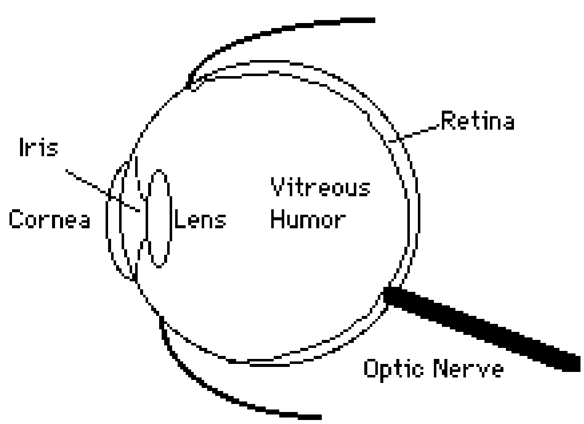
THE EYE

OBJECTIVES:

1) Know the basic process of image formation by the human eye and how it can be simulated in the laboratory.
2) Measure the far points and the near points of a simulated ideal eye and a myopic eye.
3) Learn to correct near-sightedness and far-sightedness with spectacle lenses.
4) Calculate the power of a spectacle lens required for correction of a near-sighted "eye". Observe its effect.
5) Observe the phenomenon of astigmatism and learn to correct it with a cylindrical spectacle lens.
6) Determine the depth-of-field of a simulated eye and how it changes as the diameter of the iris diaphragm is varied.
7) Determine your own near point and far point, with (if you wear them) and without spectacles. Calculate the prescriptions based on these measurements.

INTRODUCTION

Figure 1 shows the optics of a human eye. The eye has a variable focal lens. Light is first refracted at the front surface of the eye (the cornea), then at the crystalline lens. The iris acts as a variable aperture to control the amount of light that enters the eye. The transmitted light then forms an image on the retina and stimulates the optic nerve, which in turn generates electrical signals to the brain for interpretation.



The human eye
Figure 1

The eye changes its focal length by contracting or relaxing the ciliary muscles to change the shape of the crystalline lens. When the ciliary muscles are completely relaxed the crystalline lens is thin and acts as a weak lens (long focal length). The eye can then see the most distant object (the far point). When the ciliary muscles are contracted most and the lens is thickest, it is a strong lens (short focal length), and the eye can see the nearest object (the near point). The ability of the eye to focus at different object distances is called accommodation.

For an ideal eye, the far point is infinity (∞) and the near point is about 25 cm. Very few people have such perfect vision. Common imperfections of the eye include: (a) the eyeball is too long, which causes myopia or near sightedness; (b) the eyeball is too short, which causes hyperopia or far-sightedness; (c) the shape of the eyeball is non-spherical, which causes astigmatism. These imperfections can be corrected by using spectacle lenses (eyeglasses) of proper types.

In this experiment, you will work with an optical system that simulates a human eye (figure 2). Lens L_1 represents the cornea. Lens L_2 represents the crystalline lens. You will have two lenses of different focal lengths for L_2. One is a weak lens, L_2 (far), for viewing distant objects; the other is a stronger lens, L_2 (near), for viewing nearby objects. Note that a human eye can adjust its focal length anywhere between those of L_2 (far) and L_2 (near).

The lens equations assume certain sign conventions, which it is useful to gather here:

\+ is used for the focal length of converging lenses, and distances to real images. For light incident from the left, real images form on the right and are inverted.

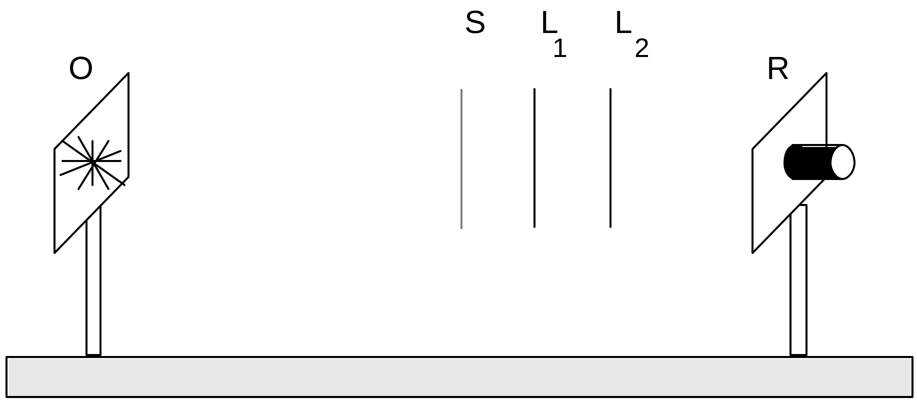
\- is used for the focal length of diverging lenses, and distances to virtual images. For light incident from the left, virtual images form on the left and are upright.

Partner ________________________ Name______________________

________________________ Section ______________________

PROCEDURE

1. Normal eye
   a) Set up the optical system as shown in figure 2. Remove L_2 (near). Screw L_2 (far) onto the back of the fixed lens L_1, which is built into the lens stand. Align L1 and R along the axis of the optical bench. Put the variable aperture and the object O aside for now. Look through the eyepiece behind the retina (screen) at a distant object. Listen to the directions of your instructor about what object you should use. Move the retina back and forth along the bench until a sharp image is obtained. Estimate the distance from L_1 to this object (far point, or FP). Then tighten all the mounts on the bench and measure the distance from L_1 to the retina (length of the "eyeball").



O = Object S = Spectacle Lens (if needed)
L_1 = Cornea (fixed) L_2 = Crystalline Lens: either L_2 (near) or L_2 (far)
R = Retina

Figure 2

   b) Replace L_2 (far) by L_2 (near) and measure the near point. To do this, place the object on the bench. Look through the eyepiece of the retina and move the object back and forth until a clear image of the object is obtained. Now the distance from L_1 to the object is the near point (NP). You will notice that there is a moderate range of object distances for which a clear image can be obtained. This range is called the depth of field. Record the two extreme near points in between which you can obtain a clear image. Then calculate the depth of field.

Length of the "eyeball" = _______________ cm
FP (estimated) = _______________ m
NP(1) = _______________ cm
NP(2) = _______________ cm
Depth of field = |NP(1) - NP(2)| = _______________ cm

c) Place the variable aperture in front of L_1. Observe the effect the aperture size has on the depth of field.

Small aperture: NP(1) = ________________ cm
NP(2) = ________________ cm
Depth of field = |NP(1) - NP(2)| = ________________ cm

Large aperture: NP(1) = ________________ cm
NP(2) = ________________ cm
Depth of field = |NP(1) - NP(2)| = ________________ cm

Q: What is the effect of aperture on the depth of field, based on your three measurements?

2. Near-sighted Eye

a) Increase the length of the “eyeball” by moving the retina (screen) back by 2.0 cm. This is equivalent to making the “eye” near-sighted. For the rest of this section keep the retina at this new position.
b) Measure the new near point. [You should still be using L_2 (near).]
c) Replace L_2 (near) by L_2 (far), and measure the new far point.

Increase in the length of the “eyeball” = 2.0 cm
NP = ________________ cm
FP = ________________ cm

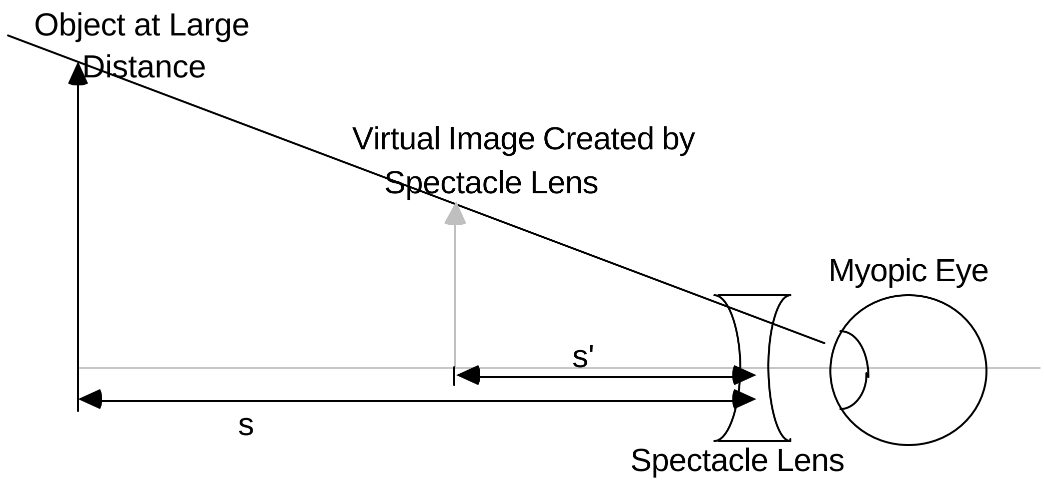
d) Calculate the focal length of the spectacle lens. We want to use it to correct the near-sighted eye, so that the corrected eye (eye plus spectacle lens) will have a normal far point of infinity (? ?

To do this, use the thin lens equation

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

where s is the object distance, s' is the image distance (s'>0 for real image; s'<0 for virtual image), and f is the focal length of the spectacle lens (f>0 for a converging lens; f<0 for a diverging lens).

In this application, s is the desired object distance which is infinity (∞), and s' (<0) is the actual far point obtained in step 2(c).



A corrective lens in front of a myopic eye indicating
the formation of a virtual object at the necessary distance
Figure 5

Show your calculation below:

f = ________________ cm (include correct sign)

Q: Should the lens be a divergent or a convergent one?

e) Convert the calculated focal length into the power in diopters, a quantity commonly used by optometrists to specify spectacle lenses. Use the equation

$$P = \frac{100cm}{f}$$

(P > 0 for convergent lenses; P < 0 for divergent lenses.)

P = ____________ diopters

f) Choose a spectacle lens that has a power closest to the desired value. Place it in front of L_1 (in the slot). Measure the far point and the near point of the corrected "eye" ("eye" plus spectacle lens). To measure the far point you should use L_2(far). To measure the near point, replace L_2(far) with L_2(near).

Power of the nearest available spectacle lens = ____________ diopters
NP of the corrected "eye" = ____________ cm
FP of the corrected "eye" = ____________ m

g) Compare your results with those for a normal eye (NP = 25 cm, FP = 8). Comment:

3. Astigmatic Eye

a) Return the eye to normal. Place a weak cylindrical lens L_3 in front of L_1 and L_2 (near). Look at the image of the object consisting of radial lines. Observe its appearance as the object distance, length of the "eyeball" and angle of the cylindrical lens are varied respectively. The effect you see is called astigmatism. Sketch the images for several typical settings to illustrate the effect:

b) Place a complementary cylindrical lens (one with the same power but opposite sign) L_4 in front of L_3 and rotate it until the astigmatism is corrected.

Q: What effect does the complementary cylindrical lens have on the astigmatic image?

4. Measure your own near point and far point, without and with spectacles (if you wear them) respectively.

	without spectacles		with spectacles	
	left eye	right eye	left eye	right eye
NP				
FP				

5. If your are near-sighted, show your calculations for the power of the spectacle lenses that you need:

Comment on your current prescription: