WEEK 2: Continue Properties of Light.

1.2. Properties of an Image

The image produced by an optical instrument can be described in terms of its *magnification*, *orientation* and *nature*.

Term		Definition
Magnification or Size (m)	Diminished	The image is smaller than the original object.
	Same size	The image is same size as the object.
	Magnified	The image is larger than the object.
Orientation	Upright	The image is same way up as the object.
	Inverted	The image is upside down compared to the object.
Nature	Real	Rays really pass through the image
	Virtual	Rays only appear to come from the image.

1.3. Mirrors

A mirror is a highly reflective surface. The most common mirrors are flat and are known as *plane* mirrors. Household mirrors are plane mirrors. They are made of a flat piece of glass with a thin layer of silver nitrate or aluminium on the back. However, other mirrors are *curved* and are either *convex* mirrors or are concave mirrors. The reflecting properties of all three types of mirrors will be discussed in this section.

1.3.1. Plane (Flat) Mirror

When you look into a mirror, you see an image of yourself. The image created in the mirror has the following properties:

i. The image is *virtual*.

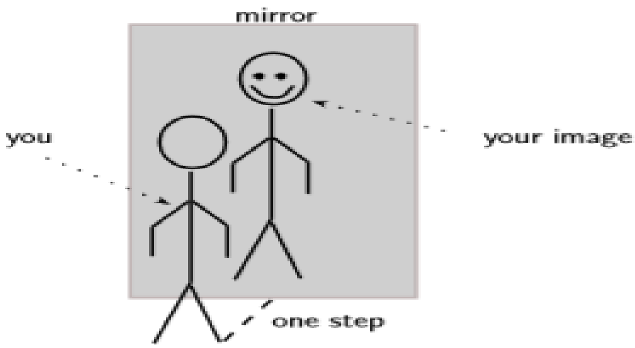


Figure 1: An image in a mirror is virtual, upright, the same size and laterally inverted.

Definition: Lateral inversion is the reversal of mirror image where the right side of the object appears on the left side behind the mirror.

ii. The image is the *same* distance behind the mirror as the object is in front of the mirror.
iii. The image is *laterally inverted*. This means that the image is inverted from side to side.
iv. The image is the same size as the object.
v. The image is *upright*.

Virtual images are images formed in places where light does not really reach. Light does not really pass through the mirror to create the image; it only appears to an observer as though the light were coming from behind the mirror. Whenever a mirror creates an image which is virtual, the image will always be located behind the mirror where light does not really pass.

Definition: Virtual Image A virtual image is upright, on the opposite side of the mirror as the object, and light does not actually reach it.

1.3.2. Spherical Mirrors

The second class of mirrors that we will look at are spherical mirrors. These mirrors are called **spherical mirrors** because if you take a sphere and cut it as shown in *Figure 2* and then polish the inside of one and the outside of the other, you will get a *concave* mirror and *convex* mirror as shown. These two mirrors will be studied in detail.

The list of terms used in spherical images are given below:

P	**Pole**	It is the midpoint of a mirror.
C	**Centre of Curvature**	It is the centre of the sphere of which the mirror forms a part.
R	**Radius of Curvature**	It is the distance between the pole and the centre of the curvature. It is twice the focal length of the mirror.
–	**Principal Axis**	It is an imaginary line passing through the pole and the centre of curvature of the spherical mirror.
F	**Focus**	It is the point on the principal axis.

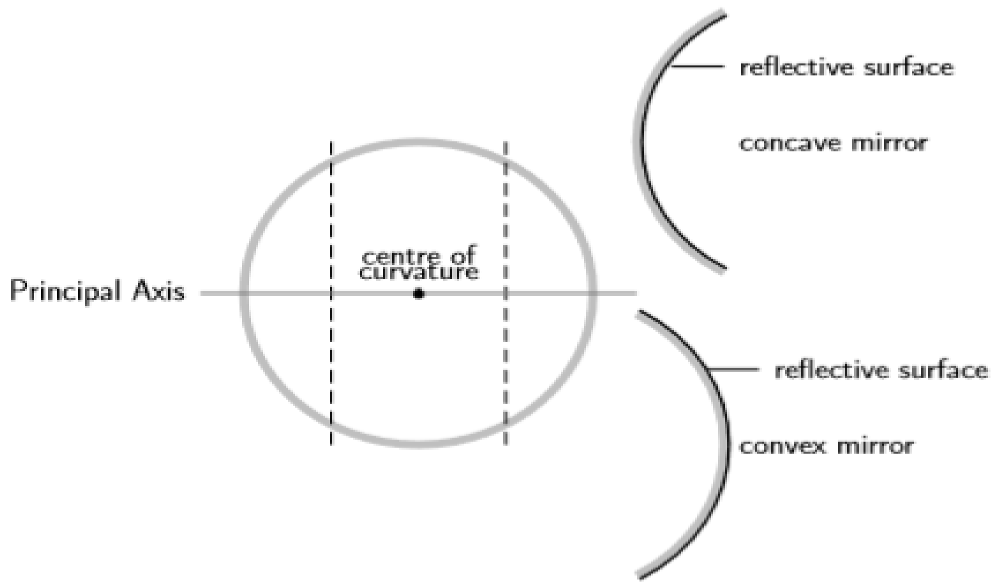


Figure 2: A sphere is cut and then polished to a reflective surface on the inside a concave mirror is obtained. When the outside is polished to a reflective surface, a convex mirror is obtained.

i. **Concave Mirrors (converging)**

The first type of curved mirror we will study are concave mirrors. Concave mirrors have the shape shown in *Figure 3*. As with a plane mirror, the principal axis is a line that is perpendicular to the centre of the mirror.
If you think of light reflecting off a concave mirror, you will immediately see that things will look very different compared to a plane mirror. The easiest way to understand what will happen is to draw a ray diagram and work out where the images will form. Once we have done that it is easy to see what properties the image has.
First, we need to define a very important characteristic of the mirror. We have seen that the *centre of curvature* is the centre of the sphere from which the mirror is cut. We then define that a distance that is half-way between the centre of curvature and the mirror on the principal axis. This point is known as the *focal point* and the distance from the focal point to the mirror is known as the *focal length* (symbol *f*). Since the focal point is the midpoint of the line segment joining the vertex and the center of curvature, the focal length would be one-half the radius of curvature.

Definition: Focal Point The focal point of a mirror is the midpoint of a line segment joining the vertex and the centre of curvature. It is the position at which all parallel rays are focussed.

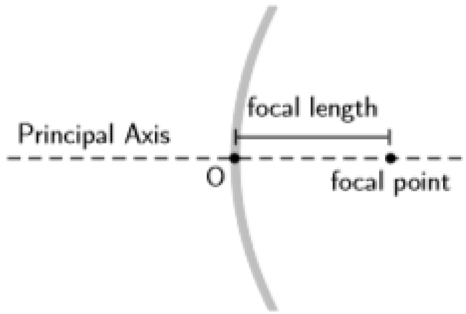


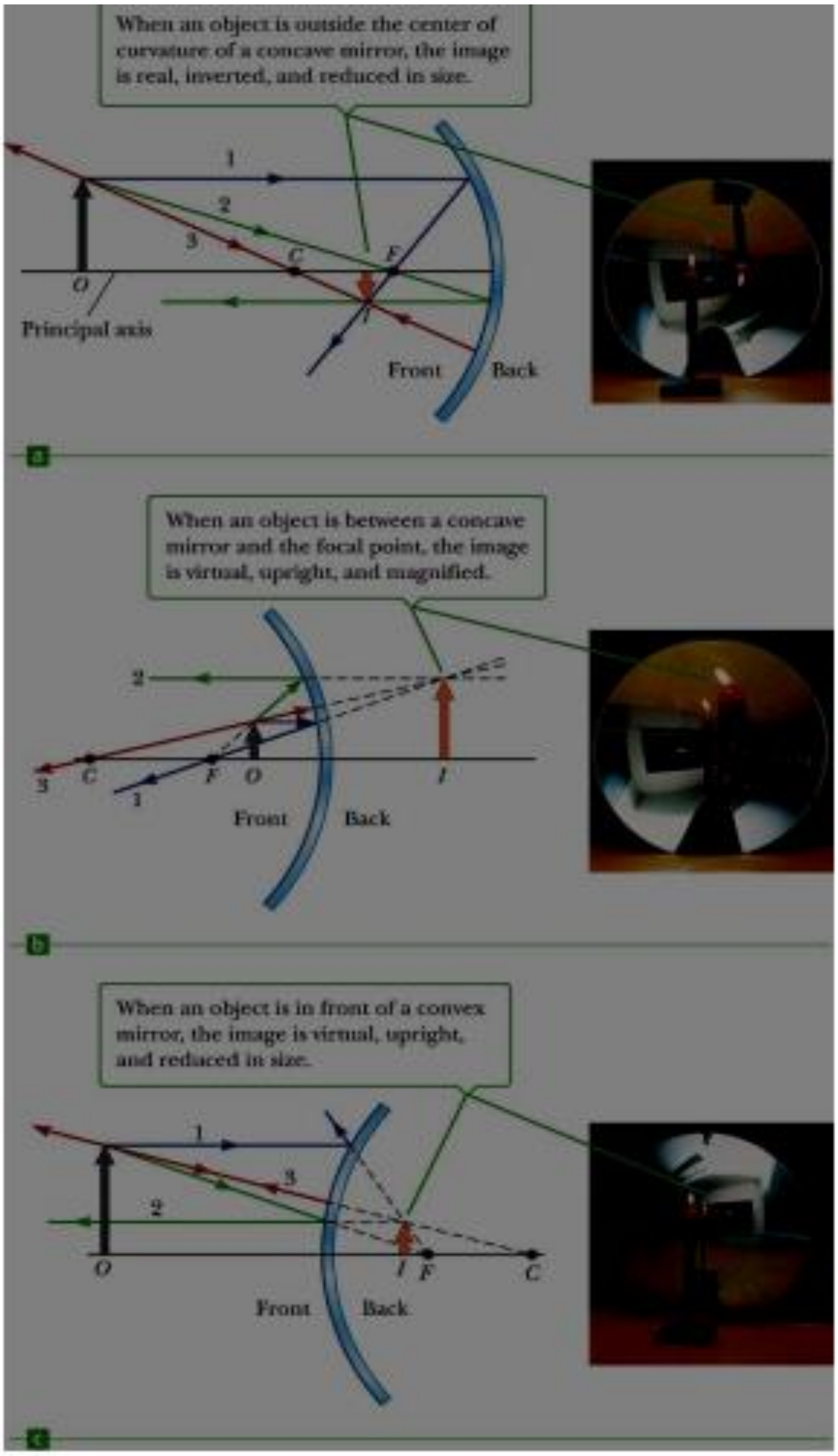
Figure 3: Concave mirror with principal axis.

- **Rays Diagram**

i. A ray diagram can be used to determine the position and size of an image.
ii. They are graphical constructions which tell the overall nature of the image.
iii. They can also be used to check the parameters calculated from the mirror and magnification equation.

- To make the ray diagram, you need to know
  - The position of the object
  - The position of the center of curvature
- Three rays are drawn
  - They all start from the same position on the object
- The intersection of any two of the rays at a point locates the image.
  - The third ray serves as a check of the construction.

- **The Rays in a Ray Diagram**
- Ray 1 is drawn parallel to the principle axis and is reflected back through the focal point, F.
- Ray 2 is drawn through the focal point and is reflected parallel to the principle axis.
- Ray 3 is drawn through the center of curvature and is reflected back on itself.
- The rays actually go in all directions from the object.
- The three rays were chosen for their ease of construction.
- The image point obtained by the ray diagram must agree with the value of q calculated from the mirror equation.
- Note the changes in the image as the object moves through the focal point.



➢ **Characteristics of Concave Mirrors**

i. Light converges at a point when it strikes and reflects back from the reflecting surface of the concave mirror. Hence, it is also known as a converging mirror.

ii. When the concave mirror is placed very close to the object, a magnified and virtual image is obtained.

iii. However, if we increase the distance between the object and the mirror then the size of the image reduces and a real image is formed.

iv. The image formed by the concave mirror can be small or large or can be real or virtual.

- **Uses of Concave Mirror**

The uses of the concave mirrors are given below:

i. Concave mirrors are mostly used in torches, vehicle headlights, flashlights, and searchlights.
ii. Shaving mirrors are also made up of concave mirrors to see the larger image of the face.
iii. Dentists also use concave mirrors to see the larger image of the patient's teeth.
iv. In order to produce heat in solar furnaces, large concave mirrors are used to concentrate sunlight.

ii. Convex Mirrors

The second type of curved mirror we will study are convex mirrors. Convex mirrors have the shape shown in *Figure 4*. As with a plane mirror, the principal axis is a line that is perpendicular to the centre of the mirror. The back of the mirror is shaded so that reflection only takes place from the outward bulged part. The surface of the spoon which is bulged outwards can be assumed to be a convex mirror. It is also known as a diverging mirror as the light after reflecting through its surface diverges to many directions but appears to meet at some points where the virtual, erect image of diminished size is formed.

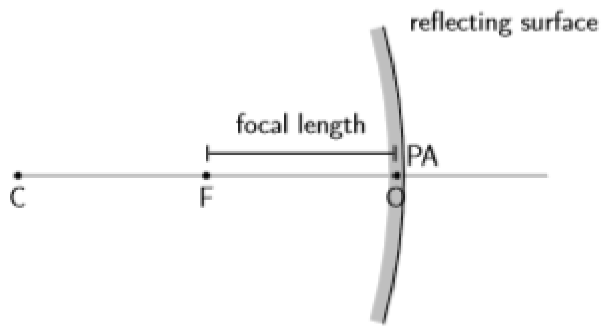


Figure 4: Convex mirror with principal axis, focal point (F), centre of curvature (C). The centre of the mirror is the optical centre (O).

- **Characteristics of Convex Mirrors**

i. A convex mirror is also known as a diverging mirror as this mirror diverges light when they strike on its reflecting surface.

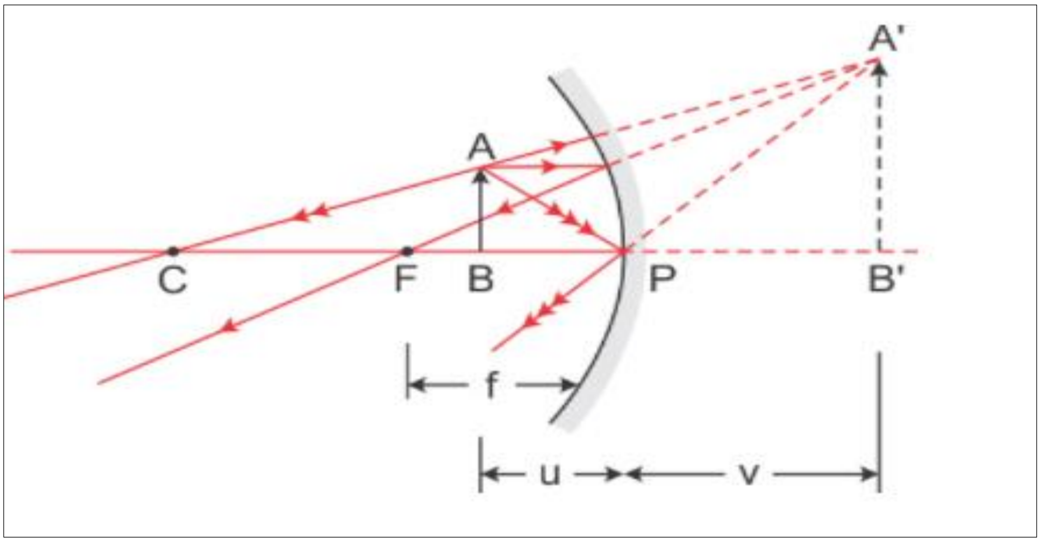
ii. Virtual, erect, and diminished images are always formed with convex mirrors, irrespective of the distance between the object and the mirror.

Uses of Convex Mirror:

i. Convex mirrors used inside buildings: large offices, stores, and hospitals use a convex mirror to let people see around the corner so that they can avoid running into each other and prevent any collision.
ii. Convex mirror used in vehicles: convex mirrors are commonly used as rear-view mirrors in case of automobiles and vehicles because it can diverge light beams and make virtual images.
iii. Uses of the convex mirror in a magnifying glass: These mirrors are mostly used for making magnifying glasses. In industries, to construct a magnifying glass, two convex mirrors are placed back-to-back.
iv. Convex mirrors used for security purposes: Diverging mirrors are also used for security purposes in many places. They are places near ATMs so that bank customers can check if someone is behind them.
v. Convex mirrors are also used in various other places like as a street light reflector as it can spread light over bigger areas.

1.3.3. The Mirror Formula

It is often quicker (and usually more precise) to find details about an image using a formula rather than a ray diagram. Both Descartes' mirror formula $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ and Newton's method $s_i s_0 = f^2$ are commonly used for both spherical mirrors and lenses.



In the figure shown above, an object AB is placed in front of a concave mirror between the pole and principal focus of the mirror. Hence, the image formed is virtual, erect and magnified. Where **u** = object distance, **v** = image distance, **f** = focal length of mirror.

$$\frac{CB}{CB'} = \frac{PB}{PB'} -----(\text{Eqn. 1})$$

Also, $CB = PC - PB$ and $CB' = PC + PB'$

Therefore, $\frac{CB}{CB'} = \frac{PC - PB}{PC + PB'} = \frac{PB}{PB'}$ (From eqn. (1))

A/C to Cartesian sign convention,

Object distance (PB) $= -u$

Image distance (PB') $= +v$

Radius of curvature (PC) $= -R$

$$\frac{-R + u}{-R + v} = \frac{-u}{v}$$

OR, $uR - uv = -vR + uv$

OR $uR + vR = 2uv$

Dividing both the sides by uvR, we get

$$\frac{1}{v} + \frac{1}{u} = \frac{2}{R}$$

OR $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

Example 1

What is the image distance in case of concave mirror if the object distance is 4 cm? It is given that the focal length of the mirror is 2 cm.

As we know from mirror formula,

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

Where u= object distance= -4cm

v= image distance=?

f= focal length of mirror= -2cm

Putting values, we get

$$\frac{1}{v} + \frac{1}{4} = \frac{1}{2}$$

$$\frac{1}{v} = \frac{1}{2} - \frac{1}{4}$$

$$\frac{1}{v} = \frac{1}{2} + \frac{1}{4}$$

$$\frac{1}{v} = \frac{-2}{4} - \frac{1}{4}$$

$$\frac{1}{v} = -\frac{1}{4}$$

Therefore, v= -4 cm

Hence the object is located 4cm in front of the mirror.

Activity 1.2

1. Define lateral inversion.
2. Define Reflection.
3. Construct ray diagrams to illustrate the formation of images of an object by curved mirrors.
4. Describe characteristics of images produced by plane (flat) and curved mirrors.
5. Define the following:

a. Pole
b. Focus
c. Focal length
d. Radius of Curvature

6. List the properties of:

a. Concave mirrors
b. Convex mirrors

7. Differentiate between the uses of concave and convex mirrors.