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Experiment No. 1

Diagnosis and correction of refractive eye defects

I. Experiment Objective

- ✓ Diagnosis and correction of spherical and non-spherical eye abnormalities using the Sciascopy method
- ✓ Diagnosis and correction of eye abnormalities using glasses, glasses case, and Snellen chart
- ✓ Differentiation of different spherical and non-spherical lenses from each other

II. Required Equipment

Light source (ordinary lamp), perforated mirror (for reflecting and focusing light inside the patient's eye), eye phantom, glasses, glasses case, Snellen chart, converging lens, diverging lens.

III. Experiment Theory

The structure of the eye is similar to a sphere. In the front part of this sphere, there is a transparent window called the cornea, through which the internal structures of the eye, such as the iris and pupil, can be seen. The colored part of the eye is called the iris. The muscles of the iris change the size of the pupil (the black dot in the center of the eye). Behind the pupil, there is a transparent screen called the lens. Light enters the cornea from the external environment and after passing through the pupil, reaches the lens. The lens bends the light rays in such a way that an inverted image of the objects you are looking at is formed on the retina curtain behind your eye. The main function of the eye is to focus the light rays it receives from outside onto the retina curtain in such a way that an accurate image of the desired object is created on the retina curtain. The retina sends these images as nerve messages to the brain. The brain then flips these images back and forth so that you see them as they really are. Therefore, in order to see clearly, it is necessary for light to be accurately focused on the retina curtain.

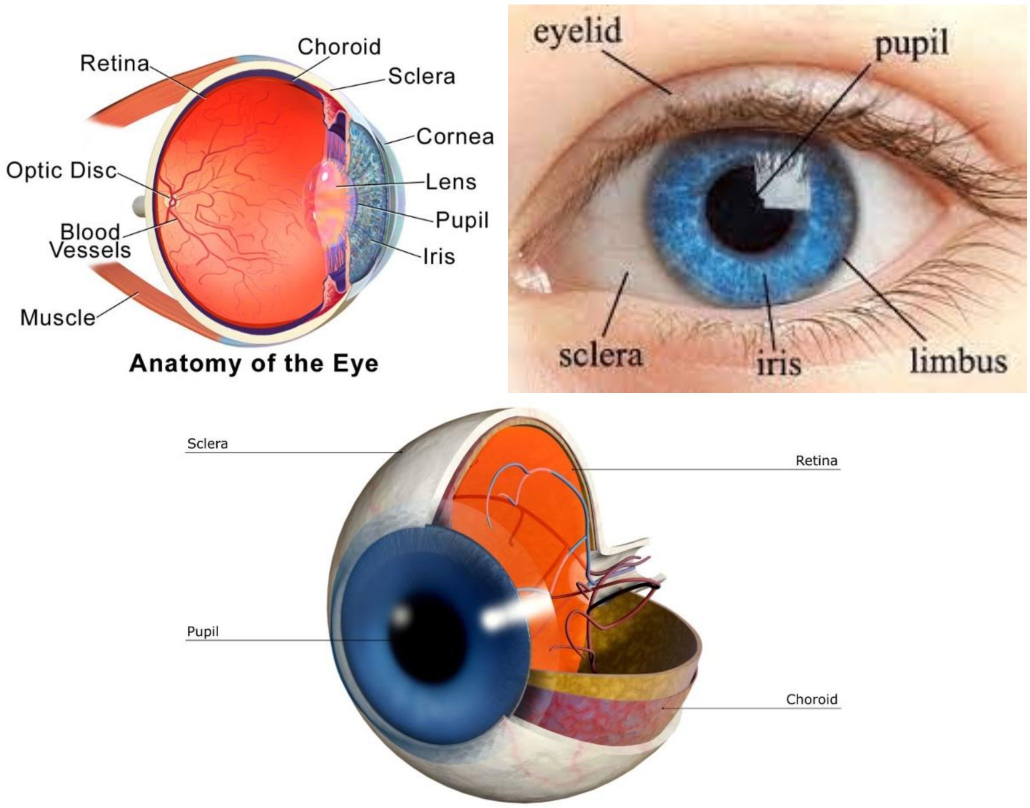


Figure 1 Anatomy of the human eye

A. Accommodation in the Eye

The lens of the eye is a flexible lens, meaning that it can change its curvature radius by changing its focal length with the help of the ciliary muscles. Adjusting the focal length in the eye and focusing the image on the retina is called accommodation. This action is performed from maximum eye vision (far point) to minimum eye vision (near point). (An eye that can see objects in the distance clearly without accommodation is considered a healthy eye)

B. Diopter

Refractive errors are measured in a unit called diopter. Diopter indicates the amount of prescription glasses. The higher the degree of farsightedness or nearsightedness, the higher the prescription glasses.

C. Causes of Spherical Abnormalities

Spherical eye abnormalities can be classified into three types based on their physical characteristics:

1. Axial abnormalities

   The eye is normal in terms of convergence power, but the visual axis in a myopic eye is longer and in a hyperopic eye is shorter than usual.

2. Curvature abnormalities

   In this abnormality, the dimensions of the eye are normal, but the curvature of different diopter surfaces of the eye is greater in myopia and less in hyperopia than usual.

3. Index abnormalities

   In this case, the axis and curvature of the eye are normal, but the refractive index of the transparent media of the eye is different from the normal refractive index. In other words, in myopia, it is higher, and in hyperopia, it is lower than the normal state. Most abnormalities are of the first type, which is axial. The second type is sometimes observed, and the third type is rare.

D. Types of Eye Abnormalities

1. Myopia

Myopia is an eye condition in which the convergence power of the eye is higher than normal. Therefore, light rays reach a point in front of the retina. In fact, this condition occurs when the curvature radius of the lens forming elements of the eye deviates from the normal state. If the cornea has a greater curvature compared to the size of the eye or the size of the eye has a greater curvature than usual, myopia is created.

Correction of Myopia

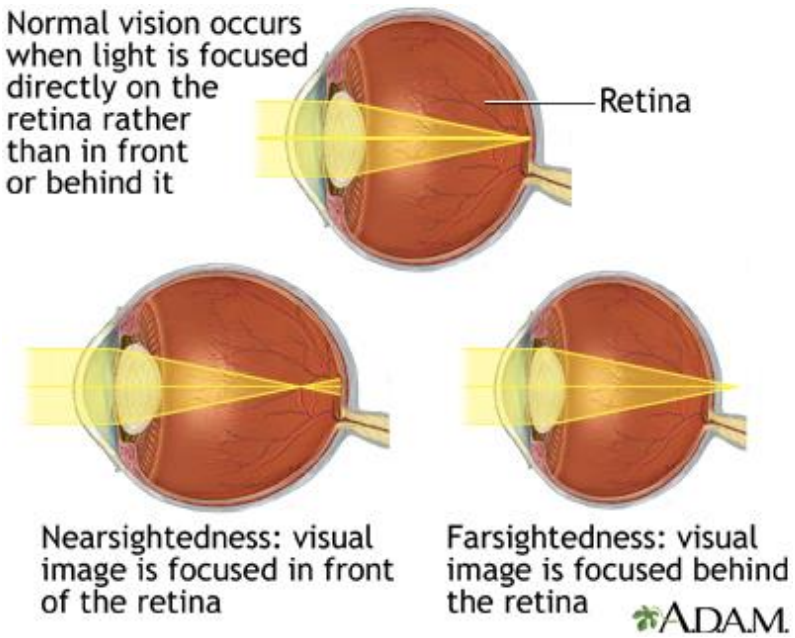
To correct this condition, we need to bring the convergence power of the eye back to normal. To eliminate some of the convergence power, we use a diverging lens in front of the eye, which reduces the convergence power depending on the power of the lens. The maximum vision in myopic eyes decreases. Therefore, when the rays reach the myopic eye from maximum vision, the divergence of the lens plus the convergence of the eye creates an image on the retina. So the diverging lens should focus the image of the incoming rays from infinity onto the maximum vision center of the myopic eye. Therefore, the prescribed glasses will have a focal length equal to the maximum vision center of myopic eye.

2. Hyperopia

Hyperopia is an eye condition in which the convergence power of the eye is less than normal and the image is formed behind the retina and virtually. In this condition, the intersection point of the rays with the retina is a surface and the image is not clear. Hyperopia occurs when either the eye has a shorter length compared to the curvature of the cornea or the cornea has less curvature compared to the length of the eye.

Correction of Hyperopia

To correct this eye condition, we need to use converging lenses. In this condition, both the amount of converging lens power is determined by determining the maximum vision center of hyperopic eye.



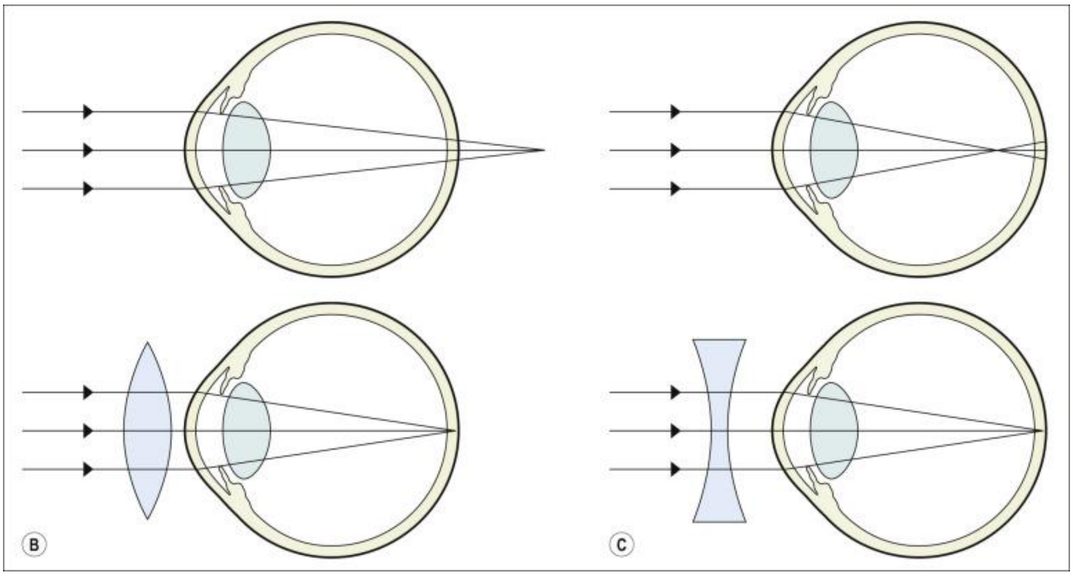


Figure 2. Image formation location in the Normal, Hyperopia (B), Myopia (C) eye and how to correct them by the using convex (B) or concave (C) lenses.

3. Presbyopia

Presbyopia is caused by the abnormality of the eye's components. In this condition, the different parts of the eye have lost their maximum powers. In the natural state, the muscles change the thickness of the lens by pulling or pressing, but in this condition, the muscles have lost their ability to fully exert pressure or tension. In fact, in this condition, the range of accommodation has decreased. That is, the minimum vision has moved away from the far eye and the maximum vision has moved closer to the near eye. Presbyopia starts at the age of 45 in different individuals and increases by 0.5 diopters every 5 years.

Correction of Presbyopia

In presbyopia, both minimum vision and maximum vision should be corrected. Therefore, either two glasses are used or bifocal glasses are used, which today gradient refractive index is used to make bifocal glasses.

4. Astigmatism

Many people with myopia also have degrees of astigmatism or corneal elasticity. Astigmatism occurs when the cornea is like a cross section of a baseball to a basketball. As a result, due to unequal refraction in different parts of the cornea, the images do not focus perfectly on the retina and become blurry both near and far. Therefore, people with high degrees of astigmatism not only see distant objects blurry like nearsighted people, but also see near objects blurry.

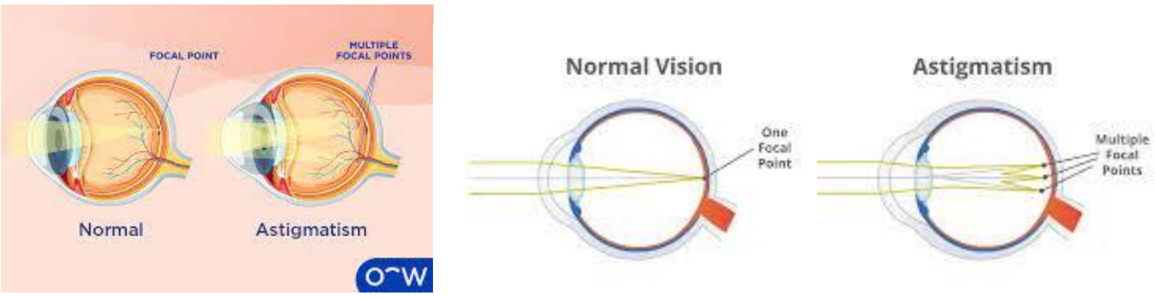


Figure 3: Image of light paths in astigmatism and normal eyes

Types of Astigmatism

Astigmatism has different types and can exist alone, along with myopia or hyperopia

a) Regular Astigmatism

In this type of astigmatism, the two meridians are perpendicular to each other, such astigmatism is correctable in the eye. The half meridians of the astigmatism device are mostly vertical and horizontal. If the half meridians are not perpendicular to each other, it is called oblique astigmatism, which is more common.

b) Irregular Astigmatism

In this type of astigmatism, the meridians of the astigmatism system differ in various directions. These types of astigmatism cannot be fully corrected by regular glasses.

Types of Regular Astigmatism

(1) Simple Astigmatism

In this type of astigmatism, one focus is on the retina while the other focus is either in front of the retina (simple myopic astigmatism) or behind the retina (simple hyperopic astigmatism).

(2) Compound Astigmatism

In this type of astigmatism, neither of the two foci of the system is on the retina. Both foci can be formed behind the retina, which is called compound hyperopic astigmatism, or both foci can be formed in front of the retina, which is called compound myopic astigmatism.

(3) Mixed Astigmatism

In this type of astigmatism, one focus is in front of the other behind the retina, or in other words, the way light is refracted is different in one direction compared to the other (either myopic or hyperopic).

Measurement of Astigmatism

The separation between two surfaces along each principal ray of a point object is a measure of astigmatism for that object and is proportional to the square of the distance from the optical axis. The measurement of astigmatism is in diopters. Astigmatism is classified as follows:

- ✓ Mild Astigmatism: Less than 1 diopter
- ✓ Moderate Astigmatism: 1 to 2 diopters
- ✓ Severe Astigmatism: 2 to 3 diopters
- ✓ Very Severe Astigmatism: More than 3 diopters

Correction of Astigmatism

Correction of Astigmatism involves adding a cylindrical lens and combining their powers to correct the refractive error .

First part of the experiment

Diagnosis and correction of spherical and non-spherical eye abnormalities using the shadow test (sciascopy[1])

Procedure of the experiment

In this method, the examinee sits at a distance of one meter from the examiner and looks at a distant point (the eyes will not converge in this state). The examiner uses a device called an ophthalmoscope or sciascope to study the examinee's eye and directs a beam of light into the examinee's eye. By moving the ophthalmoscope, the examiner tracks the movement of the retinal reflex and determines the type of abnormality (spherical or astigmatism) and then the type of spherical abnormality (hyperopia or myopia) of the examinee's eye. By placing suitable lenses (converging or diverging) with appropriate powers, the refractive error of the examinee's eye is corrected.

Figure 4 a) Sciascope mirrors, b) eye phantom

To perform the experiment, a phantom eye is used instead of the examinee's eye. The phantom eye is a device that functions like a real eye, meaning it has a hole

[1] Sciascopy is alternative form of Skiascopy or Retinoscopy

in the front through which light enters and after passing through its various parts, it illuminates the retina of the phantom eye. The reflection of light from the phantom eye through the aperture of the ophthalmoscope is then studied by the examiner. Additionally, there are degrees on the phantom eye that indicate abnormalities (-3, 0, +3). With some knowledge of classical optics, understanding this experiment will be very simple.

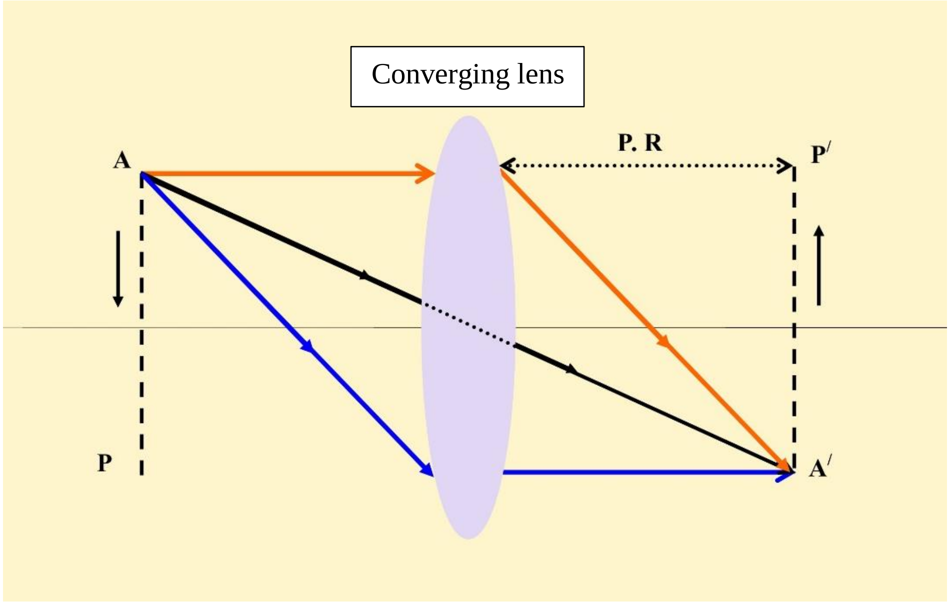


Figure 5. Schematic image of light paths in the encounter with a converging lens

Whenever a light point (A) moves on the surface P and in front of the converging lens L from top to bottom (as shown above), its image (A') on the surface P' (the dual surface of P) will move from bottom to top. When an observer is placed between the surface P' and the lens (surface O_1), during the movement of the light point (A) from top to bottom, they will see that the lens becomes brighter in the direction of the movement of this point (from top to bottom) because first ray 1 and then rays 2 and 3 reach the eye, resulting in the upper part of the lens and then the central and lower parts of the lens becoming bright. If the observer is positioned at location O_2, in this case, the same phenomenon as before occurs, meaning that first the lower part of the lens and then the central and upper parts become bright (first ray 3 and then 2 and 1 reach the observer's eye). And if the observer is positioned exactly on surface P', they will see the entire lens bright or dark at once, meaning all three rays 1, 2, and 3 reach their eye (instantaneously perceiving light and shadow of the lens).

Now, if we place the examiner's eye (phantom eye) at a distance of one meter and look at it through a perforated Sciascope mirror, and perform this action in darkness to better visualize the fundus, By rotating (or moving up and down) the sciascope mirror, we will observe a movement in a light spot in the examiner's eye depending on the direction and speed of movement of this spot indicating firstly the type of abnormality (spherical or astigmatism) of the eye and secondly, the degree of abnormality. To diagnose and correct it, we will follow these steps:

i. If the spot moves in agreement with the rotation of the Sciascope mirror, in this case, it is as if we are in the O_1 state, where we will first see the upper part of the lens, then the middle part, and finally the lower part. Therefore, in this case, considering the distance between us and the examiner's eye or phantom, which is one meter, the point of far vision of the examiner (Punctum Remo tom = P.R) will be more than one meter (P.R > 1m). In this case, three situations may occur: the eye is healthy, it is nearsightedness less than one diopter, or it is a farsightedness.

   To distinguish between these three situations, we can use a converging lens (+1). In this case, if the movement of the light spot in the phantom eye is in agreement with the rotation of the Sciascope mirror, it is a farsighted eye. And if it is opposite, it is a nearsighted eye less than one diopter. If the movement of the spot is fast (instantaneous disappearance), the eye is healthy.

ii. If the spot in the examiner's eye or phantom moves opposite to the rotation of the Sciascope mirror, in this case, it is as if we are in the O_2 state, meaning that we first see the lower part of the lens, then the middle part, and finally the upper part. In this case, considering the distance between us and the examiner's eye or phantom, which is one meter, the point of far vision of the examiner (Punctum Remo tom = P.R) will be less than one meter (P.R < 1m). It means that the examinee must be nearsighted by more than 1 diopter, and in order to diagnose and correct this eye, diverging lenses will be used, which by increasing the power, the movement of the light spot will gradually move towards instantaneous movement, the eyeglass score is equal to the lens number plus (-1).

iii. The light spot in the examiner's eye or phantom is seen instantaneously on the retina (it appears and disappears rapidly with the rotation of the Sciascope mirror). In this case, we are in the state of (P.R = 1m), meaning that considering that we need to add (-1) diopter to the corresponding lens power (0). In fact, the lens power will be (-1) diopter. In this case, since the distance from the phantom is fixed at 1 meter and we see instantaneous movement, the point of far vision is 1 meter and therefore the examiner/phantom is nearsighted with a lens power of (-1) diopter.

Second part of the experiment

Diagnosing and correcting eye abnormalities using glasses, an eyeglass box, and a Snellen char.

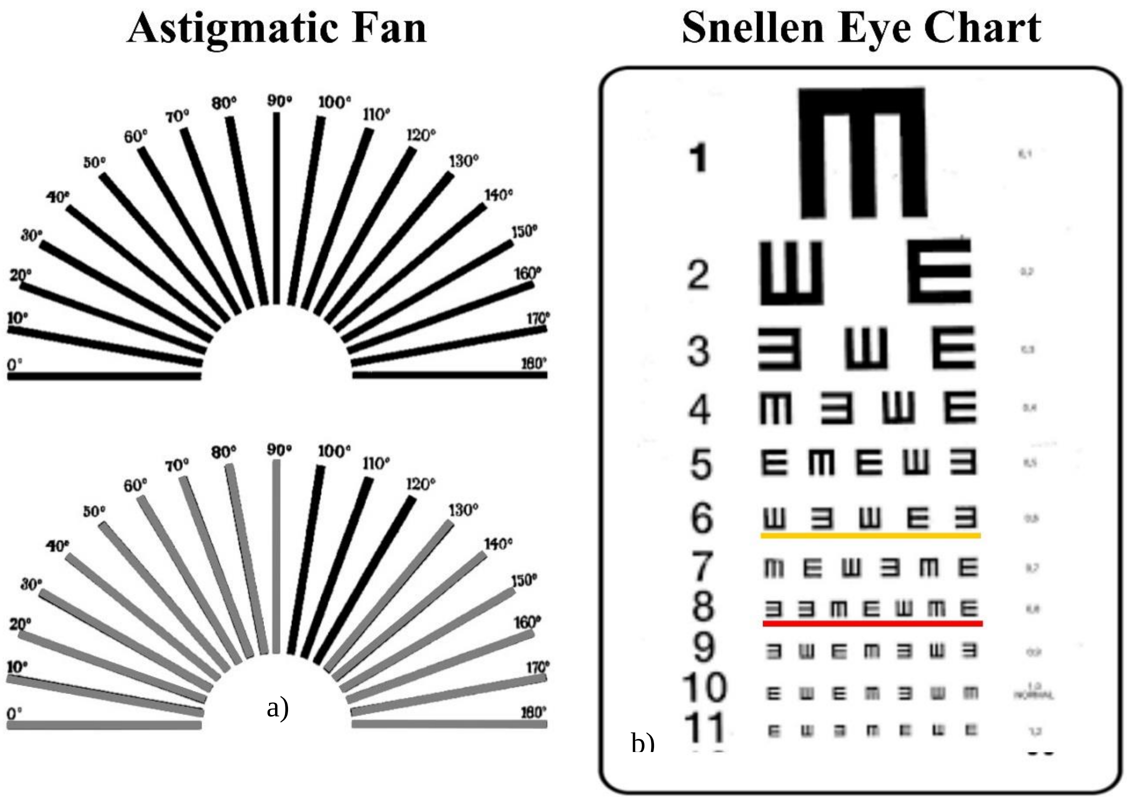


Figure 6. a) Astigmatic Fan and b) Snellen eye chart

Method of conducting the experiment

In this method of diagnosing and correcting spherical and astigmatic eye abnormalities, the examiner is placed 6 meters away from the Snellen chart (Figure 6).

The point of far vision

The farthest point from the eye that we can see clearly without accommodation and in a resting state, which is infinite and actually more than 6 meters for a healthy eye). Additionally, an eyeglass frame is placed in front of the examiner's eye, with one eye covered by a frosted lens and the other eye being studied. In this method (for determining spherical eye abnormalities), there can be two general situations:

Situation 1:

The examiner sees the entire chart clearly. This indicates that their eye is healthy or farsighted. To distinguish between these two situations, we place a converging lens of +1 diopter in front of their eye. If their vision worsens, it means their eye is healthy (as we have brought their eye closer with the lens).

Situation 2:

The examiner does not see part or all of the chart clearly and sees it blurry. In this case, it is likely that they are nearsighted. To correct their eye abnormality, we start with a diverging lens of -0.5 diopter in front of their eye and gradually increase the lens power until their vision improves. In any case, once we have diagnosed and corrected the spherical eye abnormality using converging or diverging lenses, we move on to diagnosing astigmatism or non-spherical abnormalities.

Diagnosing and correcting astigmatism

To diagnose and correct astigmatism, the examiner is placed in front of a clock chart (composed of lines with equal angles) with their eye corrected for spherical abnormalities (nearsightedness or farsightedness). In this case, the distance between the examiner and the chart is approximately 6 meter.

Two situations can occur:

1) The examiner sees all the lines as uniform in color, indicating that their eye does not have astigmatism.
2) The examiner sees some lines clearly (darker) and some lines blurry or faint. In this case, the examiner has astigmatism. (Usually, the clearest line becomes blurrier). In this case, we place converging and diverging

cylindrical lenses in front of their eye, starting from low power and adjusting the lens axis perpendicular to the line that the examiner sees clearly (the axis of the cylindrical lens is visible on it). This way, the examiner will see all the lines clearly, and their astigmatism will be corrected. Finally, we place corrected spherical and cylindrical lenses in front of the examiner's eyes, in front of the eyeglass frame, and the examiner will be able to see the entire Snellen chart clearly .

Part 3 of the experiment

Differentiating between different types of spherical and non-spherical lenses.

Method of conducting the experiment

First, select a spherical lens (converging or diverging) and compare it with a non-spherical lens (cylindrical or astigmatic lens) .

- ✓ If we place a spherical lens on our fingertips and rotate it while looking through it, the objects will not rotate. However, if we use a cylindrical lens, the image of the objects will rotate around the axis of the lens. Therefore, this method is used to differentiate between spherical and non-spherical lenses. (Repeat this process for several spherical and cylindrical lenses and take note of the results).

Now, we choose a converging lens and a diverging spherical lens to distinguish between converging and diverging lenses.

Several situations arise

A) We move the lens horizontally on a text. If the image is in the same direction as the lens movement, it is a diverging lens, and if it is in the opposite direction, it is a converging lens (and if there is no movement, it is a glass). Also, the speed of image movement indicates the power of the lens.

B) When we place the respective lens vertically on a text, gradually increasing its distance from the text, the image will gradually become larger in a converging lens and smaller in a diverging lens. (Of course, the speed of image enlargement or reduction depends on the power of the lens).

C) The center of a diverging lens is thinner, while the center of a converging lens is thicker. Again, the thinness or thickness of the centers of the lenses depends on their power.

D) When the eye of the person wearing glasses is farsighted, their eye behind the glasses will appear larger than its actual size. If this person has nearsightedness, their eye will appear smaller than its actual size. Therefore, through this method, it is possible to identify the type of lens. However, the extent to which the size of the eye is enlarged or reduced by spherical lenses (converging or diverging) is proportional to the power of the lens.

In different situations from A to D, study spherical and non-spherical lenses and record the results in your report. Therefore, at the end of this section of the experiment, you will be able to first learn the difference between spherical and non-spherical lenses and then learn the differences between converging and diverging spherical lenses.

Questions:

1) If we have an unknown spherical lens (converging lens), how can its power be determined?
2) Define hyperopia and myopia.
3) Which of the methods for diagnosing and correcting eye abnormalities (Sciascopy or eyeglass frames and eyeglass boxes) is more accurate? Why? Explain.
4) In which of the curvature, axial and refractive index defects is the sciascopy examination method used in the clinic (examination on the real eye)?
5) What is the reason for observing a distance of one meter between the examiner and the examinee in order to perform a sciascopy examination?
6) In the eye examination of a myopic patient of more than one diopter, what is the reason for the opposite movement of the reflection of light from the examinee's eye compared to the rotation direction of the sciascope mirror?
7) In the sciascopy examination method, what is the working method for differentiating hyperopia, normal or myopia between less than one diopter of the examined eye?
8) Do you think there is a possibility of creating astigmatism and presbyopia with the phantom state of the eye in the sciascopy examination, in addition to the state of myopia, farsightedness?