Physics 223/224 ~ Experiment 26

Optics of the Eye

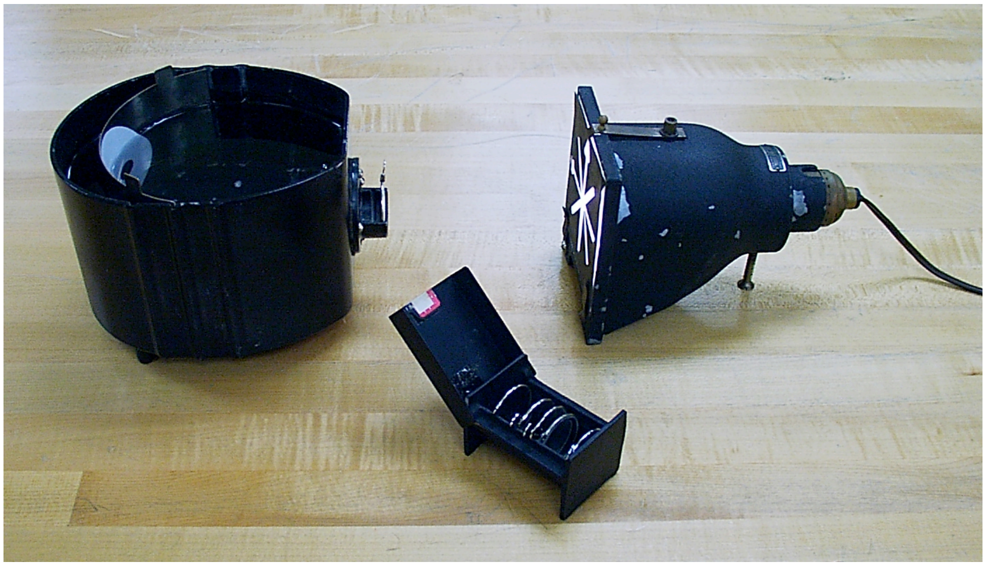

Fig. 26-1 Eye Model, Lenses, Light Source

EQUIPMENT

Cenco Eye Model
Set of Lenses
Object Box (Light Source)
Meter Stick
Eye Chart
Video on the Eye
1 Flashlight/person
Lens Cleaning Towelettes

Set of Lenses

1 Diaphragm

4 Spherical Lenses

-1.75 D
+2.00 D
+7.00 D
+20.00 D

2 Cylindrical Lenses

-5.50 D
+1.75 D

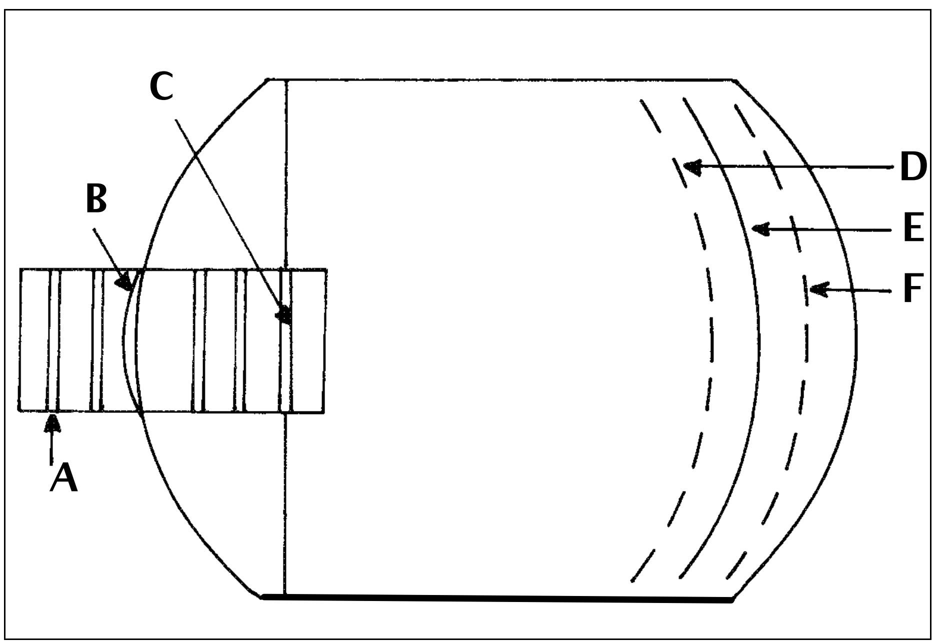

Fig. 26-2 Eye Model Schematic
Lens Positions: (**A**) Corrective Lens (**B**) Cornea (**C**) Crystalline Lens
Retina Positions: (**D**) Farsighted Eye (**E**) Normal Eye (**F**) Nearsighted Eye

Physics 223/224 ~ Experiment 26

Optics of the Eye

Advance Reading

Text: Vision, myopia, hyperopia, astigmatism, cornea, retina, blind spot.

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, the retina. Most of the refraction of light occurs at the cornea-air interface (at the surface of the eye), since this interface has the greatest change in the index of refraction. Internal parts of the eye have indices of refraction approximately equal to that of water ($n_{water} \cong 1.333$).

The eye model (Fig. 26-1 and Fig. 26-2) simulates the human eye by means of a metal tank filled with water and various lenses. At the front of the tank is a lens that 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 connects the retina to the brain. This area has no rods or cones (photoreceptor cells) to perceive light.

The human eye can have conditions that affect vision. This can be caused by refractive parts (cornea, lens) having abnormal curvature, as well as an alteration in the length or shape 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. The rays focus at a greater distance, on the retina.

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. The rays focus in a shorter distance, on the retina.

A third condition is *astigmatism*. In this case the cornea's curvature is asymmetric (curvature different in one direction than in another). A cylindrical lens is used to correct for this problem (Fig. 26-3).

Accommodation refers to the ability of the crystalline lens to contract/relax to make minor adjustments in focusing an image. As people age, this ability is reduced – *presbyopia*.

The power of a lens is referenced when discussing corrective lenses:

$$P = \frac{1}{f} \qquad \textbf{Eq. 26-1}.$$

Lenses can be converging (positive) or diverging (negative). The power of a lens is also, of course, positive or negative. The unit is *diopter*, D, or m^{-1}.

Visual pigments are found in the rods and cones of the retina. The rods are receptive to low-level light; they are not sensitive to variations in wavelength (color). The cones are receptive to higher intensity light of various wavelengths; each cone contains one of three visual pigments. Visual purple is a fourth light sensitive pigment found only in the rods; this pigment permits night vision. It is bleached out by light conditions brighter than twilight and takes about 30 minutes to regenerate. Keep your flashlights pointed *below horizontal* at all times, please.

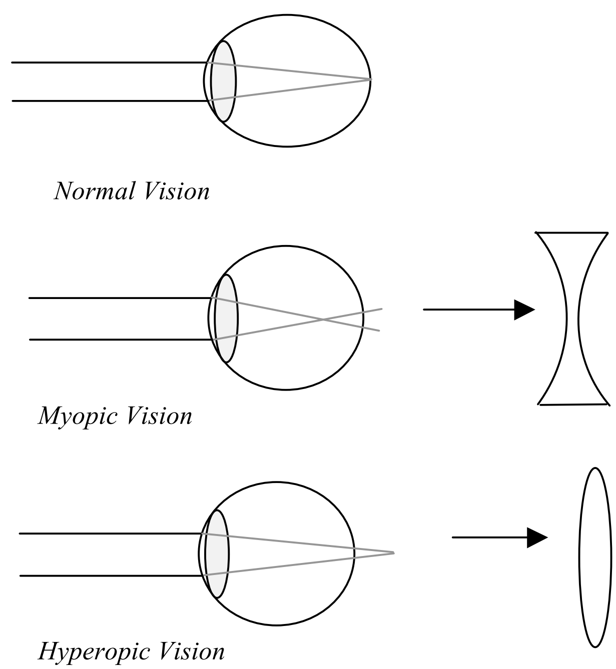

Fig. 26-3 Vision Problems

Physics 223/224 ~ Pre-Lab 26

Optics of the Eye

Name ____

1. What are the objectives of this experiment? (5 pts.)

2. What is a real image? (10 pts.)

3. What is nearsightedness? (10 pts.)

4. How is nearsightedness corrected? (10 pts.)

5. What is farsightedness? (10 pts.)

6. How is farsightedness corrected? (20 pts.)

7. What is astigmatism? (20 pts.)

8. How is astigmatism corrected? (15 pts.)

Physics 223/224 ~ Pre-Lab 26

Optics of the Eye

Physics 223/224 ~ Experiment 26

Optics of the Eye

PROCEDURE

1. Review the Eye Model Schematic (Fig. 26-2) before beginning the procedure. A special data sheet is attached. Record your observations on this sheet for each step. Note changes in orientation, clarification, intensity, and size.

2. Check your lens set to be sure you have all the items necessary for the experiment.

3. *Accommodation:* Place the +7D lens into the crystalline lens slot. Place the retina in the normal position. Hold the eye model in a position so that it faces a brightly lighted object at least 20 meters away. A distant object outside the window (or the doors at the end of the hallway) would be good choices.

4. *Accommodation:* Place the eye model 35 cm from the object box (distances will be measured from the cornea). Note the image.

5. *Accommodation:* Replace the +7D lens with the +20D lens. Note the image; adjust to focused image if needed; record the distance.

6. *Blind Spot:* Rotate the eye model so that part of the image falls on the blind spot. What happens to the portion of the image that falls on the blind spot?

7. *Farsighted:* Return the eye model to a clearly focused position. Move the object box closer to the eye model (the image now falls behind the retina); 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 (pupil contracts) or to a farsighted person squinting. Indicate on the ray diagram (back of data sheet) to show how squinting improves poor vision. (If you are nearsighted, 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.) Remove diaphragm.

8. *Farsighted:* Move the object box so that the image falling on the retina is in focus again. Move the retina into the farsighted 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? Remove corrective lenses.

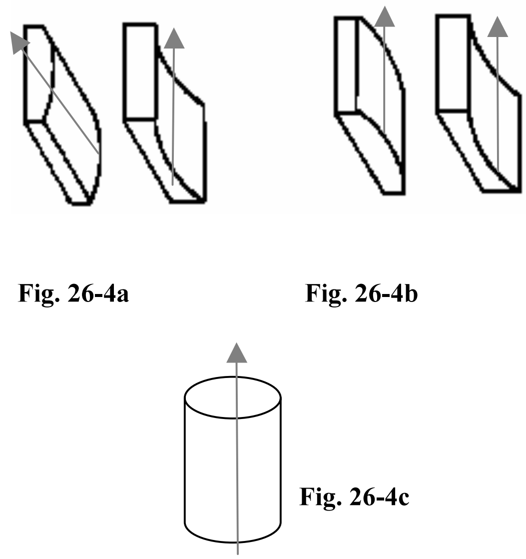

Fig. 26-4a **Fig. 26-4b**

Fig. 26-4c

26-4a: Lenses - Perpendicular Axes

26-4b: Lenses - Parallel Axes

26-4c: Standard Cylinder Axis

Fig. 26-4 Cylindrical Lenses, Axes

9. *Nearsighted:* Move the retina into the nearsighted position. Which corrective lens is needed and why? Test your hypothesis. Which lens gives the clearest vision? Remove corrective lenses.

10. *Astigmatism:* Return the retina to the normal position. Leave the +20 D lens in the crystalline lens slot, and obtain a focused image. Next, 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 axes of the lenses aligned when this occurs? To determine this, look at each lens, and find the axis (Fig. 26-4). It may be necessary to look through the lens at the door (or a window). Rotate the lens. When the door appears to be tall and narrow, the axis is vertical. Remove the cylindrical lenses.

11. *Cataract Surgery:* When the crystalline lens becomes cloudy it is removed. Years ago, there were no replacement lenses available. Leave only the +20D lens in the eye model, retina in the normal position. Obtain a focused image. Remove the lens. Try to form an image on the retina (eye model closer to or farther away from the object). Is this possible?

12. *Cataract, Corrective Lenses:* Determine what power of lens is needed to compensate for a missing crystalline lens. 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. Replace the +7D lens with the +2D lens, then the +20D lens. Measure the object distance when an image is clearly focused on the retina. These days, when the crystalline lens is removed, a manufactured lens replaces it, permitting near perfect vision.

The following tests are for information only. Any indications of vision problems should be checked by a professional.

13. Obtain *Ishihara's Tests For Colour Deficiency* from your TA. If the lab is still dark, allowing other students to finish with the parts of the procedure requiring low light, take the test to a lighted room such as the tutoring room. It is required that you have clean, dry hands, please. This is the same test that eye doctors use. Record the patterns or numbers you observe. Note any symptoms on your data sheet.

14. You *must wait* for the lights in the lab to be turned on to finish this experiment. Once the lights are on: An eye chart is located 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 affect 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 data sheet.

15. 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), this may indicate astigmatism.

QUESTIONS

1. Why does most refraction occur at the cornea-air interface?

2. Why can't you see clearly underwater without the aid of goggles?

3. Why can you see clearly underwater with goggles?

Physics 223/224 ~ Experiment 26

Optics of the Eye

STEP #	VISION TYPE (*e.g.*, normal, astigmatic)	Lens and Retina Configuration (*e.g.*, +20 D, farsighted)	Corrective Lens (if applicable)	OBSERVATIONS and COMMENTS
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				

Step 13: Color Blind Test Results: ______________________________. **Step 14**: Your vision: Right Eye _____________ Left Eye _____________.

Step 15: Symptoms of Astigmatism: ____________________________

Physics 223/224 ~ Experiment 26

Optics of the Eye

Diagram for Step 7: Farsighted Eye

Light rays refract primarily at the cornea, as this interface (air, cornea) has the greatest change in the indices of refraction. Light refracts by varying amounts as it passes through the crystalline lens, depending on s_o (how far away the object is). Realize that an image does not *actually* consist of a few, or even many, rays. One can safely assume an infinite number of rays from an object.

The emphasis of this farsighted eye diagram is that all images align behind the retina. *Think*: If each of the rays in this diagram produces a separate image, and the images are aligned only behind the retina, what is the situation *at the retina*? This diagram shows 10 separate images on the retina. To indicate squinting, draw a circle around a few of the images before they enter the eye and a corresponding circle at the retina to indicate a *reduction in the number of images* on the retina.
Fewer images → clearer vision.