

Ministry of High Education and Scientific Research
Al-Furat Al-Awsat Technical University
Al-Najaf Technical Institute

Optical physics

Optometry Department

By

Dr. raneem mohammed abbas

2025 / 2026

raneemdosh@atu.edu.iq

Theoretical Vocabulary

1	How does light travel through the eye?
2	Total internal reflection , critical angle
3	Reflection by plane parallel plate
4	Refraction by a prism
5	Convention of signs for distance
6	Refraction at spherical surfaces
7	The lens , first focal point , second focal point , focal length , types of lens
8	Gaussian law , magnification
9	Convex lens , properties of image formed by convex lens
10	Concave lens , properties of image formed by concave lens
11	Compound lens , Newton equation
12	Lens maker's equation , power of lens
13	Aberrations of lens , chromatic aberrations , monochromatic aberrations
14	Coma aberration , Astigmatism , field curvatures , Distortion aberration
15	The Eye and the Optical Instruments

The objectives of subject

1/ General objective: The students must be familiar with the foundations of the light .

2/ special objective: To be able to know the phenomena of reflection and refraction of the light in reflected and refracted mediums and applications of related laws .

▶ Unit :How does light travel through the eye?

▶ Pre test :

Q1/ follow the light path inside eye ball ?

Q2 /chose the correct answer :

The first phenomena happened for the light inside eye ball?

a/refraction

b/reflection

c/diffraction

d/interference

► Unit :How does light travel through the eye?

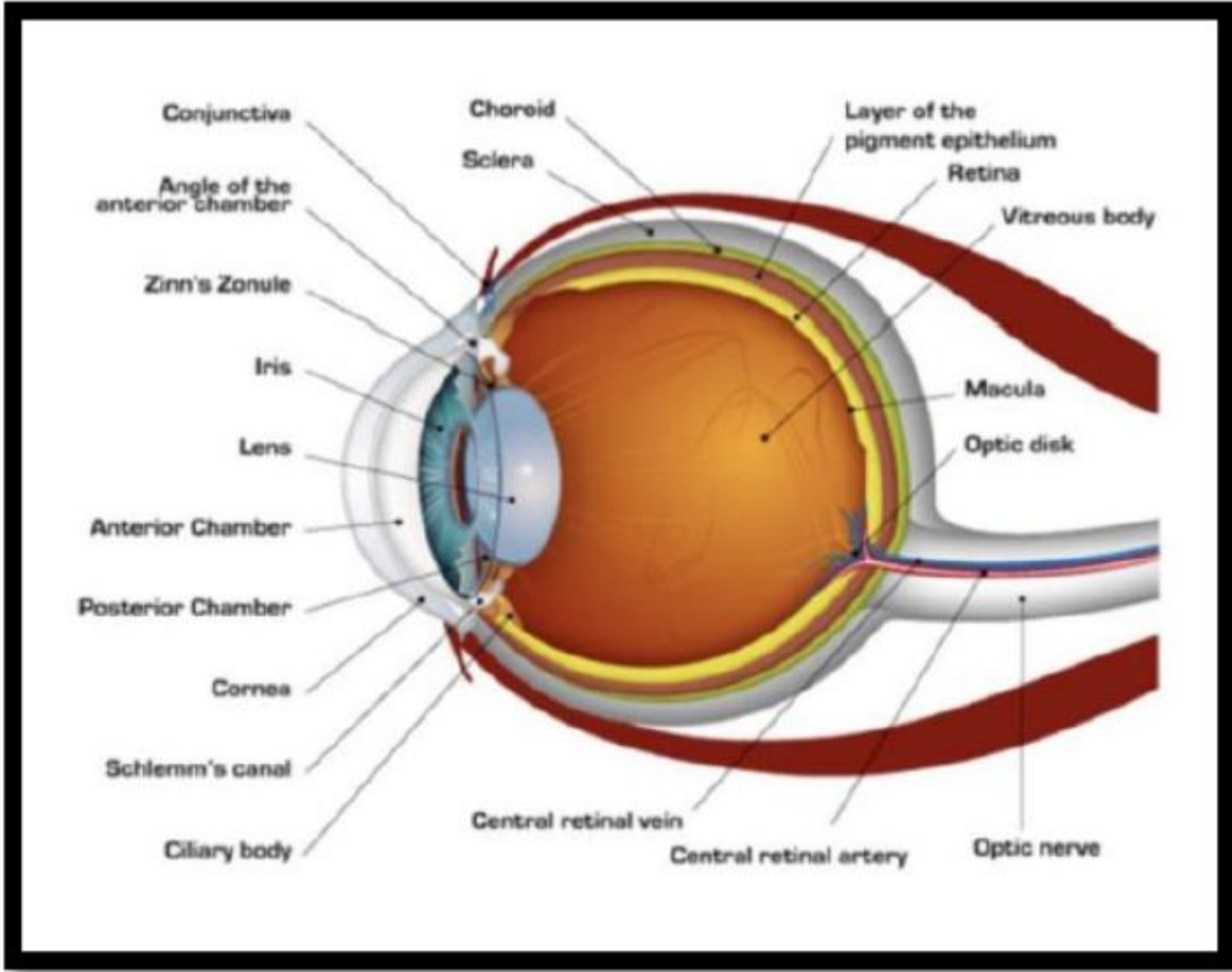
The human eye achieves vision by forming an image that stimulates nerve endings, creating the sensation of sight. Like a camera, the eye consists of an aperture and lens system at the front, and a light-sensitive surface at the back. Light enters the eye through the aperture- lens system, and is focused on the back wall. The lens system consists of two lenses: the corneal lens on the front surface of the eye, and the crystalline lens inside the eye. The space between the lenses is filled with a transparent fluid called the aqueous humor. Also between the lenses is the iris, an opaque, colored membrane. At the center of the iris is the pupil, a muscle-controlled, variable- diameter hole, or aperture, which controls the amount of light that enters the eye. The interior of the eye behind the crystalline lens is filled with a colorless, transparent material called the vitreous humor. On the back wall of the eye is the retina, a membrane containing light-sensitive nerve cells known as rods and cones. Rods are very sensitive to low light levels, but provide us only with low-resolution, black-and-white vision. Cones allow us to see in color at higher resolution, but they require higher light levels.

- ▶ The fovea, a small area near the center of the retina, contains only cones and is responsible for the most acute vision. Signals from the rods and cones are carried by nerve fibers to the optic nerve, which leads to the brain. The optic nerve connects to the back of the eye; there are no light-sensitive cells at the point where it attaches, resulting in a blind spot.

▶ **The Refraction of Light by the Eye**

Light entering the eye is first bent, or refracted, by the cornea -- the clear window on the outer front surface of the eyeball. The cornea provides most of the eye's optical power or light bending ability. After the light passes through the cornea, it is bent again -- to a more finely adjusted focus -- by the crystalline lens inside the eye. The lens focuses the light on the retina.

- ▶ They change the shape of the lens, bending or flattening it to focus the light rays on the retina. This adjustment in the lens is necessary for bringing near and far objects into focus. The process of bending light to produce a focused image on the retina is called "refraction". Ideally, the light is "refracted" in such a manner that the rays are focused into a precise image on the retina. Many vision problems occur because of an error in how the eyes refract light. In nearsightedness (myopia), the light rays form an image in front of the retina.
- ▶ In farsightedness (hyperopia), the rays focus behind the retina. In astigmatism, the cornea is shaped like a football instead of a baseball. This causes light rays to focus on more than one plane, so that a single clear image cannot be formed on the retina. As we age, we find reading or performing close-up activities more difficult.



► **Post test : chose the correct answer**

1/ Theprovides most of the eye's optical power or light bending ability

a/cornea

b/lens

c/retina

d/pupil

2/In farsightedness (hyperopia), the rays focusthe retina

a/behind

b/on

c/Infront of

d/in

▶ Unit / Total internal reflection , critical angle

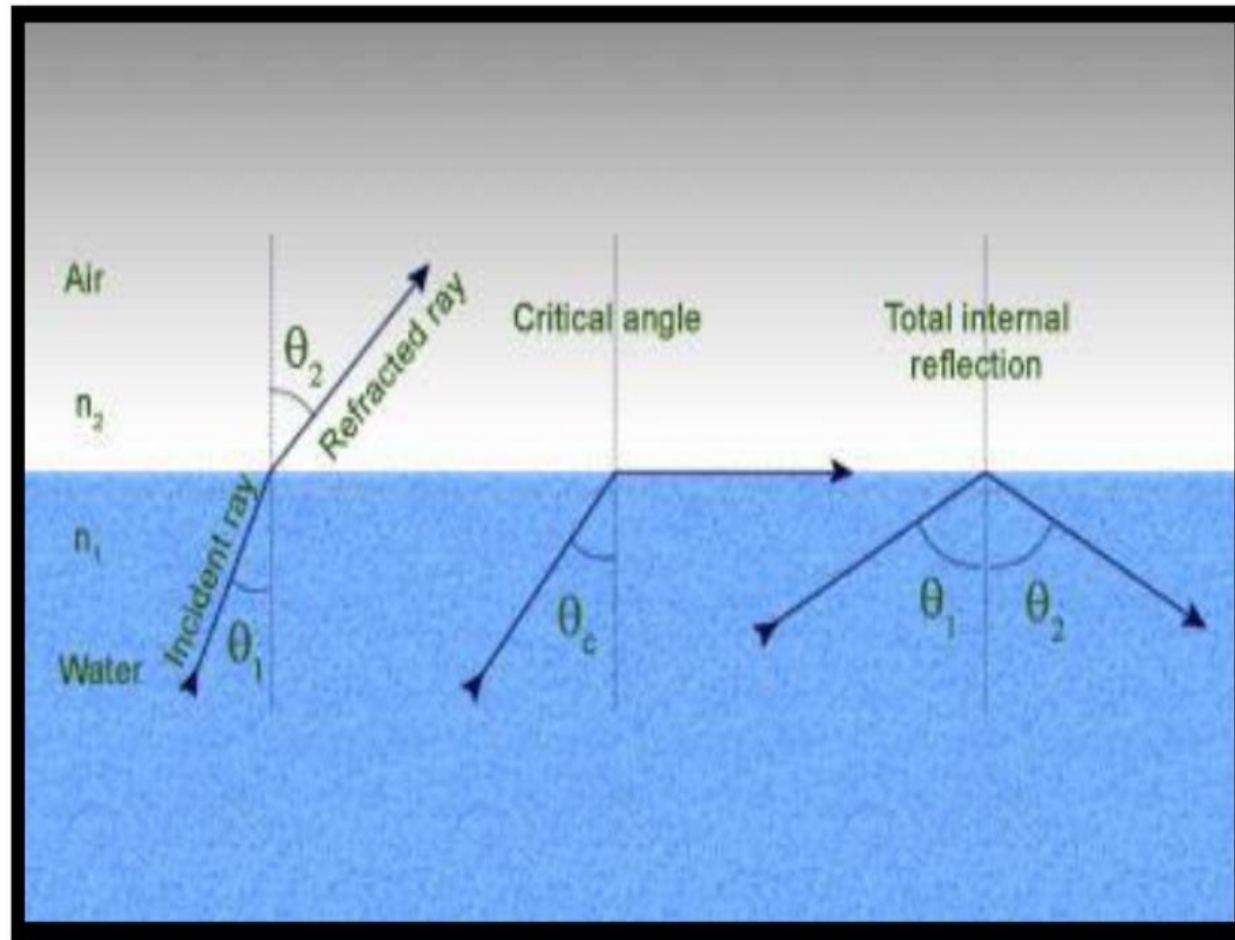
▶ Pre test :

Explain the phenomenon of Total internal reflection ?

- ▶ **Unit /Total internal reflection , critical angle**
- ▶ **Total internal reflection :**

The phenomenon which occurs when the light rays travel from a more optically denser medium to a less optically denser medium. A ray of light passes from a medium of water to that of air. Light ray will be refracted at the junction separating the two media. Since it passes from a medium of a higher refractive index to that having a lower refractive index, the refracted light ray bends away from the normal.

At a specific angle of incidence, the incident ray of light is refracted in such a way that it passes along the surface of the water. This particular angle of incidence is called the critical angle. Here the angle of refraction is 90 degrees. When the angle of incidence is greater than the critical angle, the incident ray is reflected back to the medium. We call this phenomenon total internal reflection.



Figure(1) : Total internal reflection

▶ Examples of Total Internal Reflection

Following are the examples of total internal reflection:

- ▶ **Diamond:** When the incident ray falls on every face of the diamond such that the angle formed, the ray is greater than the critical angle. The critical value of the diamond is 23° . This condition is responsible for the total internal reflection in a diamond which makes it shine.
- ▶ **Optical fiber:** When the incident ray falls on the cladding, it suffers total internal reflection as the angle formed by the ray is greater than the critical angle. Optical fibers transmit signals, not only across cities but across countries and continents making telecommunication one of the fastest modes of information transfer. Optical fibers are also used in endoscopy.

- ▶ **Critical angle** : The critical angle is defined as the angle of incidence that provides an angle of refraction of 90-degrees.

$$\theta_{\text{crit}} = \sin^{-1} (n_2/n_1)$$

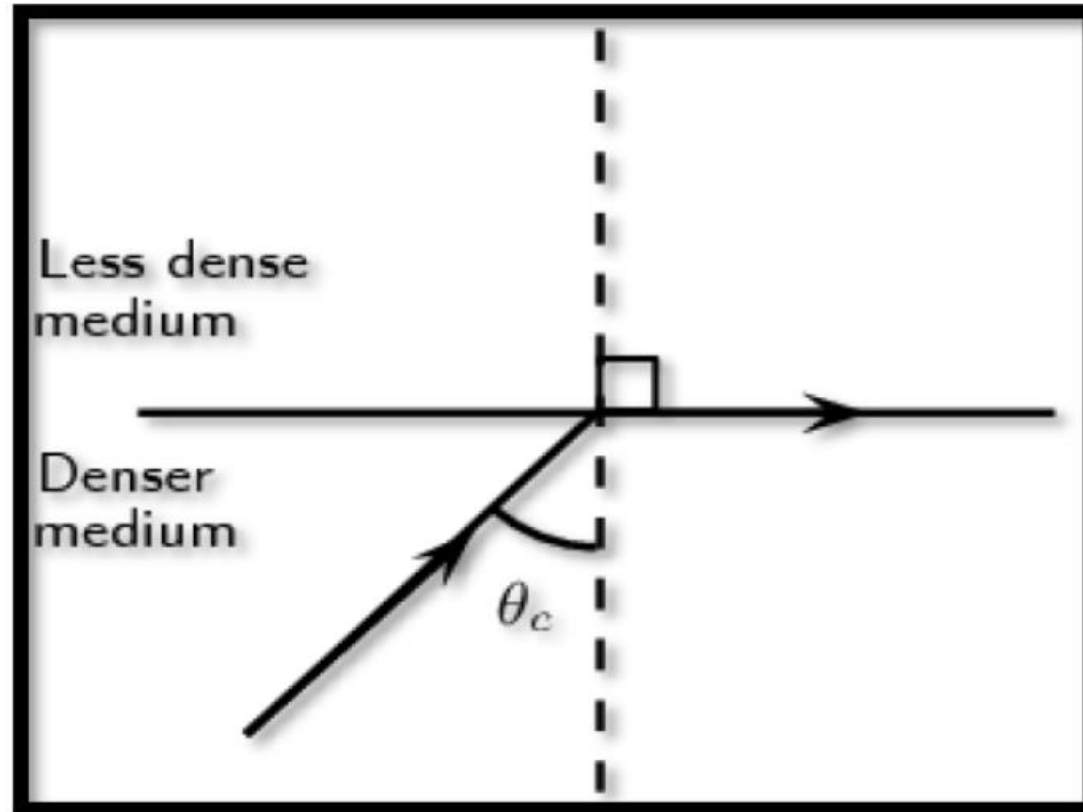


Figure (2) : critical angle

- ▶ Calculate the critical angle for the diamond-air boundary?

$$\theta_{\text{crit}} = \sin^{-1} (n_2/n_1) \quad \theta_{\text{crit}} = \sin^{-1} (1.000/2.42) = 24.4 \text{ degrees}$$

- ▶ 2- Calculate the critical angle for the glass-air boundary ?

$$\theta_{\text{crit}} = \sin^{-1} (n_2/n_1) \quad \theta_{\text{crit}} = \sin^{-1} (1.000/1.5) = 41.1 \text{ degrees}$$

Post test:

Q / A ring is placed in a container full of glycerin. If the critical angle is found to be 37.4° and the refractive index of glycerin is given to be 1.47 find the refractive index of ring.

▶ Unit / Refraction by a prism

▶ Pre test :

Q / Define the prism ?

Q /Chose the correct answer:

A prism is a lens which.....light and can correct ophthalmic misalignment

a/deflects

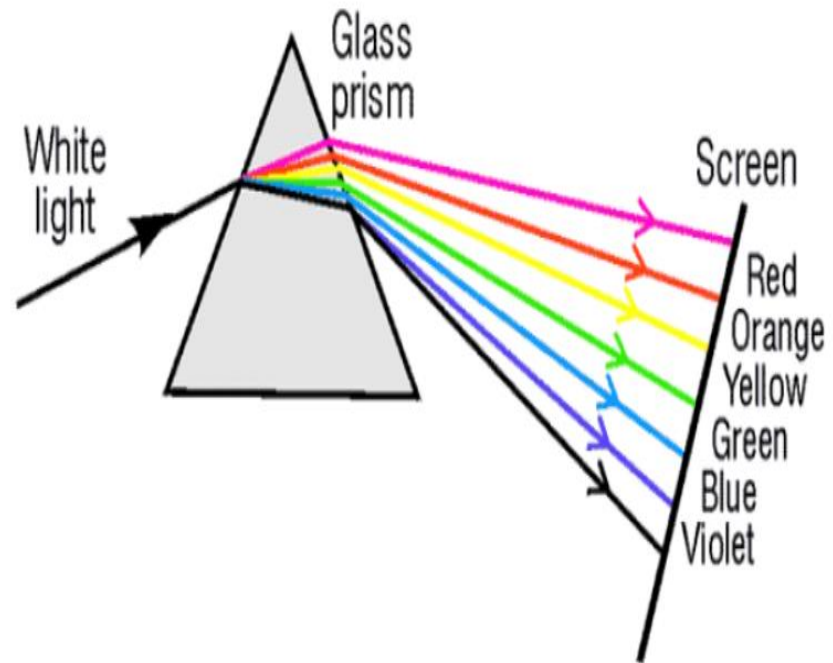
b/reflect

c/diffract

d/interface

▶ Unit / Refraction by a prism

- ▶ A prism, can be used to separate visible light into its different colors. A prism is a pyramid-shaped object made of transparent material, usually clear glass or plastic. The material that is transparent allows light to pass through it. A prism transmits light but slows it down. When light passes from air to the glass of the prism, the change in speed causes the light to change direction and bend. Due to the differences in the refraction index between the air and the glass, light bends once entering the prism. Since the sides are angled, the light bends, even more, when it exits the prism. Longer wavelengths tend to refract less while shorter wavelengths tend to refract more.



Refraction through a Glass Slab and Glass Prism

▶ Prisms in ophthalmology

Prisms are used commonly in ophthalmic practice. In strabismus, they have a diagnostic and therapeutic role.

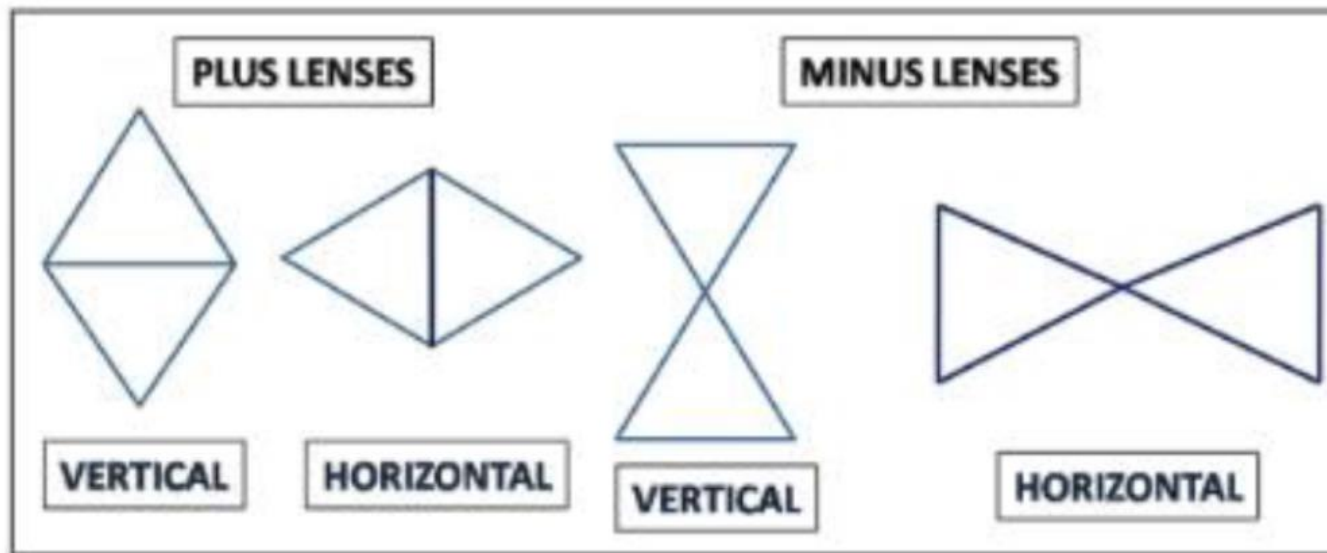
A prism is a lens which deflects light and can correct ophthalmic misalignment. An ophthalmic prism has an apex and a base. Light rays refracted through a prism always bend toward the base (Snell's law). The power of a prism is designated as "prism diopter" which is a measure of the strabismus deviation.

Types of ophthalmic prisms :

Prisms are used for diagnostic and therapeutic purposes. Diagnostic prisms are made of glass or plastic. Glass prisms have a higher refractive index and therefore deflect light more than plastic prisms. For therapeutic purposes, there are two kinds of prisms: glass and Fresnel prisms have the disadvantage of being heavy, cosmetically dissatisfying, and giving rise to disturbing reflections and aberrations. Fresnel prisms are based on the principle that the power of the prism will not depend on the thickness of the prism but on the prism angle. These prisms are thinner, cosmetically acceptable, and have less aberrations. However, they reduce visual acuity and contrast sensitivity.

► Prismatic Effect of Spherical Lenses:

A plus lens is two prism lenses stacked base to base, while a minus lens is two prisms stacked apex to apex. Therefore, spectacles affect the measured strabismus deviations. A plus lens will decrease the measured deviation and a minus lens will increase it.



Prismatic effect of spherical lenses

▶ A prism is a transparent optical element with flat, polished surfaces that refract light. The phenomenon of refraction by a prism is fundamental to understanding light dispersion, image shifting, and many optical applications, ranging from spectroscopy to ophthalmology .

▶ **Structure and Basic Principles**

A simple prism is typically triangular in shape and made of glass or transparent plastic .

When a ray of light enters a prism, it bends towards the base after two refractions: once upon entering and once upon exiting the prism.

The extent of bending depends on

- .The refractive index of the prism material ,
- . The wavelength of the incident light ,
- .The angle of incidence .

Key Definitions :

- Angle of the Prism (A): The angle between the two refracting surfaces .
- Angle of Deviation (δ): The angle between the original direction of the incident ray and the final direction of the emergent ray.

► Refraction Through a Prism: Step-by-Step

► At the first surface :

The incident ray undergoes refraction according to Snell's Law :

$$n_1 \sin i_1 = n_2 \sin r_1$$

r_1 = angle of refraction inside the prism

n_2 = refractive index of prism material

Inside the prism :

The light travels to the second surface and again refracts .

At the second surface :

The light refracts back into the air :

$$n_2 \sin r_2 = n_1 \sin i_2$$

where :

- r_2 = angle of incidence at the second surface,
- i_2 = angle of emergence .

Important Relationships

- The relation between the angles inside the prism :

$$r_1 + r_2 = A$$

- The total deviation δ caused by the prism :

$$\delta = (i_1 + i_2) - A$$

▶ Minimum Deviation Condition (δ_m):

At a particular angle of incidence, the deviation becomes minimum, and the path of light inside the prism becomes symmetric :

$$i_1 = i_2 = A + \delta_m / 2, \quad r_1 = r_2 = A / 2$$

Thus,

$$n = \sin(A + \delta_m / 2) / \sin(A / 2)$$

where n is the refractive index of the prism .

Dispersion by a Prism

Because the refractive index depends on the wavelength of light (known as material dispersion), prisms separate white light into its component colors :

- Shorter wavelengths (blue, violet) bend more ,
- Longer wavelengths (red) bend less. This phenomenon is the basis for spectrometry and is key to analyzing light spectra.

► Applications of Prism Refraction

- Spectrometers: Prisms disperse light into its spectrum for analysis .
- Ophthalmology: Prisms are used to diagnose and treat binocular vision problems .
- Laser systems: Beam steering and wavelength separation .
- Optical communication: Dispersion management .

► Factors Affecting Refraction

- Material of the prism: Different materials have different refractive indices.
- Wavelength of light: Shorter wavelengths are deviated more .
- Angle of the prism (A): Larger prism angles generally result in greater deviation .
- Angle of incidence (i): Deviation varies with the incident angle.

► **Post test :**

Q 1/A light ray falls on a prism with an apex angle $A = 60^\circ$. The refractive index of the glass is $n = 1.5$. If the ray passes through the prism at the angle of minimum deviation and the minimum angle of deviation $\delta_m = 40^\circ$

Find angle of incident i_1 , angle of refraction on the first surface r_1 .

Q 2/ list Applications of Prism Refraction and Factors Affecting Refraction

▶ Unit / Refraction at spherical surfaces

Pre test :

Q / classify the spherical lenses?

Q /define the FOCAL POINTS AND FOCAL LENGTHS

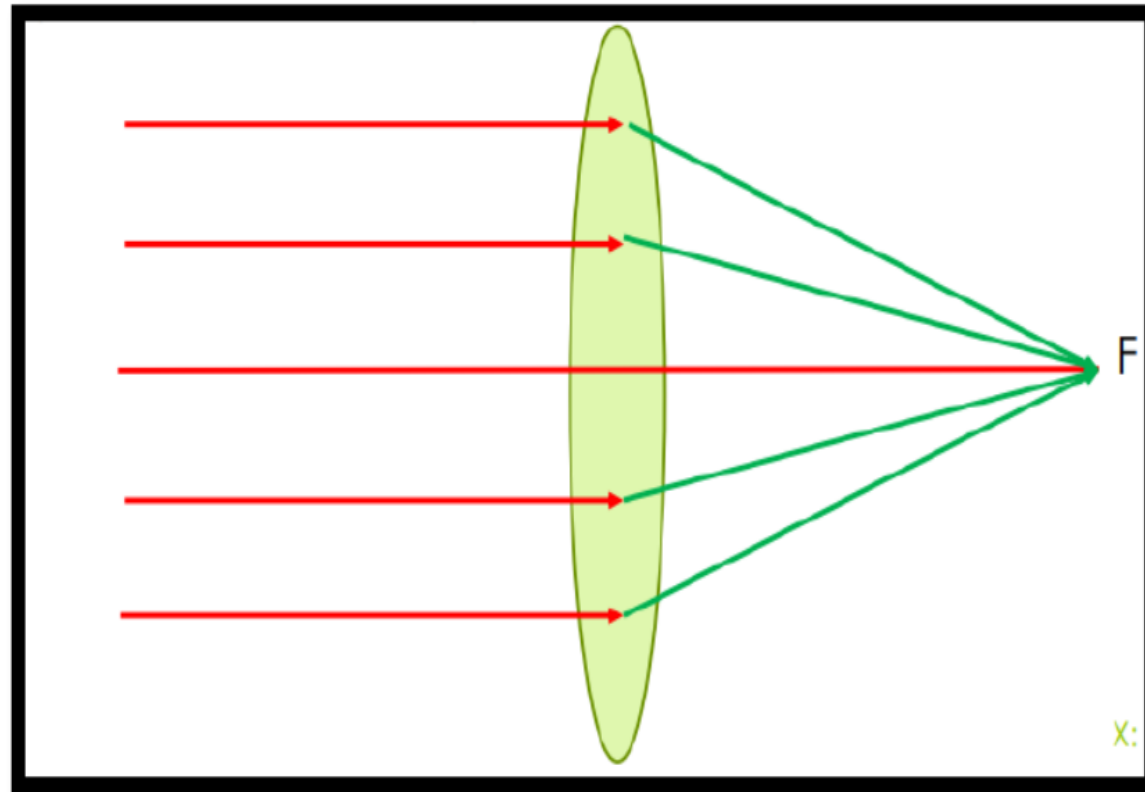
► Unit / Refraction at spherical surfaces

A simple lens consists of a single piece of transparent material, while a compound lens consists of several simple lenses (elements), usually arranged along common axis. Lenses are made from materials such as glass or plastic. A lens can focus light to form an image, unlike a prism, which refracts light without focusing. Devices that similarly focus or disperse waves and radiation other than visible light are also called lenses. Lenses are used in various imaging devices like telescopes and cameras. They are also used as visual aids in glasses to correct defects of vision such as myopia and hyperopia.

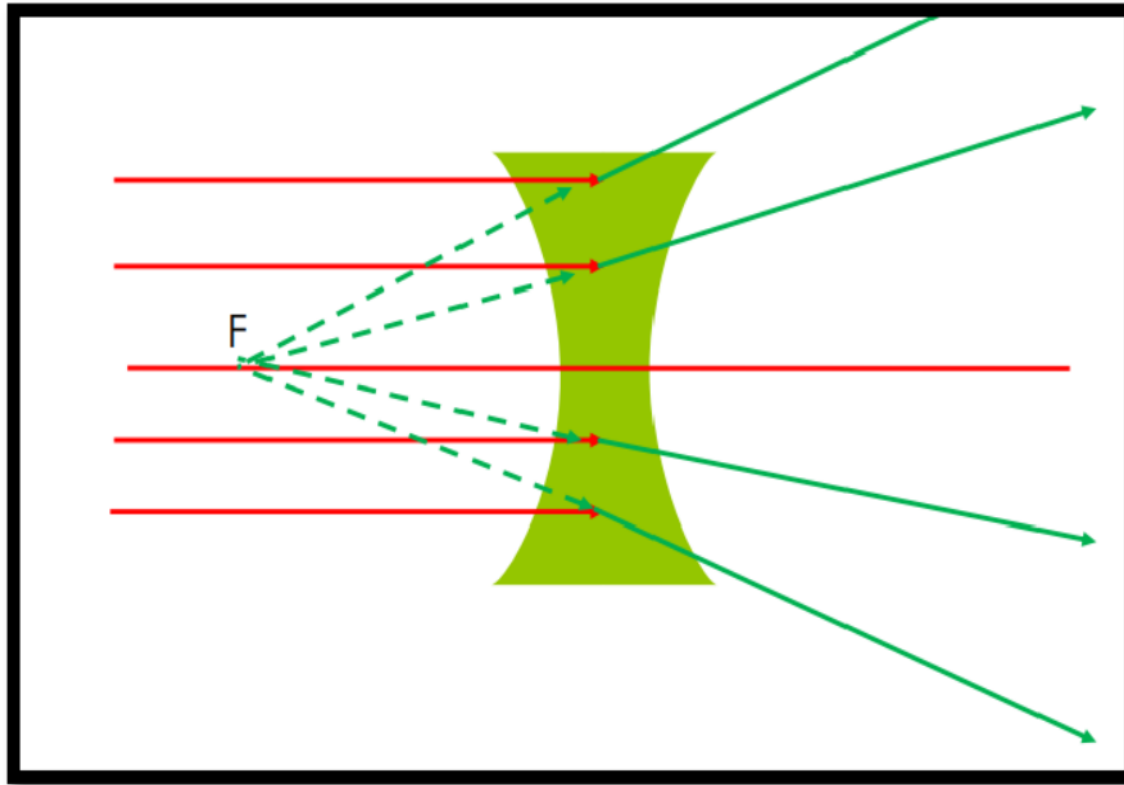
Types Of Thin Lenses The classification of a lens depends on how the light rays bend when they pass through the lens. The two main types of lenses are:

- Convex Lens (Converging)
- Concave Lens (Diverging)

A transparent material bound by two surfaces, of which one or both surfaces are spherical, forms a lens. This means that a lens is bound by at least one spherical surface. In such lenses, the other surface would be plane. A lens may have two spherical surfaces, bulging outwards. Such a lens is called a double convex lens. It is simply called a convex lens. It is thicker at the middle as compared to the edges. Convex lens converges light rays as shown in Fig

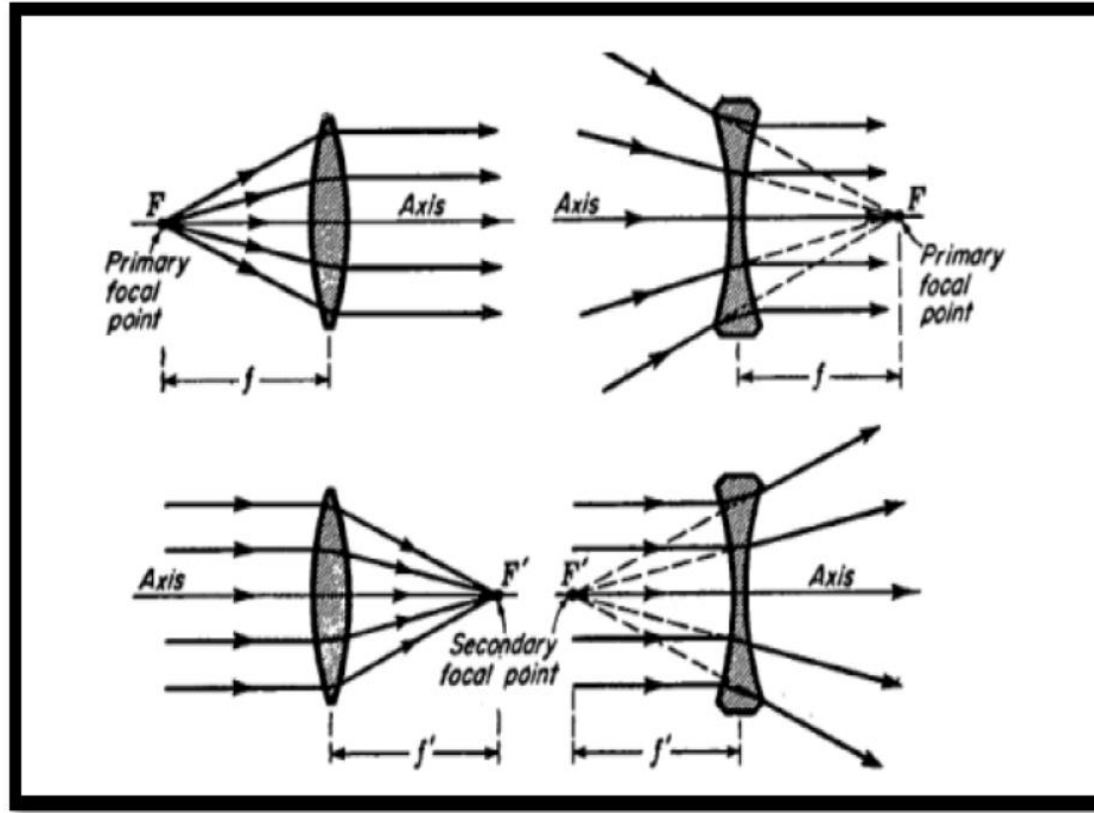


Double concave lens is bounded by two spherical surfaces, curved inwards. It is thicker at the edges than at the middle. Such lenses diverge light rays as shown in Fig. Such lenses are also called diverging lenses. A double concave lens is simply called a concave lens



FOCAL POINTS AND FOCAL LENGTHS

Diagrams showing the refraction of light by convex lens and by concave lens are given in figure. The axis in each case is a straight line through the geometrical center of the lens and perpendicular to the two faces at the points of intersection. For spherical lenses this line which joins the centers of curvature of the two surfaces.



The primary focal point (F) of convex lens: an axial point having the property that any ray coming from it , travels parallel to the axis after refraction. The secondary focal point (F') of convex lens: an axial point having the property that any incident ray traveling parallel to the axis will, after refraction, proceed toward. The primary focal point (F) of concave lens: an axial point having the property that any ray proceeding toward it travels parallel to the axis after refraction.

▶ The secondary focal point (F') of concave lens: an axial point having the property that any incident ray traveling parallel to the axis will, after refraction, appear to come from, F' . Focal length: The distance between the center of a lens and either of its focal points, these distances denoted by f and f' in the below figure.

▶ **lens equations :**

1) $1/f = 1/o + 1/i$, (Gaussian law for thin lens)

(f is always negative for concave lens , and always positive for convex lens)

2) Magnification , $m = - i/ o = h_i/ h_o$, (m, h_i : negative for inverted image and positive for upright image) , ($m > 1$ / the image larger than object) ($m < 1$ / the image smaller than object , $m = 1$ / the image in the same size with object) 3) o is always positive if the object in front of lens , i positive for real image and negative for virtual image

Unit / The lens , first focal point , second focal point , focal length , types of lens

Pre test :

Q / define the parameter of lens?

▶ Unit / The lens , first focal point , second focal point , focal length , types of lens

▶ The Lenses

Lens are used to focus light and form an image in cameras, telescopes, microscopes, eyeglasses and even in our eyes. Lenses work very much like mirrors. We will discuss two types of lenses.

▶ Convex Lenses

The double convex lens is a converging lens. When light waves parallel to the principle axis from an infinitely far object passes through the lens, it will converge at a focal point F on the principle axis. The distance between the focal point and the lens is the focal length, which is always a positive value for converging lenses.

- ▶ The primary focal point (F) of convex lens: an axial point having the property that any ray coming from it , travels parallel to the axis after refraction. The secondary focal point (F') of convex lens: an axial point having the property that any incident ray traveling parallel to the axis will, after refraction, proceed toward. The primary focal point (F) of concave lens: an axial point having the property that any ray proceeding toward it travels parallel to the axis after refraction
- ▶ Double concave lens is bounded by two spherical surfaces, curved inwards. It is thicker at the edges than at the middle. Such lenses diverge light rays as shown in Fig. Such lenses are also called diverging lenses. A double concave lens is simply called a concave lens
- ▶ the refraction of light by convex lens and by concave lens are given in figure. The axis in each case is a straight line through the geometrical center of the lens and perpendicular to the two faces at the points of intersection. For spherical lenses this line which joins the centers of curvature of the two surfaces.

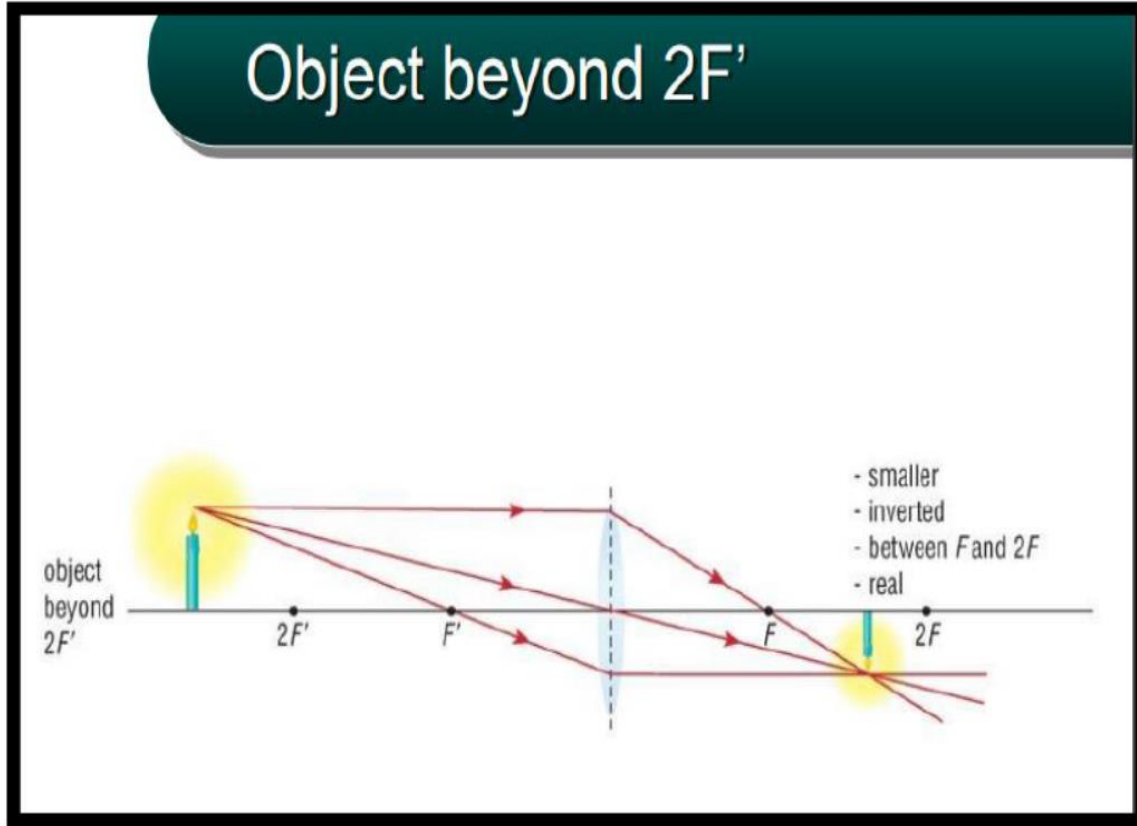
- ▶ **Unit / Convex lens , properties of image formed by convex lens**
- ▶ **Q / describe the properties of images formed by convex lens ?**
- ▶ **Q / describe the properties of images formed by concave lens ?**

▶ Unit / Convex lens , properties of image formed by convex lens

▶ Convex Lenses

The double convex lens is a converging lens. When light waves parallel to the principle axis from an infinitely far object passes through the lens, it will converge at a focal point F on the principle axis. The distance between the focal point and the lens is the focal length, which is always a positive value for converging lenses.

► Case 1 :



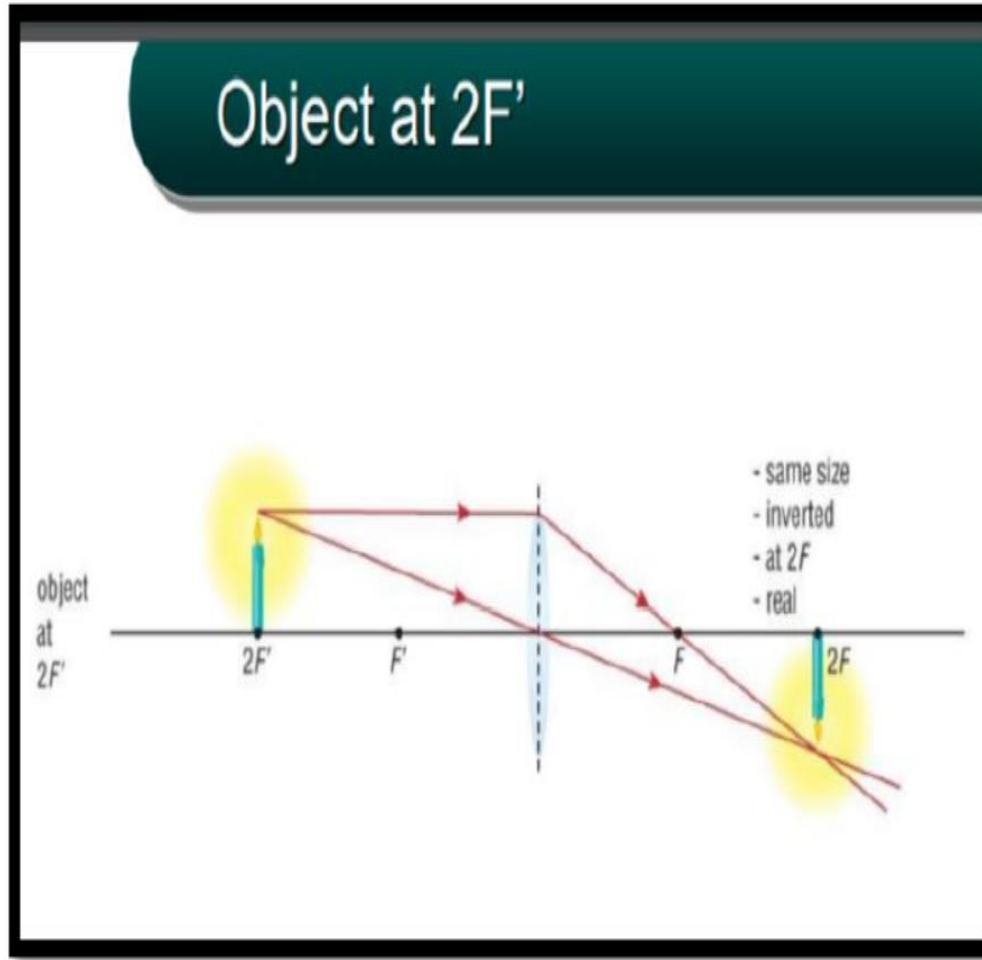
The position of object :
Beyond $2F'$

The position of image :
Between F and $2F$

Properties of image :

- 1- Smaller
- 2- Inverted
- 3- Real

Case 2 :



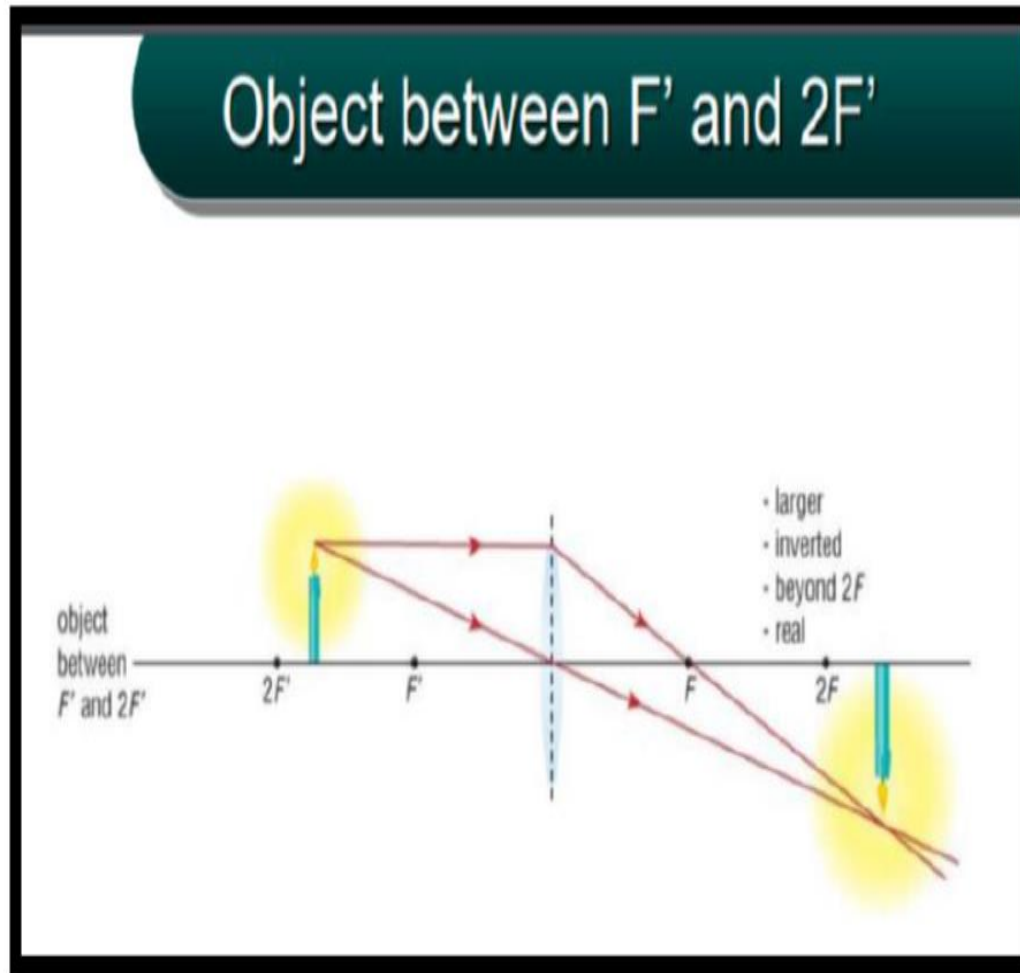
The position of object :
At $2F'$

The position of image :
At $2F$

Properties of image :

- 1-Same size
- 2-Inverted
- 3-Real

Case 3 :



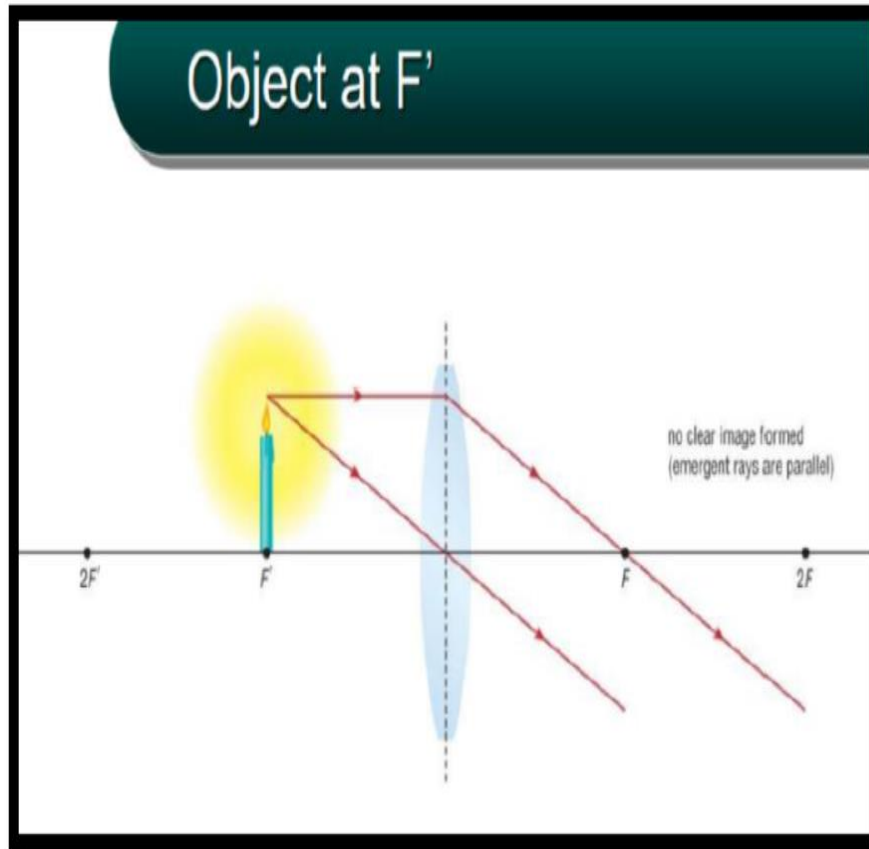
The position of object :
between $2F'$ and F'

The position of image :
beyond $2F$

Properties of image :

- 1- larger
- 2-Inverted
- 3-Real

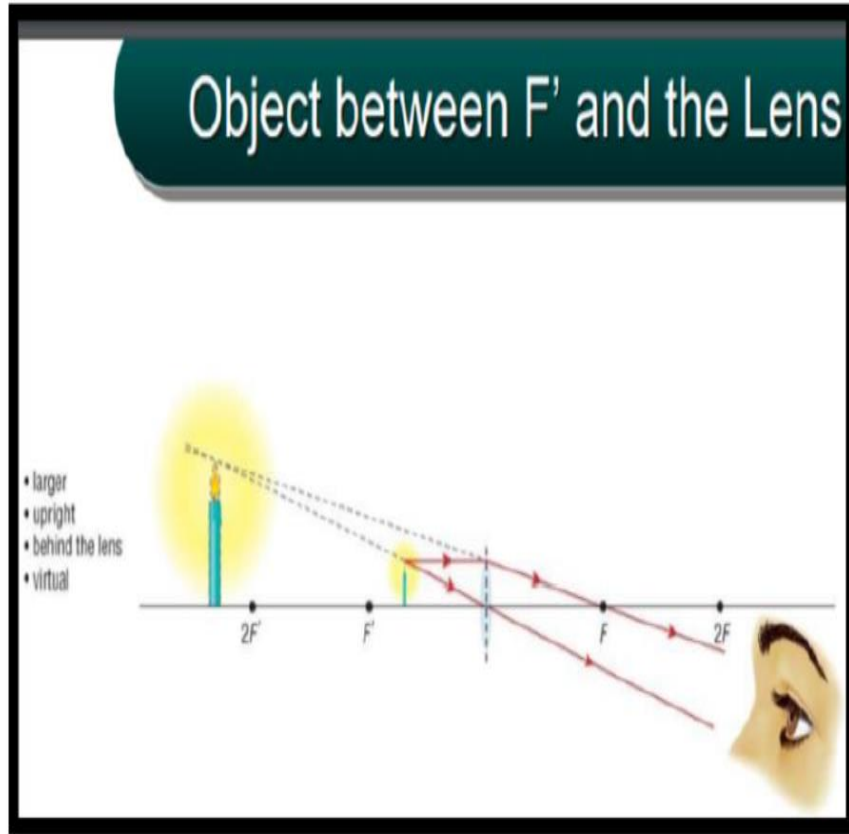
Case 4 :



The position of object :
At F'

The position of image :
No clear image formed

Case 5 :



The position of object :
between F' and the lens

The position of image :
Behind the lens

Properties of image :

- 1-larger
- 2-upright
- 3-virtual

Post test :

Q / draw the case one of formation image?

Q / what is the properties of images formed by convex lens ?

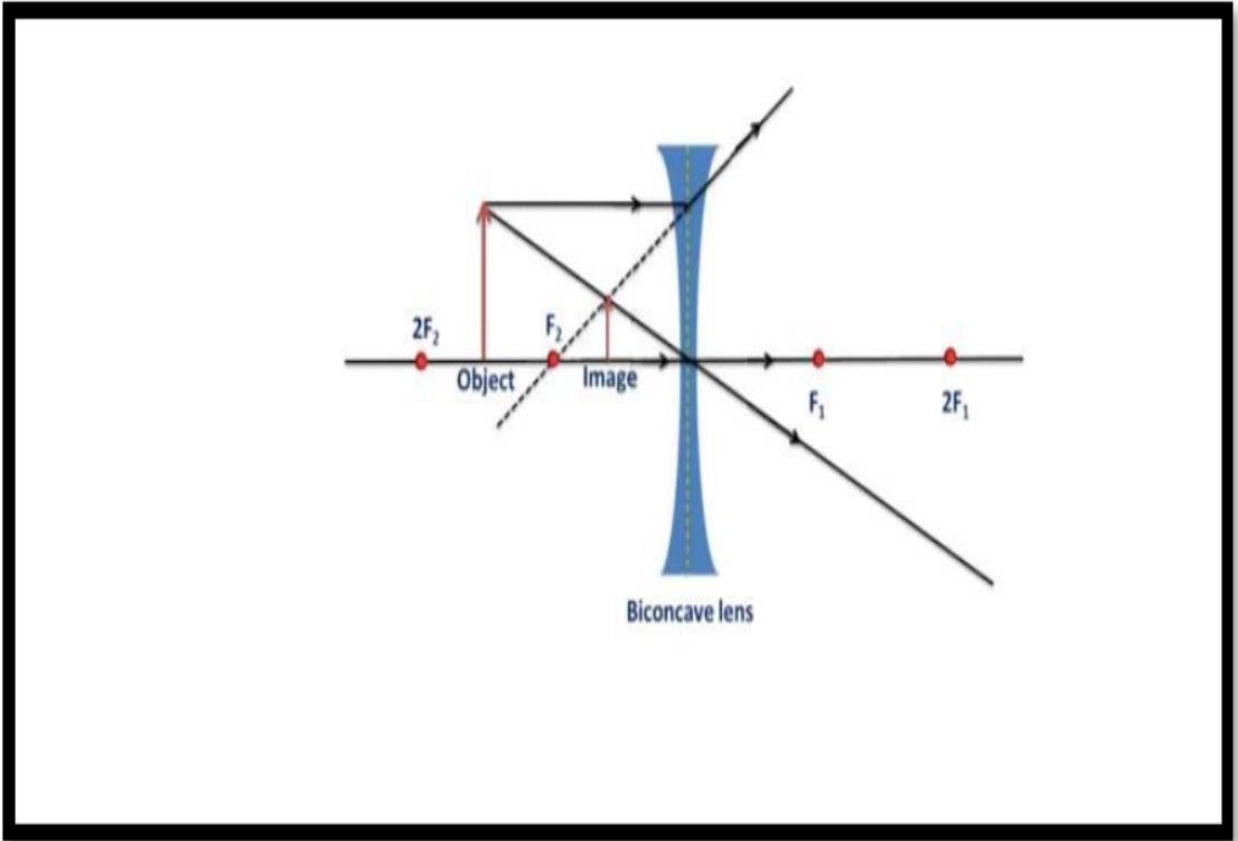
Unit / Concave lens , properties of image formed by concave lens

Q / describe the properties of images formed by concave lens ?

▶ **Unit / Concave lens , properties of image formed by concave lens**

▶ **Concave Lenses**

The double concave lens is a diverging lens. When light waves from an infinitely far object passes through the lens, the light waves will diverge as if it originated from a focal point F on the principle axis. The focal length is always a negative value for diverging lenses.



The position of object :

between $2F'$ and F'

▶ **The position of image :**

In front the lens between F' and the lens

Properties of image :

1-smaller

2-upright

3-virtual

▶ **Example** : A magnifying glass has a focal length of (10cm), a person uses it to read at a distance of 8cm, a- find a-the image distance, b- the image properties. $f= 10\text{cm}$, $o= 8\text{cm}$.

▶ Sol.:

$$1/f = 1/i + 1/o =$$

$$1/10 = 1/i + 1/8 = - 40\text{cm}$$

$$m = - (i/o) = - (-40 / 8) = 5.56$$

▶ the image is :virtual, upright, magnified

► **Post test :**

Q / find the image position of a 7.6cm high flower placed at 25cm to the left of the converging lens ($f= 5\text{cm}$), b-find the value of magnification of the lens, c- the image properties.

Q / a concave lens with a focal length of 60cm, forms a virtual image at 20cm to the left of lens for the object. Find: 1-the object distance, 2-the magnification.

Unit / Compound lens , Newton equation

Pre test :

compound lens consisting of a convex lens with a focal length of 20 cm, and a concave lens with a focal length of 20 cm, 10 cm distance between them . Calculate the equivalent focal length.

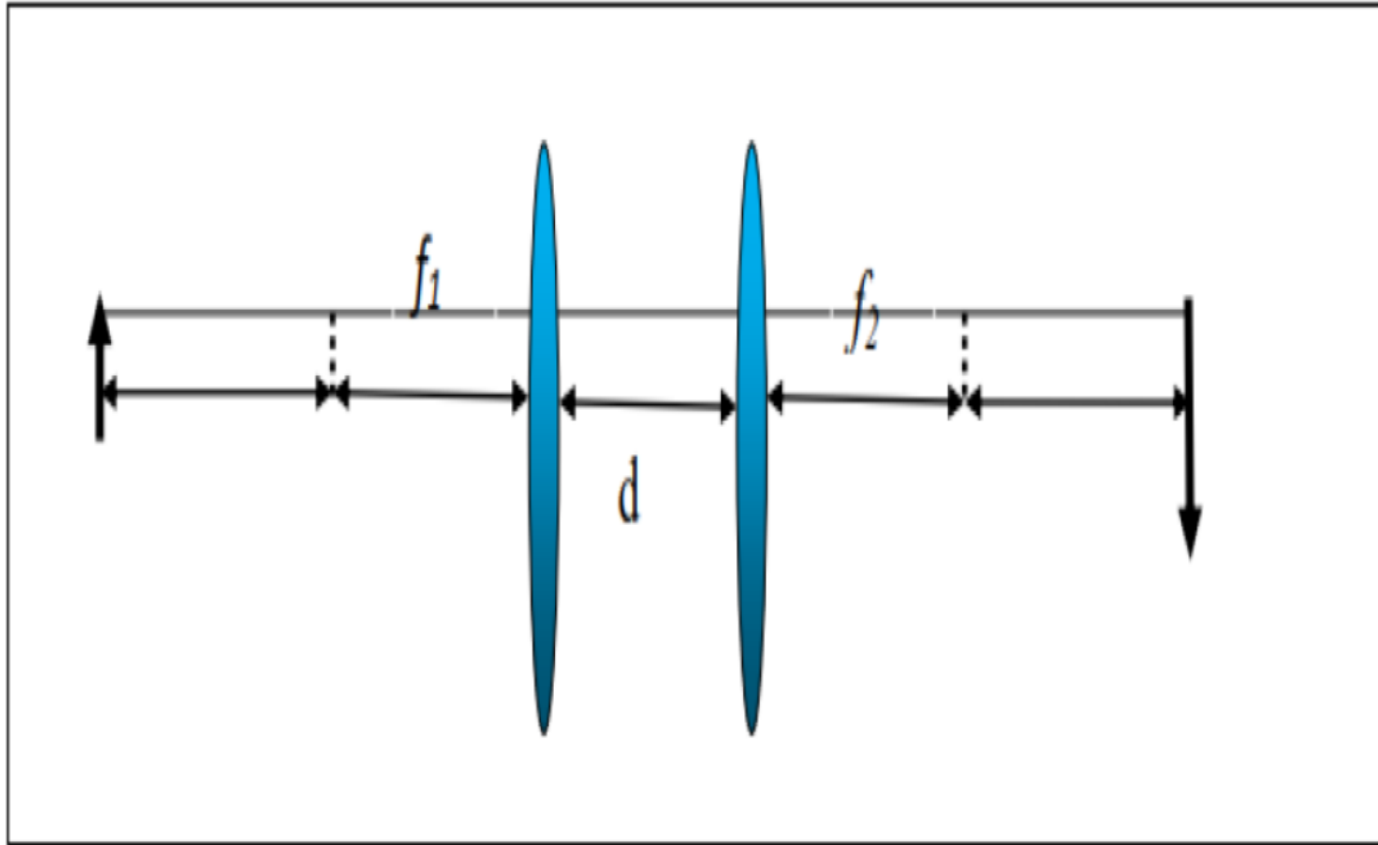
Unit / Compound lens , Newton equation

Compound lenses A compound lens uses multiple lenses. The most obvious example of a simple lens is a magnifying glass, which uses a single lens to magnify an object, while an example of a compound lens is a compound microscope, which uses multiple lenses to increase the viewer's capacity to magnify an object.

1-Increase the magnification of the image.

2-Obtain the erect image of an object.

3-Reduce aberrations or defects caused by using a single lens.



$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \left(\frac{d}{f_1 f_2} \right)$ (Newton equation for compound lens , if there is a distance between lenses)

f: equivalent focal length

f_1 : focal length for first lens

f_2 : focal length for second lens

d: distance between lenses

$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$ (if the lenses contact without distance)

Post test :

system consists of two thin converging lenses placed on the same principal axis.

- * The focal length of the first lens is $f_1 = 10 \text{ cm}$.
- * The focal length of the second lens is 15 cm .
- * The distance between the two lenses is 20 cm .
- * An object is placed 30 cm in front of the first lens.

Determine:

1. The position of the final image formed by the two-lens system.
2. The total magnification of the system.
3. Whether the final image is real or virtual.
4. Whether the final image is upright or inverted

▶ Unit /Lens maker's equation , power of lens

Pre test :

A plane convex lens made of glass with a refractive index of (1.7) Calculate the radii of curvature of the lens that gives a power to the lens of (5 D)

▶ Unit /Lens maker's equation , power of lens

▶ Lens maker's Equation

There is a special formula for lenses that relates the refractive index of a lens with the radii of curvature of its surfaces.

With the focal length known as the lens maker's formula, it is a very important formula for the optical design process, because it is related to the type of lens material through its refractive index, and the shape of the lens through its radii of curvature for surfaces, thus identifying the lens by its focal length.

▶ For a thin lens:

$$1/f = (n - 1) \left[\frac{1}{R_1} - \frac{1}{R_2} \right]$$

f is the focal length of the lens

n is the refractive index of the lens material,

R_1 is the radius of curvature of the face closest to the object

R_2 is the radius of curvature of other face

radius of curvature for plane lens is **infinity**.



biconvex



plano-convex



converging meniscus



biconcave



plano-concave



diverging meniscus



▶ **NOTE:**

- ▶ the sign of the radii is determined according to the direction of the incident rays . If the rays fall on a concave surface , the sign of (R) is **NEGATIVE** . If the rays fall on convex surface , the sign of (R) is **POSITIVE** . Finally , if they fall on a plane surface , the sign of (R) is **INFINITY** .

▶ **Power of lens**

The ability of the lens (P) is represented in the ability of the lens to collect (converging) or disperse(diverging) the light rays falling on it, and the power is calculated through the Caussian formula also with considering the special units called Diopter which equal to (1/m)

$$P= 1/f$$

► **Post test :**

Q 1/The refractive index of a lens is given as 1.5, two curved surfaces have radius of curvature 10cm and -15cm respectively. Calculate the focal length of the given lens?

Q 2 /Find the radius of curvature of the convex lens of index of refractive 1.52 when the radius of one face twice the other and the power of lens 20 D ?

Q 3 / The radii of both surfaces of an equiconvex lens of index 1.60 are equal to 8.0 cm. Find its power.

- ▶ Unit / Aberrations of lens , chromatic aberrations , monochromatic aberrations
- ▶ Q / define the aberration and classify its types?

- ▶ Unit / Aberrations of lens , chromatic aberrations , monochromatic aberrations
- ▶ Aberration In optics is a property of optical system such as lenses that cause light to be spread out over some region of space rather than focused to a point. Aberration cause the image formed by a lens to be blurred or distorted depending on the actual size shape and position. It divided into two categories monochromatic aberration and chromatic aberration.
- ▶ The aberration of an image is not due to any defect in the construction of the lens, but it is due to the reasons mentioned below: (1) The phenomenon of refraction in the lens and (2) Variation of refractive index of the material of a lens with the wavelength of light.

► Monochromatic aberration:

Monochromatic aberrations are optical distortions. These are created by white light passing through the lens at different speeds and angles. There are five different types of monochromatic aberrations. They are,

- (1) Spherical aberration
- (2) Coma
- (3) Astigmatism
- (4) Curvature of the field and
- (5) Distortion.

These are often referred to by the shape of the distortion created.

► Chromatic aberration:

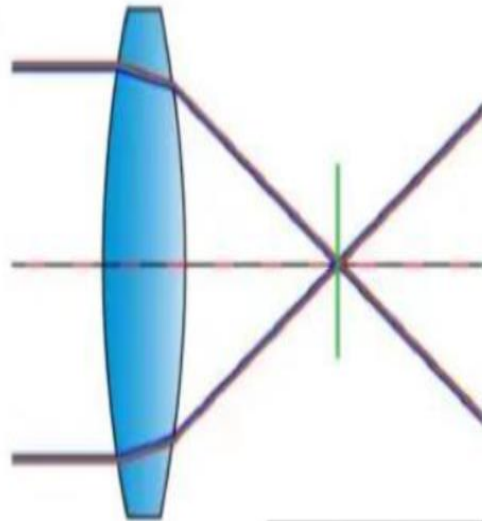
Chromatic aberration (present when using more than one wavelength of light) is the variation in the focal length of a lens with respect to the wavelength. The effect is that, for multi wavelength light, the image of an object point will not be focused on a single image point and, therefore, will be blurred. A lens is either unable to bring all wavelengths of color to the same focal plane. It is due to different colors of light travelling at different speeds while passing through a lens. As a result, the image can look blurred or noticeable colored edges (red, green, blue, yellow, purple, magenta) can appear around objects.

Chromatic aberrations are further classified into two types: transverse and longitudinal.

1/Transverse chromatic aberration (TCA): occurs when the size of the image changes with wavelength. In other words, when white light is used, red, yellow, and blue wavelengths focus at separate points in a vertical plane.

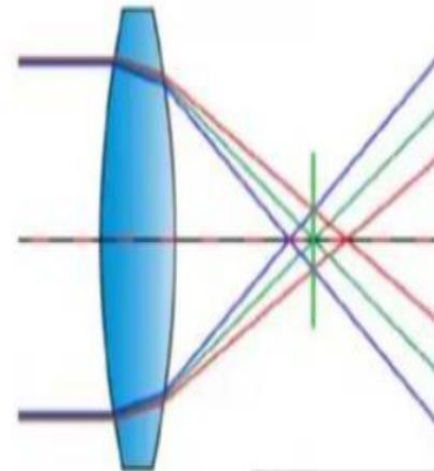
2/Longitudinal chromatic aberration (LCA): occurs when different wavelengths focus at different points along the horizontal optical axis as a result of dispersion properties of the glass.

Perfect Lens with no Chromatic Aberration



- Legend
- Light Rays
 - Optical Axis
 - Best Focus Point

Longitudinal / Axial Chromatic Aberration



- Legend
- RGB Color Rays
 - Optical Axis
 - Best Focus Point

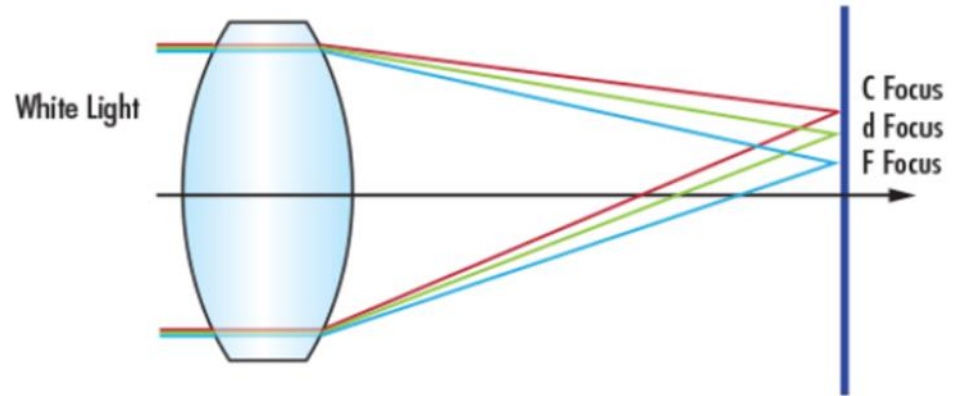


Figure 1: Transverse Chromatic Aberration of a Single Positive Lens

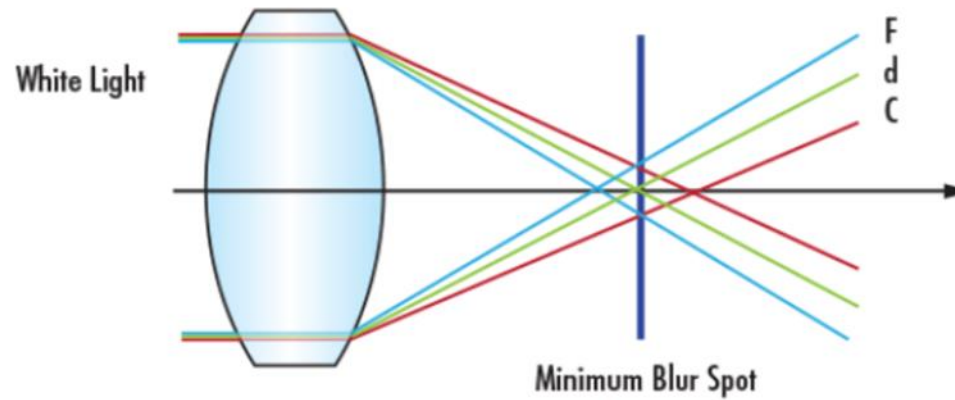


Figure 2: Longitudinal Chromatic Aberration of a Single Positive Lens

Unit /Coma aberration , Astigmatism , field curvatures , Distortion aberration

Pre test :

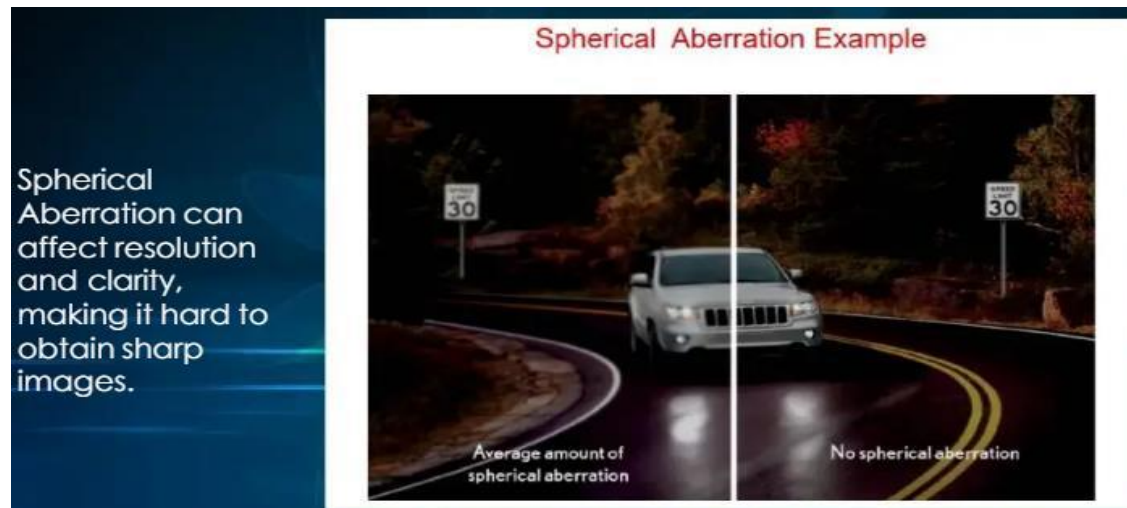
Q / explain the physical meaning of the following

Coma aberration , Astigmatism , field curvatures , Distortion aberration

▶ Unit / Coma aberration , Astigmatism , field curvatures , Distortion aberration

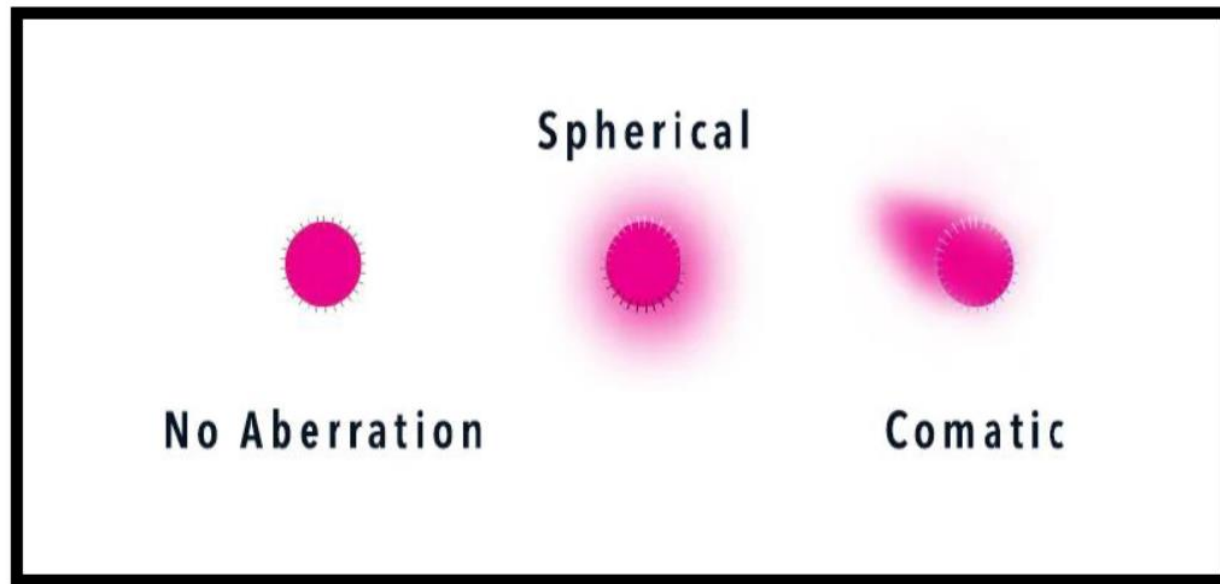
▶ Spherical Aberration

The inability of lens to bring to a focus a point object to a single point image is called spherical aberration. The glass elements of a lens are not flat but curved. The light entering at the edges of a lens refracts more than light entering in the middle. Light entering from the edges hits the optical axis at a different point than light entering in the center. This creates a soft-focus look called a spherical aberration.



Coma :

The aberration of defect Coma occurs when the image of a point object situated just off the axis is comet - like shaped. This type of aberration arises due to the fact that the different zones of a lens produce unequal lateral magnification of the image. Coma aberrations are like spherical aberrations. The difference lies in the shape of the distortion. Rather than round, the distortion is elongated, like the shape of a comet. This occurs when light entering at the edge of a lens comes in at an angle. Coma is more obvious at the edges of the frame.



▶ Astigmatism

A lens or an optical system corrected for spherical aberration and come still shows another defect known as Astigmatism. A lens suffering from astigmatism will be unable to form a point image of a point object situated far away from the axis. Instead of a point image is a pair of short lines normal to each other and at slightly different distances from the lens.

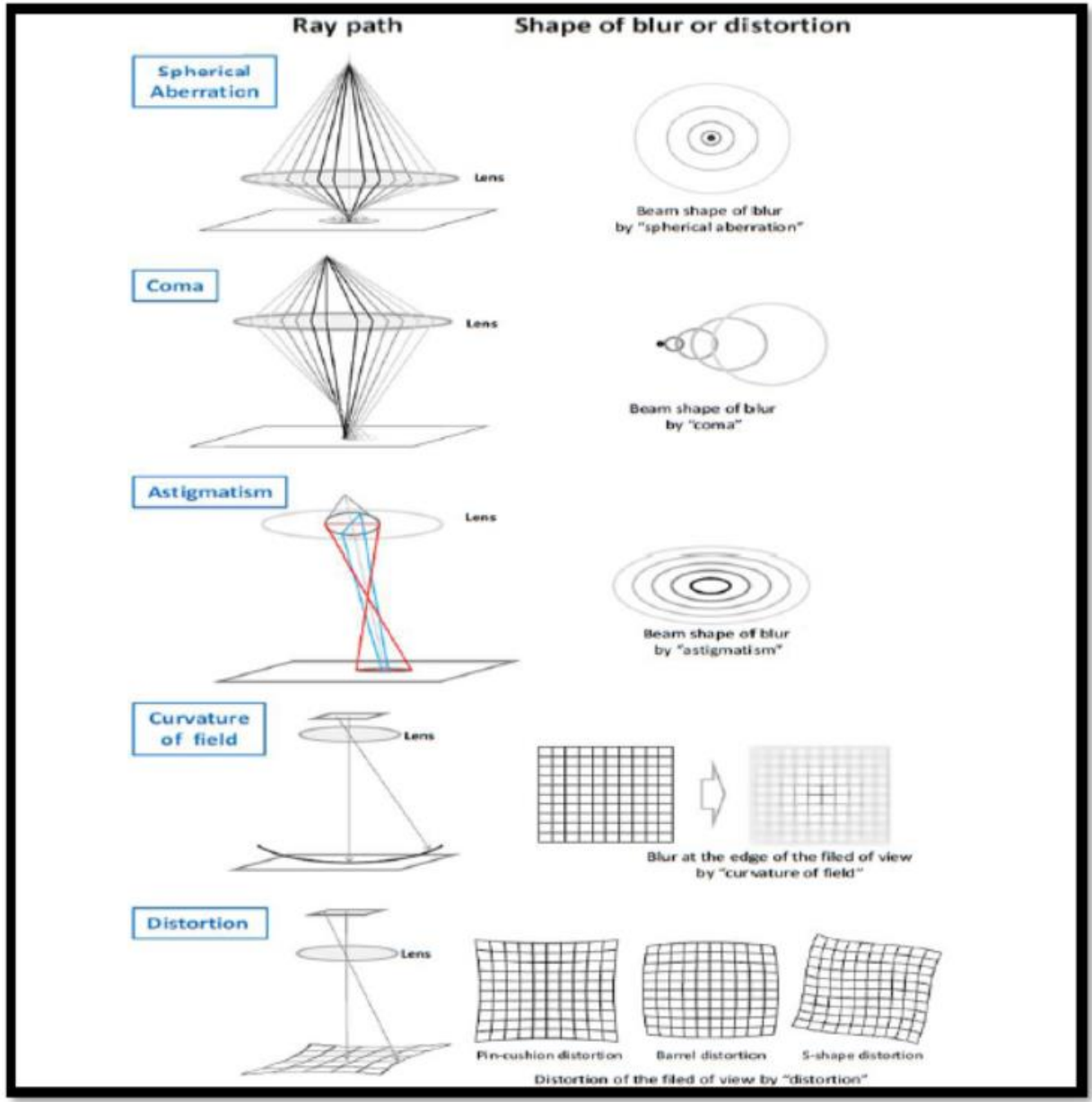
Curvature of field

Field curvature concerns the quality of focus across the frame. The image may be sharp in the middle and lose focus towards the edges.

► Distortion

Distortion, is refers to the deformation of an image. There are two kinds of deformation, namely barrel distortion and pincushion distortion. With barrel distortion, the center of the image bulges in the center and looks smaller at the edges.





► Post test :

Q / compare between aberration (Coma aberration , Astigmatism , field curvatures , Distortion aberration)

- ▶ **Unit / The Eye and the Optical Instruments**
- ▶ **Q /explain the Image Formation in the Eye?**
- ▶ **Q / list the Optical Instruments ?**

▶ Unit / The Eye and the Optical Instruments

▶ Introduction

The human eye is an extraordinarily complex and sensitive optical system that captures light and transforms it into signals interpreted by the brain as vision. Optical instruments, inspired by the eye's function, are tools developed to manipulate light, enhance vision, or enable observation of objects beyond the eye's natural limits .

▶ Image Formation in the Eye

- . The cornea and lens refract (bend) incoming light to form a real, inverted, and reduced image on the retina .
- . Focusing (accommodation) is achieved by changing the lens curvature via ciliary muscle.

▶ Optical Defects of the Eye

▶ Myopia (Nearsightedness)

- Cause: The eye is too long or the refractive power is too strong.
- Effect: Distant objects appear blurry .
- Correction: Concave lenses (diverging lenses) .

▶ Hyperopia (Farsightedness)

- Cause: The eye is too short or the refractive power is too weak.
- Effect: Close objects appear blurry .
- Correction: Convex lenses (converging lenses) .

▶ Astigmatism

- Cause: Irregular curvature of the cornea or lens .
- Effect: Distorted or blurred vision at all distances .
- Correction: Cylindrical lenses

▶ Presbyopia

- Cause: Age-related loss of lens elasticity.
- Effect: Difficulty focusing on near objects .
- Correction: Bifocal or multifocal lenses.

▶ Optical Instruments

Optical instruments extend the capabilities of the eye, allowing us to see distant, tiny, or faint objects.

▶ The Simple Magnifier (Hand Lens)

- Principle: A single convex lens is used to produce a virtual, upright, and magnified image .
- Magnification (M) : $M = 25 / f$

where f is the focal length of the lens in centimeters .

Application: Reading aids, inspection tools.

▶ The Compound Microscope

- Structure: Two lenses – the objective and the eyepiece .
- Principle :
- Objective forms a real, inverted, magnified image.
- Eyepiece magnifies the intermediate image .
- Total Magnification (M) :

$$M = M_{\text{objective}} * M_{\text{eyepiece}}$$

- Applications: Biology, materials science, microbiology .

▶ The Telescope

- Principle: Collects light from distant objects and forms a magnified, often inverted image .

- Angular Magnification (M) :

$$M = f_{\text{objective}} / f_{\text{eyepiece}}$$

- Applications: Astronomy, surveillance .

▶ The Camera

- Principle: A convex lens focuses light onto a photosensitive surface (film or sensor).

▶ • Similarities to the Eye :

- Aperture (pupil equivalent): Controls light entry .

- Lens: Focuses light.

- Film/Sensor (retina equivalent): Captures the image.

▶ two similarities between the human eye and a camera .

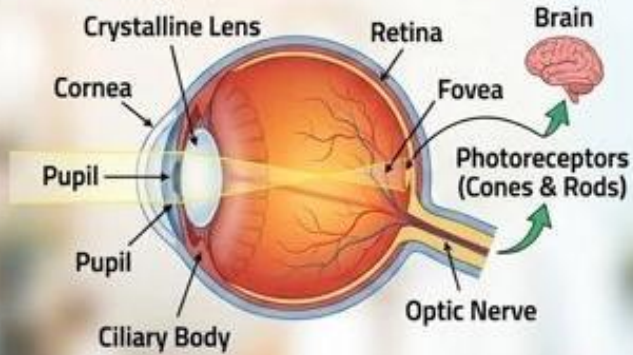
.Both have an aperture (pupil/iris in eye, diaphragm in camera) controlling light entry .

.Both form real images on a photosensitive surface (retina in eye, film or sensor in camera) .

Optical Instruments	The Eye	Aspect
Objective Lens	Cornea + Lens	Light Collection
Screen or Eyepiece	Retina	Image Formation
Focusing Mechanisms	Accommodation (lens)	Focus Adjustment
Aperture/Diaphragm	Iris (pupil size)	Light Control

COMPARISON BETWEEN HUMAN EYE & DIGITAL CAMERA

HUMAN EYE



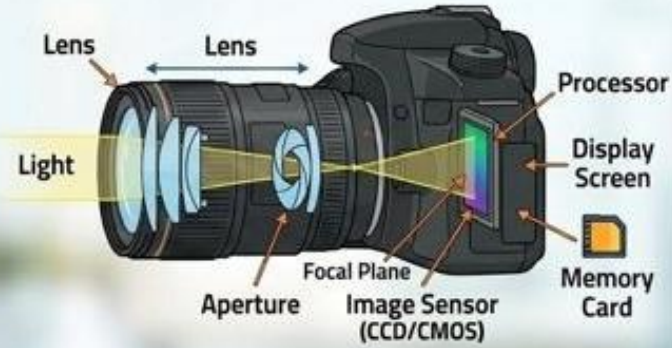
1 تركيز تلقائي وديناميكي Dynamic Autofocus

2 نطاق ديناميكي واسع High Dynamic Range & Sensitivity

3 تنظيم ذاتي لشدة الضوء Self-Regulating Light Intensity via Iris

4 معالجة معقدة في الدماغ Complex Processing in the Brain

DIGITAL CAMERA



1 تركيز بؤري ميكانيكي/إلكتروني Mechanical / Electronic Focus

2 Limited Dynamic Range & Adjustable ISO Sensitivity

3 التحكم في الضر Manual Light Control via Aperture & Shutter

4 معالجة إلكترونية وتخزين Electronic Processing & Digital Storage

▶ **Post test :**

- ▶ Q / what is the similarities between the human eye and a camera ?
- ▶ Q / list the optical instrument ?
- ▶ Q / explain the Compound Microscope ?