately behind the cornea the cylindrical –5.50 concave lens producing an astigmatism

In the human eye astigmatism is generally due to a slight cylindrical curvature of the cornea; so in the model a change of cornea would perhaps be the logical way of producing astigmatism. This being impracticable, the same purpose is accomplished by the insertion of an additional lens.

3. Turn the cylindrical lens a little to make one line sharp and the others blurred.
4. Place in front of the cornea the correcting convex cylindrical lens marked +1.75 and turn it until the image is sharp
5. What are the relative directions of the cylindrical axes in the two lenses?
6. Repeat this with the rear lens at a different angle.

Experiment 5: Understand compound defects

Astigmatism is often accompanied by farsightedness or nearsightedness.

1. Place the cylindrical lens –5.50 at G_1 immediately behind the cornea with its axis vertical. (*Notice that this makes an eye with astigmatism.*)
2. Move the retina into position R_m to make the eye nearsighted.
3. Correct these problems by choosing the proper combination of spectacle lenses.
4. Which two lenses did you use? (*Make sure about this with your TA.*)
5. If you combined the two lenses you used, imagine what shape the single compound lens would have.

Experiment 6: Understand how vision is still possible even if the crystalline lens has been removed by surgery.

The crystalline lens is only one part of the lens system of the eye. Sometimes (for instance, in the case of a cataract) it has to be removed.

1. Take out the crystalline lens. (*Take out every lens behind the cornea.*)
2. Use the +7.00 lens in front of the eye to show that vision is still possible.
3. For what distances is the image distinct?
4. Make a fictional story for a person who got his/her crystalline lens removed in terms of this part of experiment.

Experiment 7: Understand the function of a magnifier or reading glass.

1. Place the retina in the normal R position.
2. Insert the *only* +20.00 as the crystalline lens. (*Notice that this is a normal eye.*)
3. What is the diameter of the image with the object box at 35 cm?
4. Use the +7.00 lens as a magnifier in front of the eye.
5. Adjust the viewing distance until the image is distinct.
6. What does this experiment show about the use of the magnifying glass in enabling the eye to view distinctly a very close-up object?
7. Place the lamp at 35 cm and the retina in the normal eye, R, position.
8. What is the approximate size of the image?
9. Make the eye nearsighted and move the object until the image is again sharp.
10. Now what is the size of the image? What is the distance?
11. Compare the image of the magnified object with the image of the nearsighted object. What do you notice? (*Make sure about this with your TA.*)

Experiment 8: Understand the function of eyeglass lenses.

Use your own eye for this part.

1. With one eye look in turn through the +2.00 and the –1.75 lenses
2. Keep looking up front, then move only the lenses from side to side.
3. In which case do objects seem to move with the lens and in which case do objects move against?
4. What will happen if you rotate the cylindrical lens (–5.5) in front of your eye?

Now, locate a pair of glasses for the purpose of determining what they correct for.

5. Use your own or borrowed glasses.
6. Test the glasses. (*Use the above methods.*)
7. What eye defects are they intended to correct?
8. Are the two lenses the same? And if not, which is stronger?
9. Is there astigmatism?