Kirkuk University

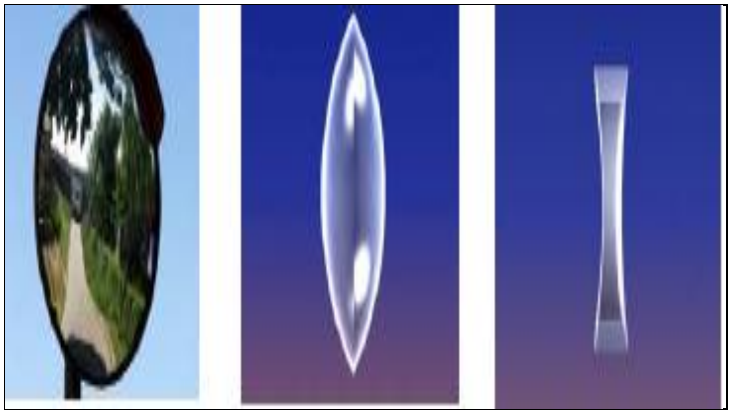
Science College

Physics Department

Lectures of

GEOMETRIC OPTICS

Lecture – 11 –



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Lecture 11: Converging Lenses (double convex lens) -Part 1

11 - 1 The Anatomy of Converging Lenses (double convex lens)
11 - 2 Rules of Refraction for Converging Lenses (double convex lens)
11 – 3 Image Characteristics for Converging Lenses (double convex lens)

11-1 The Anatomy of Converging Lenses (double convex lens)

- If a piece of glass or other transparent material takes on the appropriate shape, it is possible that parallel incident rays would either converge to a point or appear to be diverging from a point**.**
- A piece of glass that has such a shape is referred to as a lens**.**
- A **lens** is molded piece of transparent material that refracts light rays in such as way as to form an image**.**
- Lenses can be thought of as a series of tiny refracting prisms, each of which refracts light to produce their own image as shown in Fig(**11-1**)**.**

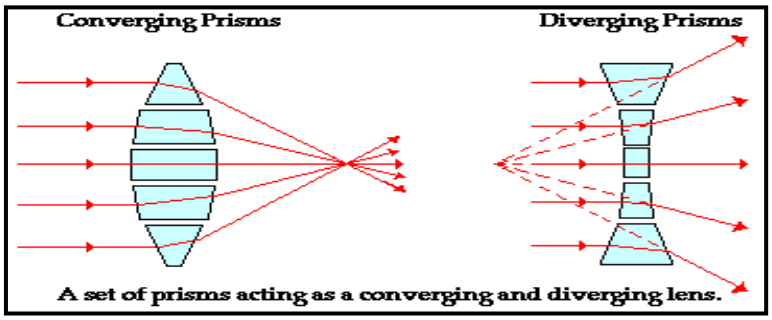

Fig.(11-1) : A set of prisms acting as a converging and diverging lens

- When these prisms act together, they produce a bright image focused at a point**.**
- There are a variety of types of lenses**.**
- Our focus will be upon lenses that are symmetrical across their horizontal axis - known as the **principal axis.**

- In this Lecture, we will explain a converging lenses**.**
- A **converging lens** is a lens that converges rays of light that are traveling parallel to its principal axis**.**
- Converging lenses can be identified by their shape; they are relatively thick across their middle and thin at their upper and lower edges as shown in Fig.(**11-2**)**.**

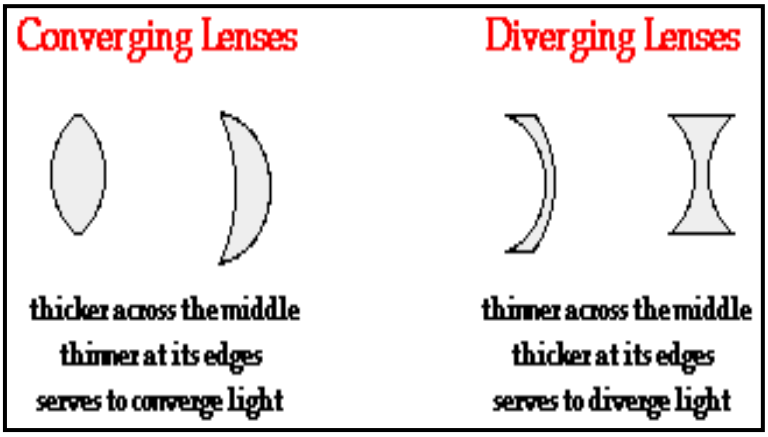

Fig.(11-2) : The shapes of two types of lenses .

- A **double convex lens** is symmetrical across both its horizontal and vertical axis**.**
- The fact that a double convex lens is thicker across its middle is an indicator that it will converge rays of light that travel parallel to its principal axis**.**
- A double convex lens is a converging lens**.**

- As we begin to discuss the refraction of light rays and the formation of images by two types of lenses, we will need to use a variety of terms**.**
- These terms describe the various parts of a lens and include such words as the following as shown in Fig(**11-3**)**:**

Principal axis — Vertical axis

Focal Point — Focal Length

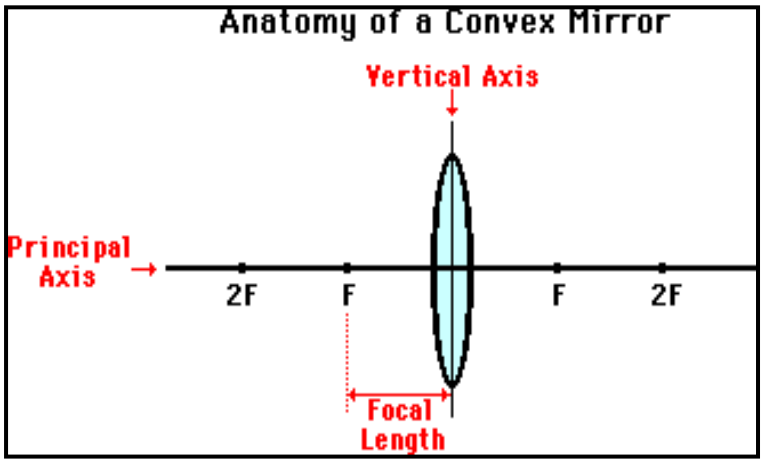

Fig.(11-3) : Anatomy of a converging lens

- A lens has an imaginary horizontal line passing through the exact center of the lens**.**
- This imaginary line is known as the **principal axis,** as shown in Fig(**11-3**)**.**
- A lens also has an imaginary **vertical axis** that bisects the symmetrical lens into halves, as shown in Fig(**11-3**)**.**
- As mentioned above, light rays incident towards either face of the lens and traveling parallel to the principal axis will either converge or diverge**.**

- If the light rays converge (as in a converging lens), then they will converge to a point**.**
- This point is known as the **focal point** of the converging lens**.**
- If the light rays diverge (as in a diverging lens), then the diverging rays can be traced backwards until they intersect at a point**.**
- This intersection point is known as the **focal point** of a diverging lens**.**
- The focal point is denoted by the letter **F** on the diagrams above**.**
- Note that each lens has two focal points - one on each side of the lens**.**
- Unlike mirrors, lenses can allow light to pass through either face, depending on where the incident rays are coming from**.**
- Subsequently, every lens has two possible focal points**.**
- The distance from the vertical axis of the lens to the focal point is known as the **focal length** (abbreviated by **f**), as shown in Fig(**11-3**)**.**
- Technically, a lens does not have a center of curvature**.**
- However a lens does have an imaginary point that we refer to as the **2F point.**
- This is the point on the principal axis that is twice as far from the vertical axis as the focal point is , as shown in Fig(**11-3**)**.**

11-2 Rules of Refraction for Converging Lenses (double convex lens)

- As a ray of light enters a lens, it is refracted; and as the same ray of light exits the lens, it is refracted again**.**
- The net effect of the refraction of light at these two boundaries is that the light ray has changed directions**.**
- Because of the special geometric shape of a lens, the light rays are refracted such that they form images**.**
- We will investigate the refractive ability of converging lenses**.**
- Suppose that several rays of light approach the double convex lens; and suppose that these rays of light are traveling parallel to the principal axis**.**
- Upon reaching the front face of the lens, each ray of light will refract towards the normal to the surface**.**
- At this boundary, the light ray is passing from air into a denser medium (for example glass)**.**
- Since the light ray is passing from a medium in which it travels fast into a medium in which it travels relatively slow, it will bend towards the normal line**.**
- This is shown for two incident rays in the Fig.(**11-4**) below**.**
- Once the light ray refracts across the boundary and enters the lens, it travels in a straight line until it reaches the back face of the lens**.**
- At this boundary, each ray of light will refract away from the normal to the surface**.**

- Since the light ray is passing from a medium in which it travels slow to a medium in which it travels fast, it will bend away from the normal line**.**

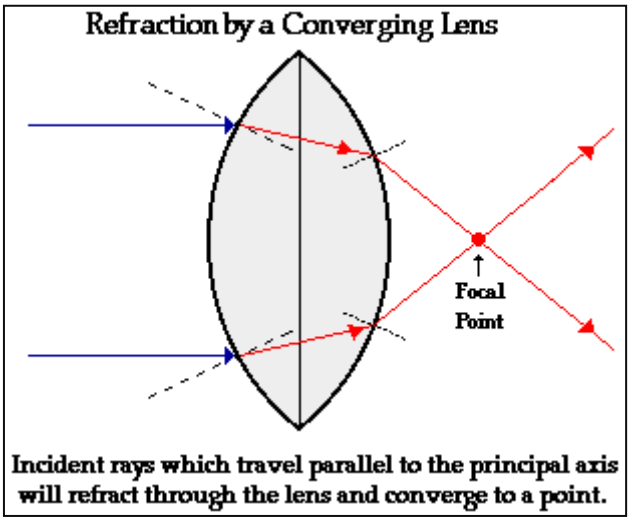

Fig.(11-4) : The behavior of two incident rays travel parallel to the principal axis of Converging Lenses

- The above diagram shows the behavior of two incident rays approaching parallel to the principal axis**.**
- Note that the two rays converge at a point; this point is known as the focal point of the lens**.**
- The first generalization that can be made for the refraction of light by a double convex lens is as follows**:-**

1- Any incident ray traveling parallel to the principal axis of a converging lens will refract through the lens and travel through the focal point on the opposite side of the lens**.**

- Now suppose that the rays of light are traveling through the focal point on the way to the lens as shown in Fig.(**11-5**).
- These rays of light will refract when they enter the lens and refract when they leave the lens.
- As the light rays enter into the more dense lens material, they refract towards the normal; and as they exit into the less dense air, they refract away from the normal.
- These specific rays will exit the lens traveling parallel to the principal axis.

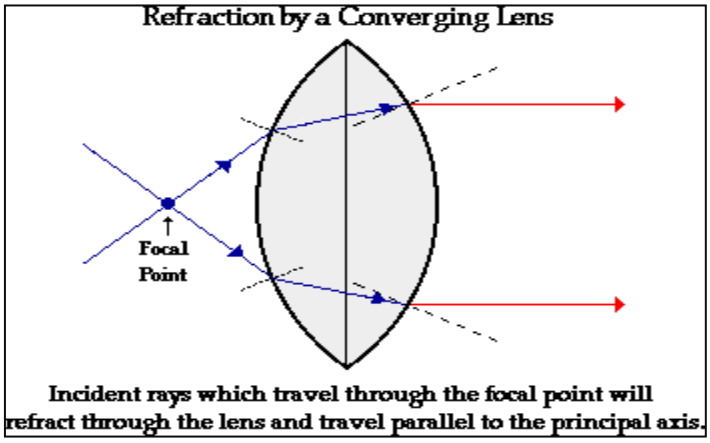

Fig.(11-5) : The behavior of two incident rays travel through the focal point of Converging Lenses

- The above diagram shows the behavior of two incident rays traveling through the focal point on the way to the lens.
- Note that the two rays refract parallel to the principal axis.
- A second generalization for the refraction of light by a double convex lens can be added to the first generalization.

2- Any incident ray traveling through the focal point on the way to the lens will refract through the lens and travel parallel to the principal axis.

11-3 Image Characteristics for Converging Lenses (double convex lens)

- The purpose of this portion of the Lecture is to summarize the object-image relationships - to practice the **L•O•S•T** art of image description**.**
- We wish to describe the characteristics of the image for any given object location**.**
- The **L** of **L•O•S•T** represents the relative **location.**
- The **O** of **L•O•S•T** represents the **orientation** (either upright or inverted)**.**
- The **S** of **L•O•S•T** represents the relative **size** (either magnified, reduced or the same size as the object)**.**
- The **T** of **L•O•S•T** represents the **type** of image (either real or virtual)**.**
- The best means of summarizing this relationship between object location and image characteristics is to divide the possible object locations into five general areas or points , as shown in Fig.(**11-6**)**:**

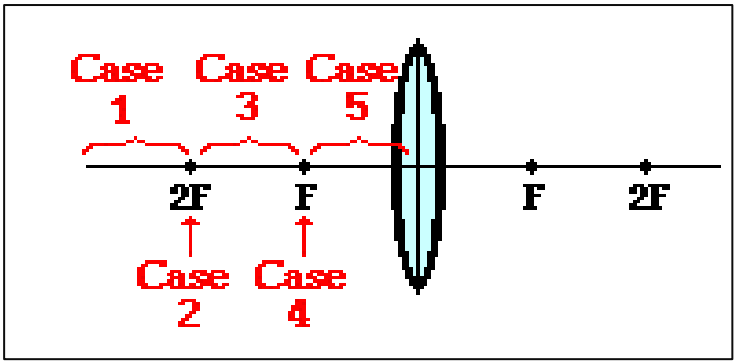

Fig. (11-6): Five general areas or points of possible object locations in front of a double convex lens

- In the next lecture, ray diagrams were constructing in order to determine the location, size, orientation, and type of image formed by converging lenses**.**