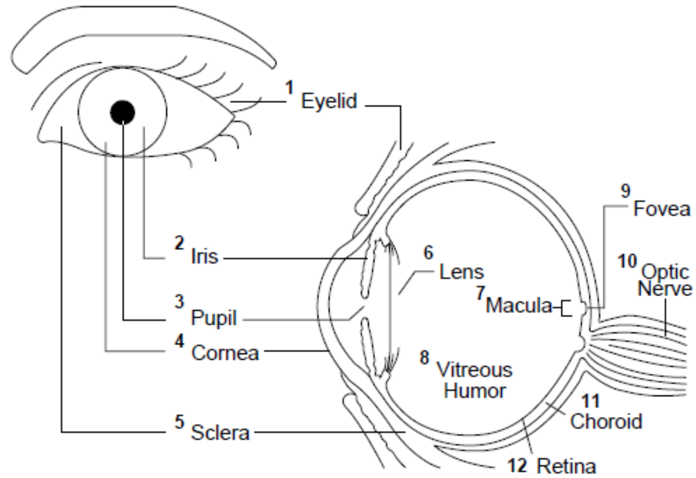
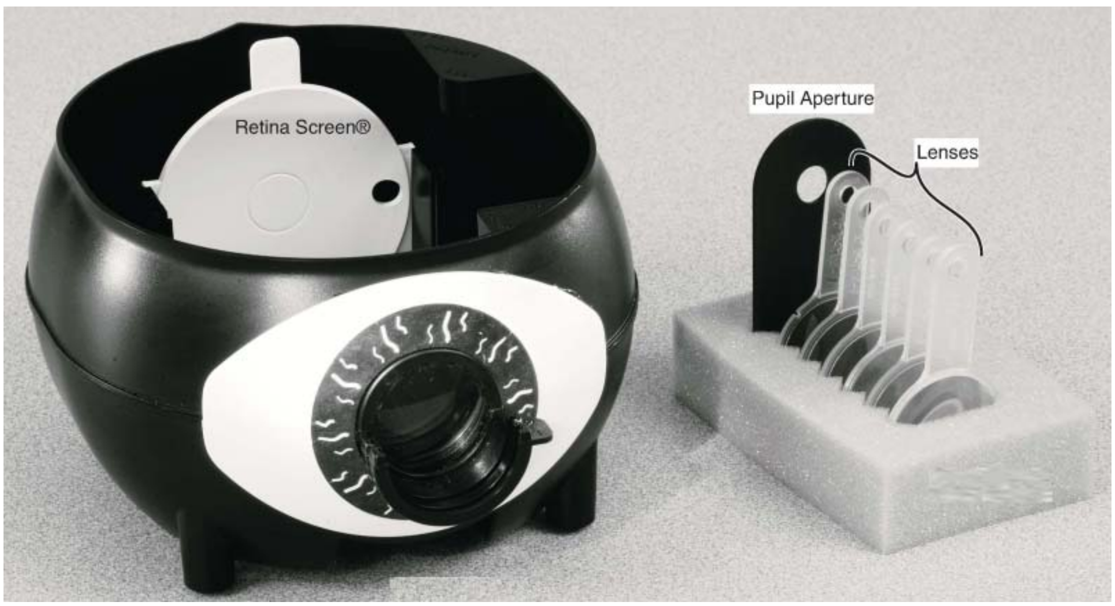
The Human Eye

The schematic shows a simple model of the eye. Light enter the eye through the translucent cornea, it passes through the anterior chamber that is filled with a liquid called aqueous humor, then through the pupil into the posterior chamber, then through the lens into the main eye chamber and finally onto the retina at the back side of the eye. The main eye chamber is filled with a gel like fluid called vitreous humor. In this activity, we will explore the optics of the eye by using a simple model of the eye. The model is shown below.



A white movable screen is used to simulate the retina. A dark spot on the screen designates the position of the optic nerve. A set of lenses can be positioned in slots labeled SEPTUM, A and B, to simulate various accommodations of the eye lens. Aqueous and vitreous humor are simulated with water.



The properties of the various optical elements used in the model eye are provided in the following table..

Plano-convex Corneal Lens		**Polycarbonate Plastic Movable Lenses Focal Lengths (In Air)**	
Material	B270 Glass	**Spherical Convergent**	+120 mm
Diameter	3 cm	**Spherical Convergent**	+62 mm
Thickness	4 mm	**Spherical Convergent**	+400 mm
Radius of Curvature	71 mm	**Spherical Divergent**	-1000 mm
Focal Length (in air)	140 mm	**Cylindrical Convergent**	+307 mm
		Cylindrical Divergent	-128 mm

Procedure

Accommodation

1. Do not fill the eye model with water yet. Put the retina screen in the middle slot, marked NORMAL. Put the +400 mm lens in the slot labeled SEPTUM. Position the eye model about 35 cm from the light source, with the eye looking directly at the illuminated screen. Can you see a clear focused image on the retina? Move the object away from the eye until the image is in focus.

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2. Fill the eye model with water to within 1 or 2 cm of the top. Return it to the same position as in step 1. Is the image still in focus? Explain.

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3. Try changing the distance; can you get the image to focus? Explain. What effect do the aqueous and vitreous humors (modeled by the water) have on the focal length of the eye's lens system?

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4. Place the eye model about 35 cm from the light source. Replace the +400 mm lens in the SEPTUM slot with the +62 mm lens. Is the image in focus now? Move the eye model as close as possible to the light source while keeping the image in focus. Describe the image on the retina.

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5. Measure the object distance, d_o, from the screen of the light source to the top rim of the eye model. (The front of the rim is a convenient place to measure to and marks the center of the eye model's two-lens system.) Record this distance, which is the **near point** of the eye model when equipped with the +62 mm lens.

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6. How would you measure your near point? Try it out. The average human eye has a near point for distinct vision of about 25 cm.

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7. Add the +400 mm lens to slot B. This combination models a different focal length for the eye lens. How close can the eye focus now?

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8. Keep the +400 mm lens in slot B and replace the lens in the SEPTUM with the +120 mm lens. At what distance does the eye focus now?

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9. What does a real human eye do to change the focal length of the its lens?

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10. Remove both lenses and place the +62 mm lens in the SEPTUM slot. Adjust the eye-source distance to the “near point” distance for this lens (which you have found earlier) so that the image is in focus. While looking at the image, place the round pupil in slot A.

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11. What changes occur in the brightness and clarity of the image? Move the light source several centimeters closer to the eye model. Is the image still in focus? Remove the pupil and observe the change in clarity of the image. Both with and without the pupil, how much can you change the eye-source distance and still have a sharp image?

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12. Position the eye model (with pupil removed) so that it is looking towards a *distant* object (the object 2.0 m away or more). Is the image on the retina in focus? Replace the lens in the SEPTUM slot with one that makes a clear image of the distant object; this is the **far-vision lens**. Record the focal length marked on the handle of the lens.

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13. What do you think is the effective focal length of the eye model under this configuration?

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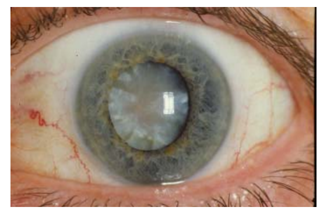
Cataracts



1. One of the earlier treatments of one of the eye defects, cataracts, is to surgically remove the eye lens. Remove the crystalline lens from the eye model and observe the image of the distant object on the retina. What do you conclude; can an unaided eye without a crystalline lens focus on distant objects?

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2. Place the +400 mm lens in slot 1 to act as an eyeglasses lens. Does this restore clear vision?

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3. Focus the eye now on nearby light source. Can you adjust the near object distance to form a clear image? Replace the eyeglasses lens in slot 1 with the +120 mm lens. Now can you adjust the object distance to form a clear image?

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4. What do you conclude about Cataracts?

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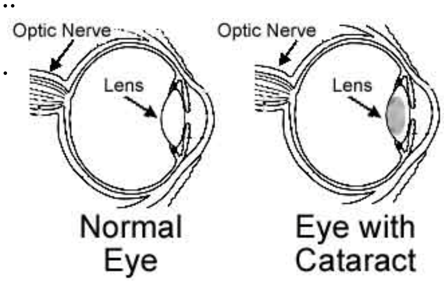

In an eye with a cataract, the lens becomes cloudy. This is due to changes in the chemical makeup of the lens which happens with age. The lens, which is composed primarily of protein, becomes thicker and less clear. This clouding distorts rays of light and prevents light from being focused on the retina[1].

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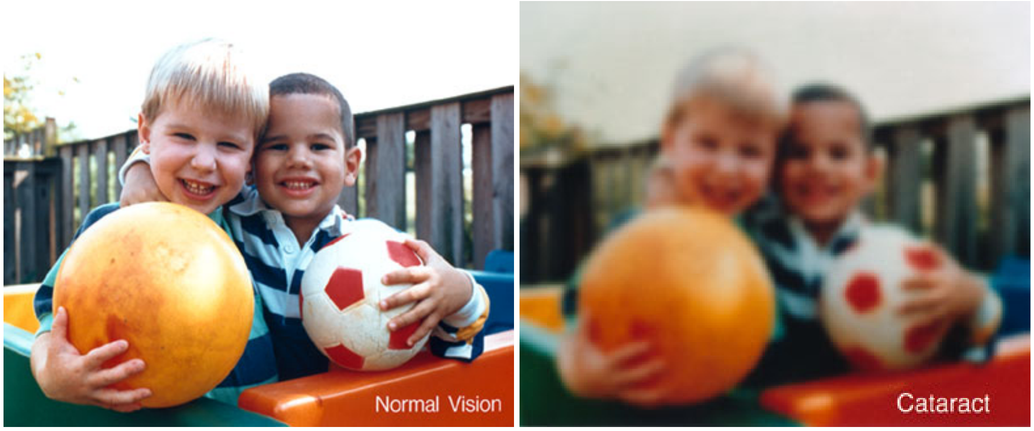
[1] This information along the drawing of the eye were obtained from: http://faculty.washington.edu/chudler/neurok.html

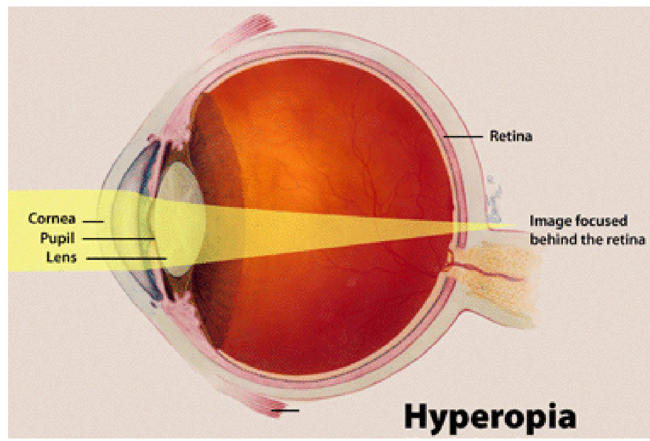
The following images illustrate what a person with Cataract sees:



Images from National Eye Institute, National Institutes of Health

Far-sightedness (Hyperopia)

A person affected by Hyperopia can have a shorter-than-normal eye ball or an eye lens that focuses too far. This causes images of near objects to be formed behind the retina. We model that in this lab by placing the retina close to the lens system.



1. Set the eye model to normal near vision (put the 62 mm lens in the SEPTUM slot, remove other lenses, and make sure the retina is in the NORMAL position). Position the eye to look at the nearby light source. Adjust the eye-source distance to the near-point distance so that the image is in focus.
2. Move the retina screen to the forward slot, labeled FAR. Describe what happens to the image. This is what a far-sighted person sees when trying to look at a near object. Decrease the pupil size by placing the round pupil in slot A. What happens to the clarity of the image? Remove the pupil.

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3. Try a distant object now, and describe the image. Does a far-sighted person have trouble seeing distant objects? Why was it not necessary to change the lens to look far away?

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4. Return the eye model to looking at the nearby light source. You will now correct the Hyperopia by putting eyeglasses on the model. Find a lens that brings the image into focus when you place it in front of the eye in slot 1. Record the focal length of this lens. Rotate the eyeglasses lens in the slot. Does this affect the image on the retina?

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5. A corrective lens is not usually described by its focal length, but rather by its light-bending power, which is measured in units called diopters. To calculate a lens's power in diopters, take the reciprocal of its focal length in meters. What is the power of the eyeglasses lens that you selected for the model eye?

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6. Make sure that the image is still in focus. Remove the eyeglasses. Add the +120 mm lens in slot B to simulate what happens when the crystalline lens increases its power by accommodation. Does the image become sharper?

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This shows that the eye can compensate for Hyperopia if it can accommodate sufficiently.

The following image[2] illustrates what a far sighted person can see. Can you explain how?

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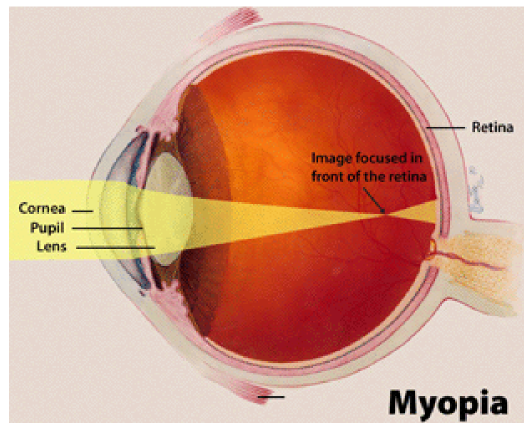
Near-sightedness (Myopia)

A person affected by myopia can have a longer-than-normal eye ball or an eye lens that focuses too near. This causes images of near objects to be formed ahead of the retina. We model that in this lab by placing the retina far from the lens system.



1. Set the eye model to normal, near vision (put the +62 mm lens in the SEPTUM slot, remove other lenses, and put the retina screen in the NORMAL position). With the eye model looking at the nearby light source, adjust the eye-source distance so that the image is in focus.
2. Move the retina screen to the back slot, labeled NEAR. Describe what happens to the image.

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3. Decrease the pupil size by placing the round pupil in slot A. What happens to the clarity of the image? Remove the pupil.

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4. You will now correct the myopia by putting eyeglasses on the model. Find a lens that brings the image into focus when you place it in front of the eye in slot 1. Record the focal length of this lens. Calculate its power in diopters. Does rotating the eyeglasses lens affect the image?

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5. Remove the eyeglasses. Adjust the eye-source distance so that the image is in focus. Is this distance different from the normal near-point distance you found earlier? Why?

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6. Turn the eye model to look at the distant object. Describe the image. Replace the lens in the SEPTUM slot with the normal far-vision lens. Is the image in focus?

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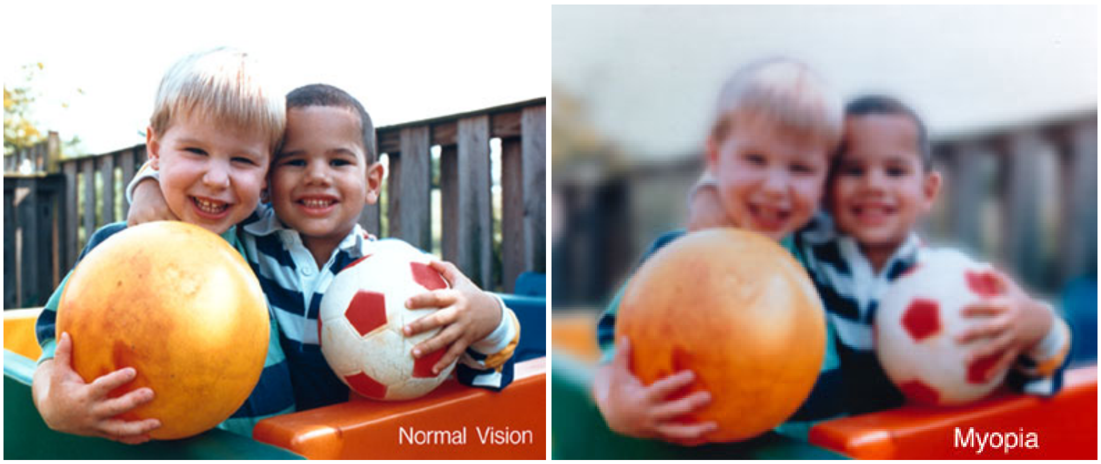
[2] This image is from http://images.eyehub.com/images/eyecyclopedia/farsightedness.jpg

7. This is what a near-sighted person sees when trying to look at a far-away object. The lens in the SEPTUM slot represents the crystalline lens in its most relaxed state, with its longest-possible focal length. Can an eye compensate for myopia by accommodation?



Images from National Eye Institute, National Institutes of Health

Astigmatism

In a normal eye, the lens surfaces are spherical and rotationally symmetrical; but an eye with astigmatism has lens surfaces that are not rotationally symmetrical. This makes the eye able to focus sharply only on lines of certain orientations, and all other lines look blurred. Astigmatism can be corrected with a cylindrical eyeglasses lens that is oriented to cancel out the defect in the eye. Each cylindrical lens included with the eye model has its cylindrical axis marked by two notches in the edge. The figure below is a test chart for astigmatism. All of the lines are printed the same thickness and brightness, but a person with astigmatism sees some lines as darker than others.

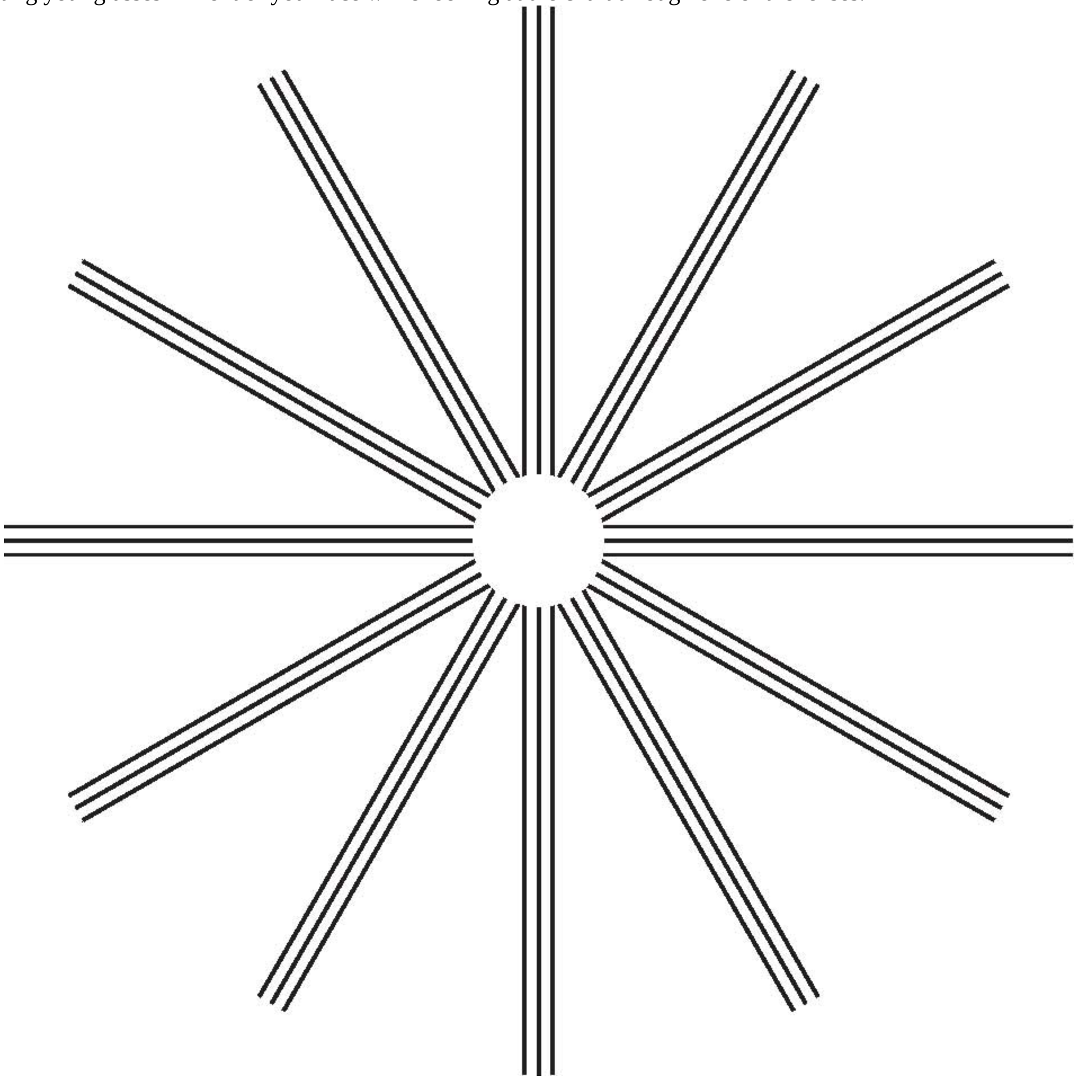
1. Set the eye model to normal, near vision (put the +62 mm lens in the SEPTUM slot, remove other lenses, and put the retina screen in the NORMAL position). With the eye model looking at the nearby light source, adjust the eye-source distance so that the image is in focus.
2. Place the -128 mm cylindrical lens in slot A. The side of the lens handle marked with the focal length should be towards the light source. Describe the image formed by the eye with astigmatism.

3. Rotate the cylindrical lens. What happens to the image?

This shows that astigmatism can have different directions depending on how the defect in the eye's lens system is oriented.

4. You will now correct the astigmatism with eyeglasses. Place the +307 mm cylindrical lens in slot 1. The side of the lens handle marked with the focal length should be towards the light source. Rotate the corrective lens and describe what happens to the image. Find the orientation of the eyeglasses lens at which the image is sharpest. What is the angle between the cylindrical axes of the crystalline lens and the corrective lens?

5. Cover one eye and look at the chart. Do some of the lines look darker than others? If they do, rotate the figure 90° to convince yourself that the lines are actually the same and it is only your eye that causes the effect. If you wear glasses, look at the figure both with and without your glasses. Try rotating your glasses in front of your face while looking at the chart through one of the lenses.



6. An eye can have more than one defect. Make the eye model have both astigmatism and Hyperopia (far-sightedness) by moving the retina screen to the FAR slot. Which additional eyeglasses lens do you have to put in slot 2 to bring the image back in focus?

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The following images[3] illustrates what a person with astigmatism sees:

[3] Images from: http://www.visique.co.nz/family-eye-care/common-eye-conditions/astigmatism.asp