Optical Systems

The normal eye

The ciliary muscles can adjust the shape of the lens of the human eye. As the eye attempts to see objects at different distances, the muscles will adjust the focal length of the lens until the lens, in conjunction with the cornea/air interface, can place a real image of the object on the retina. The image distance for a given eye is always the same since the distance from the lens to the retina is unchanging.

Although the real eye can accommodate having on objects at a wide range of distances, in lab today we will model the eye at its two extremes. We will use one lens to represent the bending power of the eye when viewing an object at its near point. We will use a different lens to represent the bending power of the eye when viewing an object near the eye’s far point.

- The NEAR model will have the minimum focal length achievable, set by the "+10 cm lens".
- The FAR model will have the maximum focal length achievable, set by the "converging lens #2", which has a nominal focal length of ~15 cm.

We will change lenses depending on whether the eye is looking at the most distant objects it can see (FAR model) or the closest objects it can see (NEAR model).

1. Place the screen at the 70 cm position. Place the lens from the FAR model (converging lens #2) so that the image of an object at infinity (Patterson Hall) appears on the screen. For your records, sketch a diagram showing the placement of source, lens, and screen.

2. What is the **fixed distance** between the lens and the retina for this eye?

3. What is the focal length of the FAR model lens? (The longest focal length achievable in this eye.)

4. If the eye is going to focus on an object that is closer, the ciliary muscles must act to push on the lens, changing its curvature and producing a smaller focal length. This process is called "accommodation." By swapping out the NEAR lens for the FAR lens we represent the maximum accommodation possible for our model eye (and hence the shortest possible focal length).

Position the light source on the rail so that the image on the screen is in focus. Sketch a diagram showing the placement of source, lens, and screen. What is the near point for this normal eye?

5. Using the thin-lens equation, calculate the actual focal length of the NEAR model lens.

The nearsighted eye

A nearsighted person usually has an eye that is too long—the fixed distance between lens and retina is longer than it should be. For this person, the relaxed eye (with the longest possible focal length) will no longer produce a clear image of objects at infinity. The furthest object that can be clearly seen is at the far point.

1. Move the screen to the 88 cm position to represent a nearsighted eye.

2. The FAR model lens represents the relaxed eye (greatest focal length). Place FAR model lens in the same location as before. Move the source on the rail to determine the far point of this nearsighted eye. Sketch a diagram showing the placement of source, lens, and screen.

3. Use the thin lens equation to predict what the far point *should be* for this nearsighted eye and compare your calculation to what you observed.

4. Remember that the near point is the closest distance the eye can see clearly. To look at a nearby object, the lens will change shape and have its smallest possible focal length. Swap the FAR model out for the NEAR model lens to represent the accommodation. Move the source on the rail to determine the near point of this nearsighted eye. Sketch a diagram showing the placement of source, lens, and screen.

4. You can use the thin lens equation to predict what the near point should be for this eye. Compare your prediction to what you observed.

Correcting the nearsighted eye

Compared to the normal eye, the nearsighted eye experiences a significant loss of distance vision (a much smaller far point) and a small improvement in close vision (a slightly smaller near point). To correct this vision defect, we can use a diverging lens to change the path of light rays before they enter the eye. Properly corrected, the nearsighted eye will then be able to focus clearly on very distant objects again.

1. Experimentally determine where you should place the "diverging lens" in order to give this nearsighted eye the ability to see Patterson Hall at infinity. (Remember, the eye uses its maximum focal length to try to see an object at infinity, so use the FAR model lens.) Placing the diverging lens at this location effectively corrects the far point of the nearsighted eye to infinity. Sketch a diagram showing the placement of source, lenses, and screen.

2. We can think about the way a corrective lens fixes the problem by treating the image produced by the corrective lens (which the light encounters first) as the source object for the second lens. In other words, the "diverging lens" produces an image, which is the object for the eye's lens.

Explain why the diverging lens has to put its image at the eye's far point if the relaxed eye is going to be able to see it.

3. Since you now know that the image produced by the diverging lens is at the nearsighted eye's far point, you can use the thin-lens equation to find the focal length of the diverging lens.

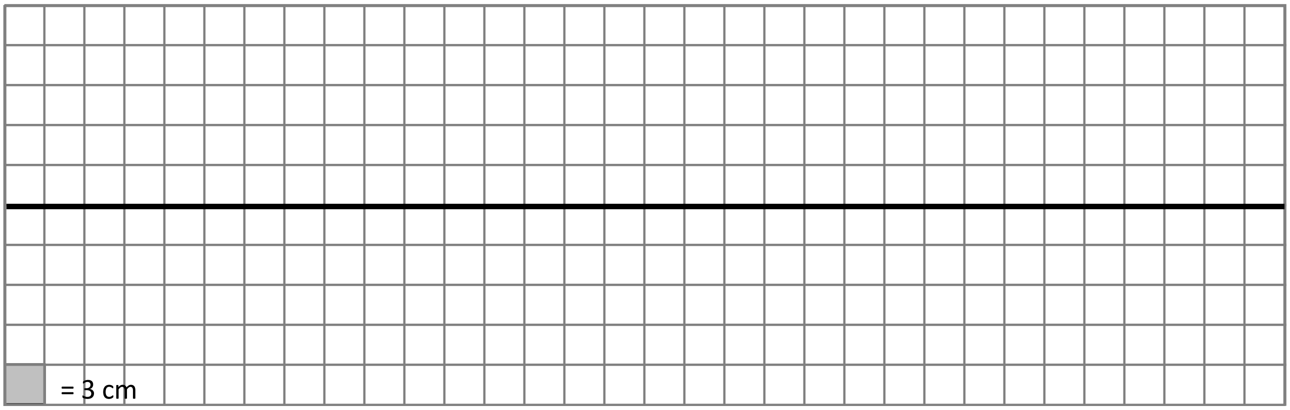
4. The corrective lens changes the eye's effective near point as well. We need to use NEAR model lens to represent the eye at maximum accommodation. Move the source on the rail to determine the near point of this corrected nearsighted eye. Sketch a diagram showing the placement of source, lens, and screen.

In correcting the nearsighted eye's far point, we have made its near point a little larger, but the overall range of vision for this nearsighted eye has been vastly improved by the correction.

5. You now have a source at a known location and two lenses with known focal lengths at known locations. We should be able to predict the location of the final image using the thin lens equation (twice) or by drawing principal rays.

Use the thin lens equation to determine where the final image produced by this system should be. How close to your actual screen position is it?

6. Use ray tracing to illustrate the formation of the first image and then the second.



Compound microscope

In our microscope we will have a tube length of 16 cm and use two lenses:

- An objective lens, for which we will use the +10cm lens.
- An eye piece, for which we will use a +5cm lens.

1. Place the objective lens at 30cm on the rail. Since our microscope will have atube length of 16 cm, a real image will form at 46 cm, place a screen there.

2. Use the thin lens equation to determine where our specimen (object) should go if we want to put the image at the end of the tube. Once you have a value, place your lamp there to verify the location.

3. Now remove the screen at 46 cm and swap the lamp out for your specimen (small font text).

4. Complete your microscope by placing the 5 cm eye piece. Where do you need to put that eyepiece to complete our compound microscope? Place it there.

5. What total magnification should this microscope have (assuming the final image would form at 25 cm)?

6. Look through the eyepiece. You may need to adjust the position of the source document just a bit to get the image in focus—just like you would with any microscope.