12 SOURCES, PROPAGATION AND REFLECTION OF LIGHT

Sources and propagation of light

Light is the visible form of energy. It is also a wave motion. The human eye can detect light. We can convert light energy to other forms of energy; photocells convert light energy to electrical energy. During photosynthesis, light energy is converted to chemical energy by plants. All these show that light is a form of energy. The Sun is the main source of light and all other forms of energy on earth. Light travels through vacuum (empty space) or air at a speed of 3.0 Ã— 10^8 ms^{-1}.

Light wave has a very short wavelength of $\frac{1}{2000}$ mm or 5 Ã— 10^{-4} mm.

OBJECTIVES

At the end of this topic, students should be able to:

- list some sources of light and classify them into natural and artificial sources;
- state what happens when light interacts with matter;
- list evidences to show that light travels in a straight line between two points;
- describe pin hole camera and state the effects of increasing the size of pinhole on the size of image;
- explain how shadows are formed;
- distinguish between two types of shadow.

Luminous and non-luminous objects

1. Luminous objects:

A luminous object is one that produces and emits its own light.

Some objects are self-luminous because they produce their own light by nature. Objects like the Sun, stars and glow-worms are called natural luminous object. Man-made sources of light are artificial luminous objects. These include electric flashers, electric lamps, burning candles, etc. Luminous objects radiate energy when their atoms become excited and jump from the excited state to the stable state.

Figure 12.1: Luminous objects

2. Non-luminous objects:

A non-luminous object is one that cannot produce its own light but reflects light falling on them.

We see these objects because light reflected from them enters our eye. Non-luminous objects include the moon, mirror, paper, wall and most objects we see around us.

Interaction of light with matter

When light travelling through space hits a medium, it may be **absorbed, transmitted** or **reflected**. One or more of these may occur depending on the medium.

(a) Transmission of light

Light can pass through some materials without being distorted. *Materials which transmit light in such a way that we can see clearly through them are said to be* **transparent**. Examples are plain glass, clean water, gases and cellophane.

Translucent materials transmit light but we cannot see through them. They include frosted glass, television screen, fluorescent tubes, oiled papers and a thin sheet of paper.

(b) Absorption of light

Most objects absorb light reaching them transmitting none. They are called **opaque** objects. Opaque objects cast a shadow behind them because they absorb most of the light falling on them. Walls, blackboards, trees, humans, etc., are all examples of opaque objects.

(c) Reflection of light

Objects like mirror, water and polished or shiny surfaces reflect greater percentages of light falling on them. They are called **reflectors**. Every object reflects some amount of light reaching them. We see these objects through the light they reflect.

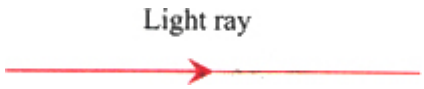
Most opaque objects absorb and reflect light. Some materials like glass transmit most of the light reaching them, absorbing and reflecting some.

Light rays and beams

Every moving body has a path or way through which it travels. Vehicles and lorries travel on road, aeroplanes have airways and ships have sea routes. The path followed by light as it moves away from its source is called a **ray**.

A ray is the direction of the path in which light is travelling.

A ray is represented on paper by a thin straight line with an arrowhead on it. The arrow shows the direction the ray is moving.

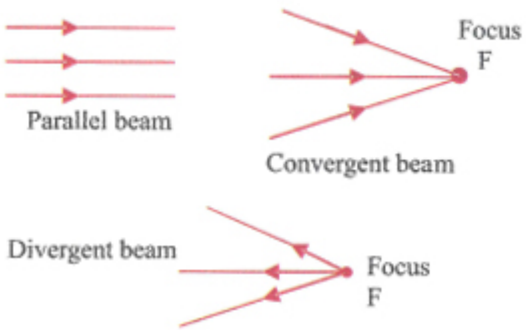


It is difficult to produce a single ray because it has no thickness. The path of a ray can only be approximated by a collection of rays called a **beam of light**.

A beam is a collection of many light rays.

A beam of light can be represented by two or more rays. A light beam may be **parallel, convergent** or **divergent**.

A beam is parallel if the rays that make up the beam are parallel. A convergent beam moves towards a common point and divergent beam spreads from a common point.



Rectilinear propagation of light

Light travels in straight lines between two points. This is called **rectilinear propagation** of light. The following evidences show that light travels in a straight line between two points.

â€¢ We cannot see round a sharp bend or a corner.

â€¢ Formation of sharp edges of shadow by opaque objects: Opaque objects placed in the path of light cast shadows with sharp edges behind them.

â€¢ Formation of a sharp image in a pinhole camera.

â€¢ Beams of sun light seen through the leaves of trees in the morning travel in straight line.

We can demonstrate that light travels in straight lines between two points in the same medium using the set up in Figure 12.2.

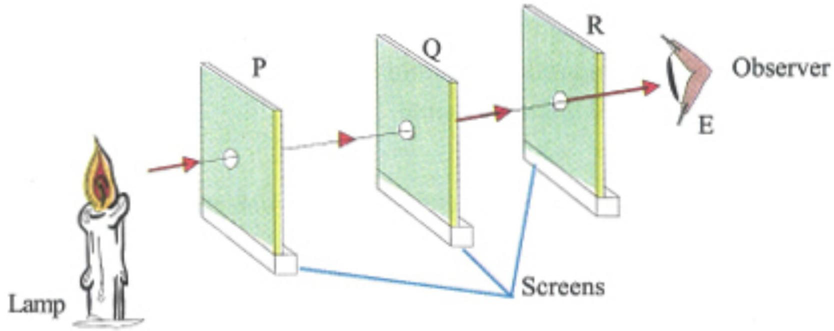


Figure 12.2: Rectilinear propagation of light

Three screens P, Q and R with holes at their centres are placed one after the other such that the holes form a straight line between the eye E and light source L. The observer E sees the light L when the screens are arranged in straight line but when the screen Q is displaced a little, the holes are no longer in straight line. The light coming from L is cut off and will not reach the eye E, this shows that light from the source L travels in straight lines between L and E.

The pinhole camera

A pinhole camera consists of a lightproof box with a pin size hole in the centre of its front. A screen made of translucent paper or a photographic film is placed at the back. The inside of the pinhole camera is painted black to reduce internal reflection of light which makes more than one image to be formed. When the camera is put in front of a luminous or a well illuminated object, an inverted image is formed on the screen. A ray of light leaving the head of the object O, travelling in a straight line enters the pinhole camera through the pinhole H. The ray continues moving in straight line until it strikes the screen at M. Another ray from the foot B strikes the screen at I after passing through the pinhole H. This explains why the image formed on the screen is inverted or upside-down. The size of image formed depends on the:

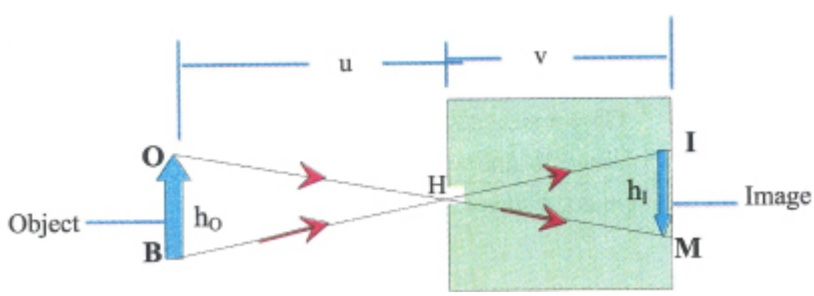


Figure 12.3: A pinhole camera

â€¢ distance of the object from the pinhole;

â€¢ length of the pinhole camera.

A pinhole camera with two or more pin size holes lets in more light but forms more than one image. For a camera with two pinholes, two overlapping images are formed. The final image produced is **brighter** and **bigger** but loses its **sharpness** or **focus**. A single large pinhole has the same effect as many pinholes.

Effect of large pinhole on the image produced

(i) The **image** formed is **brighter** because more rays of light enter the camera.

(ii) The **image** formed is **bigger** because many images overlap to form a single image.

(iii) The **image** formed is **blurred**. The image loses its **sharpness** or **focus**.

â€¢ **BBB (bigger, brighter and blurred)**

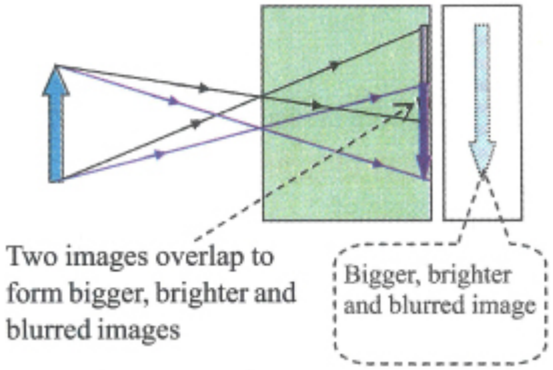


Figure 12.4: Effects of a large pinhole on the image

Linear magnification

Magnification is the ratio of image size (distance) to the object size (distance).

Mathematically, we can define linear magnification as:

$$\text{Linear magnification} = \frac{\text{Image size}}{\text{Object size}} = \frac{h_i}{h_0}$$

$$\text{Linear magnification} = \frac{\text{Image distance}}{\text{Object distance}} = \frac{v}{u}$$

$$m = \frac{h_i}{h_0} = \frac{v}{u}$$

Worked examples

A man 1.85 m tall stands 5.35 m in front of a pinhole camera of length 25 cm. Find the magnification and the size of image formed.

Solution

$$\text{Linear magnification} = \frac{\text{Image distance}}{\text{Object distance}} = \frac{v}{u}$$

$$m = \frac{0.25}{5.35} = 0.0467$$

$$\text{Linear magnification} = \frac{\text{Image height}}{\text{Object height}} = \frac{h_i}{h_0}$$

$$0.0467 = \frac{\text{Image height}}{1.85}$$

$$\text{Image height} = 0.0467 \times 1.85 = 0.086 \text{ m.}$$

Shadows

Shadows are formed because light travels in straight lines. A beam of light falling on an opaque object is absorbed while the rest of light beam are passing through the edges and beyond continue in their straight motion until a shadow is cast on a screen. The shadow of the opaque object is formed on the screen because partial or no light gets to the screen. The type of shadow formed depends

(i) the size of the **source of light.**

(ii) the **distance of the opaque object** from the light.

1. Shadow formed by a point source of light

A point source is a very small source of light. Light rays from such points diverge or spread out from a common point.

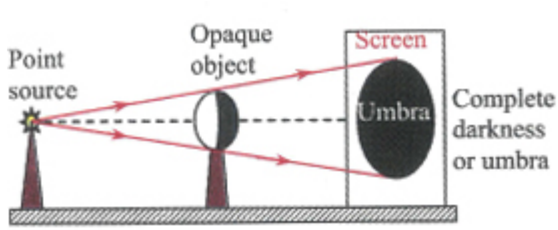


Figure 12.5: Formation of shadow by point source of light

If an opaque object is put in the path of a point source of light, the shadow formed on the screen is **sharp** and **uniformly dark**. The shadow is called **umbra** because no light gets to the screen at that region. **Umbra is the region of complete darkness**.

2. Shadow formed by an extended source of light

A large source of light is called an **extended source**. The shadow formed by an extended source of light is bigger and consists of two parts of different degrees of darkness. The **central dark part** is called the **umbra** because no light gets to it. Around the umbra is a blending of light and darkness (partial darkness) called **penumbra**. The penumbra nearer the umbra is darker than the ones near the edges. Beyond the shadows is complete light.

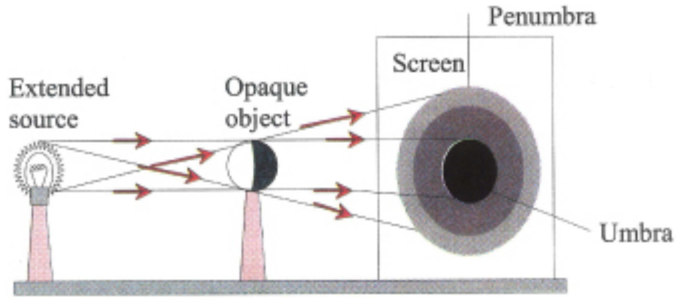


Figure 12.6: Formation of shadow by extended source of light

Eclipses

Eclipse occurs if a heavenly body (the moon or a planet) prevents the light of the sun from reaching the earth. Two types of eclipses are:

â€¢ eclipse of the sun or solar eclipse;

â€¢ eclipse of the moon or lunar eclipse.

Eclipse of the sun

Eclipse of the sun occurs anytime the moon comes in between the sun and earth such that the earth gets dark during the day and the three are in a straight line. The sun becomes an extended source, the moon an opaque object and the earth acts as a screen. The places on the earthâ€™s surface where the umbra **D** is formed will experience a total darkness. People living in the places where the penumbra P_1 and P_2 are formed will see partial darkness.

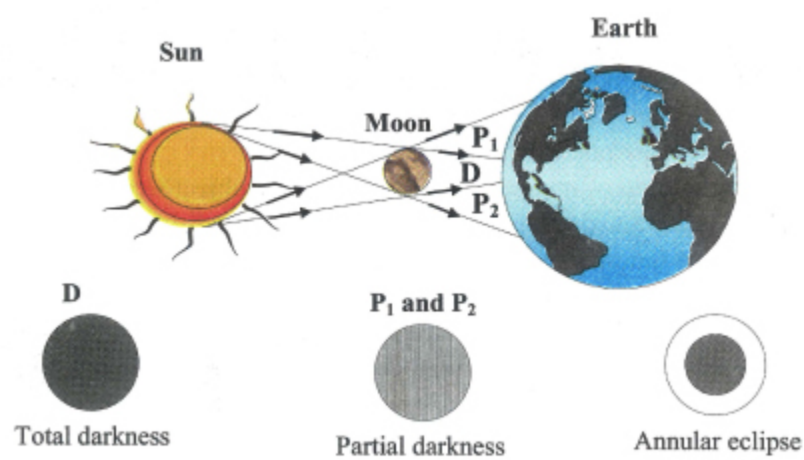


Figure 12.7: Solar eclipse

When the moon is far from the earth, its shadow (umbra) may not get to the earth, therefore the people living at D will see annular eclipse (darkness with a ring of light) which represents the part of the sun not covered by the moon.

Eclipses are results of large shadows cast by the moon and the earth.

Eclipse of the moon (Lunar eclipse)

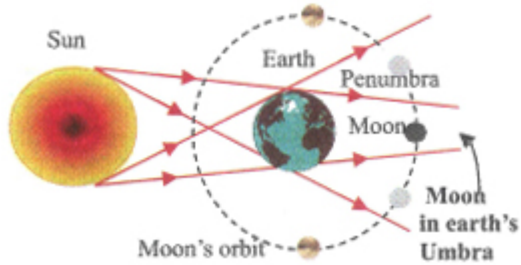


Figure 12.8: Lunar eclipse

Eclipse of the moon occurs when the earth as an opaque object blocks the light of the sun from reaching the moon. The shadow of the earth covers the moon for about two hours.

Lunar eclipse occurs more often than solar ecplise.

Summary

â€¢ Light is the **visible** form of **energy**. It travels in straight lines between two points.

â€¢ **Luminous objects** produce and emit their own light. Examples are the sun and the stars.

â€¢ **Non-luminous objects** do not produce their own light but reflect light falling on them.

â€¢ **Transparent** materials transmit light and we can see clearly through them.

â€¢ **Translucent** materials transmit light but we cannot see through them.

â€¢ **Opaque objects** absorb most of the light falling on them and cast shadows behind them.

â€¢ **Reflectors** are materials which reflect most of the light reaching them. Every object reflects some amount of light reaching them.

â€¢ **A ray** is the direction of the path in which light is travelling.

â€¢ A **beam** is a collection of many light rays. Light beams may be **parallel, convergent** or **divergent**.

â€¢ **A pinhole camera** is a light tight box, which produces an inverted image of the object put in front of it. If the size of the hole is increased, the image produced is **brighter, bigger** and **blurred** (loses its sharpness or focus).

â€¢ **Magnification** is the ratio of image size (distance) to the object size (distance).

â€¢ **Shadows** are formed because opaque objects block the path of light travelling in straight lines. The shadow of the opaque object formed on the screen is **sharp** and **uniformly dark** and is called umbra. **Umbra is the region of complete darkness.**

â€¢ **Penumbra** is a partial darkness formed around the umbra.

â€¢ **Eclipse of the sun** occurs anytime the moon come in between the sun and earth such that the three are in a straight line.

â€¢ **Eclipse of the moon** occurs when the earth as an opaque of object blocks the light the sun from reaching the moon.

Practice Questions 12a

1. (a) Give **two** evidences which suggest that light is a form of energy;
   (b) What is (i) luminous (ii) non-luminous objects?
   (c) Give **two** examples of luminous objects.
2. (a) What do you understand by rectilinear propagation of light?
   (b) How will you demonstrate that light travels in straight lines between two points?
   (c) Give **two** evidences to prove that light travels in straight lines between two points.
3. (a) Describe a pinhole camera and explain how it works.
   (b) What is the effect on the image on:
      (i) increasing the size of pinhole;
      (ii) increasing the length of the pinhole camera?
      (iii) moving the object away from the pinhole?
   (c) A pencil 2 cm long is 20 cm in front of a pinhole camera of length 15 cm. What is the height of the image produced?
4. (a) Draw a labelled diagram of a pinhole camera showing how an image is formed on the screen.
   (b) Explain why the image is always inverted.
   (c) State the changes you will notice if:
      (i) another pinhole is produced closed to the first pinhole.
      (ii) the size of the pinhole is doubled.
      (iii) the object is moved closer to the pinhole.
5. A pinhole camera of length 1 m is used to form the image of the sun. If the diameter of image of the sun is 10 mm;
   (a) Draw a ray diagram (not to scale) to show how the image of the sun is formed.
   (b) What is the diameter of the sun if it is 1.5 Ã— 10^{11} m from the pinhole camera?
6. (a) What is a shadow?
   (b) Describe how an umbra is formed. Why is the shadow uniformly dark?
   (c) What happens to the shadow if the size of the light is made bigger?
7. (a) Explain how shadows are formed.

(b) Distinguish between umbra and penumbra.
(c) Draw diagrams to show how umbra and penumbra are produced.

8. What is an eclipse? Explain how an eclipse of the sun is formed.

Reflection of light

Reflection is the sending back of light waves when it strikes a surface. Surfaces, which reflect light very well are called good **reflectors**. A good example of reflector is a mirror; a mirror is a glass coated on one side with silvered paint. Non-luminous objects are seen because they reflect light reaching their surface.

Reflection at plane surface

OBJECTIVES

At the end of this topic, students should be able to:

- explain reflection and determine the angle of reflection for a given angle of incidence;
- draw ray diagrams to show the formation of images by plane mirrors;
- locate the position of image formed by plane mirrors;
- state the characteristics of image formed by plane mirrors;
- state the uses of plane mirrors.

Reflection and diffuse reflections

Reflection from a surface depends on how smooth or rough it is. **Reflection from smooth surfaces like mirrors is regular**. If parallel light rays are incident on a smooth surface, the reflected light rays are also parallel.

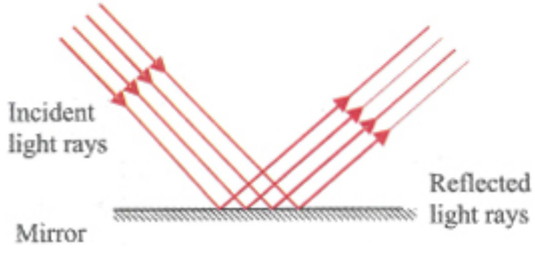


Figure 12.9: Regular reflection

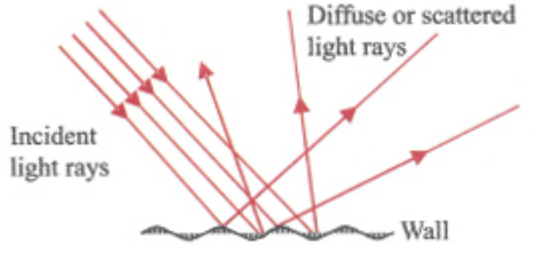


Figure 12.10: Diffuse or scattered reflection

Reflection from rough surfaces like walls and paper is irregular

or diffuse. Parallel light beam is scattered in different directions so that no image is formed.

Reflection by plane mirror

When a narrow beam of light from a ray box hits a plane mirror M, it is reflected as shown in Figure 12.11.

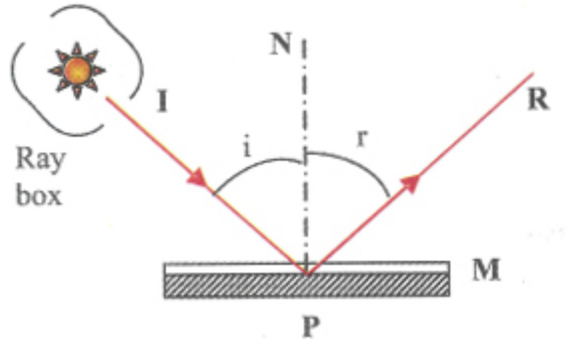


Figure 12.11: Diffused or scattered reflection

The ray **IP** moving towards the mirror is called the **incident ray**, the ray **PR** moving away from the mirror is called the **reflected ray**. The point of incidence is **P** and the line **NP** perpendicular to the mirror is called **normal**. The angle (i = ∠IPN) which the incident ray makes with the normal is called the **angle of incidence** and the angle (r = ∠NPR) between the normal and the reflected ray is called the **angle of reflection**.

The laws of reflection

The law of reflection state that:

1. The incident ray, the normal and the reflected ray at the point of incidence, all lie on the same plane.
2. The angle of incidence = angle of reflection.

Verification of laws of reflection

Apparatus: Optical pins, plane mirror, sharp pencil, plasticine and plane paper.

Method

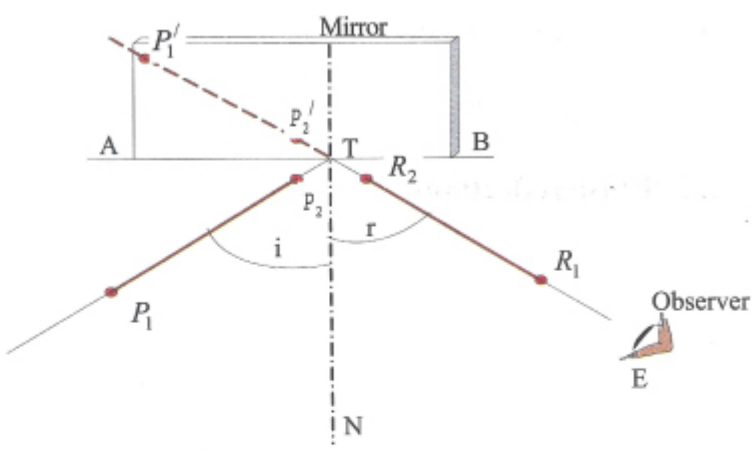


Figure 12.12: Demonstrating the laws of reflection

i Using a sharp pencil, draw a line AB to represent the mirror. Draw lines NT normal to the line AB at the point T, line FT to represent the incident ray and measure the angle ($\angle$FTN = i) the angle of incidence. Place the mirror exactly on AB.

ii Fix two pins P_1 and P_2 along FT. Looking into the mirror from the position E, fix two others pins R_1 and R_2 such that they appear to be on a straight line with the images P_1 and P_2 of P_1 and P_2.

iii Remove the mirror, join the points R_1 and R_2 with a ruler to T.

iv Measure the angle $\angle$ETN = r (angle of reflection).

v Repeat the experiment for different angle of incidence and tabulate your readings as shown in the table below.

Angle of incidence (i)	Angle of reflection (r)
?	?

The result of the experiment shows that the angle of incidence **i** = angle of reflection **r**.

How an image is formed by plane mirror

The position of the image in a plane is located by using two or more rays from any part of the object. This is illustrated in figure 11.13, two rays **OP** and **OT** from the head of the arrow **O** strikes the mirror at **P** and **T** respectively and are reflected along **PA** and **TB**. The eye **E** sees the image of the arrow at **I**, because the reflected rays **PA** and **TB** appear to be coming from the point **I** behind the mirror. **I** is a **virtual image** since no light ray passes through that point. It cannot be formed on a screen placed at **I** (behind the mirror).

A virtual image is formed by apparent intersection of light rays; it cannot be formed on a screen.

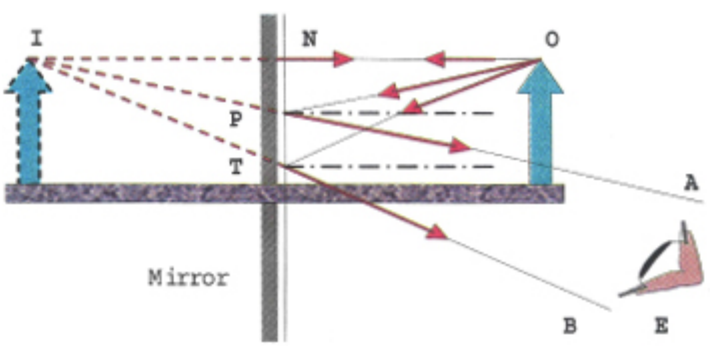


Figure 12.13: Formation of an image with a plane mirror

How to locate the position of image in a plane mirror

Apparatus: Optical pins, plane mirror, sharp pencil, plasticine, ruler and tracing paper.

Method:

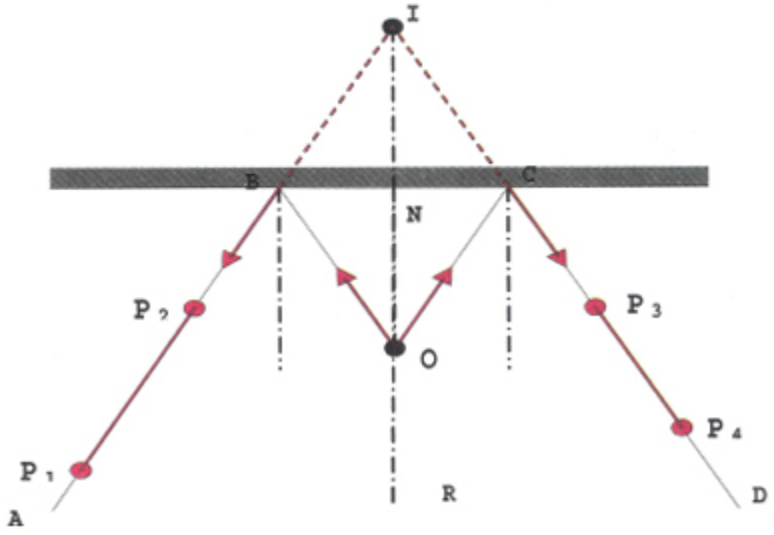


Figure 12.14: Locating the position in a plane

(i) Place the mirror on the tracing paper and trace its outline XY. Remove the mirror and draw a normal RN to XY.

(ii) Fix the object pin **O** on **RN** such that **ON =** 2 cm. Fix two pins $\mathbf{P_1}$ and $\mathbf{P_2}$ such that they appear to be in straight line with the image of the object pin **O**. Fix other two pins $\mathbf{P_3}$ and $\mathbf{P_4}$ so that they are in a straight line with the image of the object pin **O**.

(iii) Remove the pins and join the $\mathbf{P_1P_2}$ and $\mathbf{P_3}$ $\mathbf{P_4}$ to meet line **RN**, produce to **I**, (the position of the image).

(iv) Measure **IN** the distance of the image from the mirror.

(v) Repeat the experiment with **ON =** 3, 4, 5 and 6 cm. In each case measure and record the image distance **IN.**

(vi) Tabulate your readings.

Object distance ON cm	Image distance IN cm
?	?

Conclusion: The distance of the image from the mirror is equal to the distance of the object from the mirror.

Lateral inversion

When a person eats in front of a plane mirror with a right hand, his image behind the mirror eats with the left hand. All images formed by plane mirrors are turned left to right. The turning of image from left to right by plane mirrors is called **lateral inversion**. Lateral inversion is seen clear when we view alphabets in front of a mirror. This is illustrated in Figure 12.15.

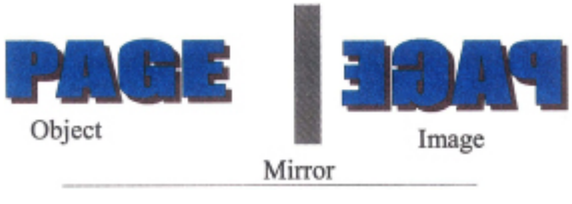


Figure 12.15: Lateral inversion

Characteristics of images formed by plane mirrors

The following are the characteristics of the image formed by plane mirrors.

1. The size of the image is equal to the size of the object.
2. The distance of the image behind the mirror is equal to the distance of the object in front of the mirror.
3. The image formed is always erect.
4. A virtual image is formed behind the mirror.
5. The image is laterally inverted.

Rotation of plane mirror

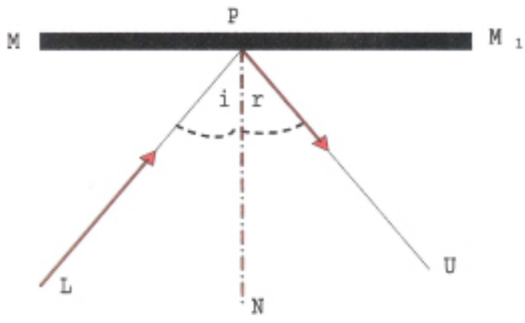


Figure 12.16a: Rotating a plane mirror

Turning a mirror through a small angle Î¸ makes the reflected ray to shift through an angle twice the angle of rotation of the mirror. We can demonstrate as follows:

Figure 12.16a shows an incident ray **LP** striking the mirror at **P** and is reflected along **PU**. The angle between the incident ray and the reflected ray is ∠**LPU** = 2*i*(*i* = r).

If the mirror is turned through an angle Î¸ as shown in Figure 11.16b while the direction of the incident ray **LP** is not changed, the normal shifts from $\mathbf{N_1}$ to $\mathbf{N_2}$ turning through an angle Î¸. The new angle of incident because of the rotation of the mirror is ∠$\mathbf{LPN_2}$ = (*i*+Î¸) and the angle of reflection now is 〈$\mathbf{N_2PE}$ = (i+Î¸). The angle between the incident ray **LP** and the new reflected ray **PE** is ∠**LPE** = 2(*i*+Î¸). The angle **UPE** between the old reflected ray **PU** and the new reflected ray **PE** is ∠**UPE** = 2(*i*+Î¸) - 2*i* = 2Î¸. The reflected ray is therefore shifted by 2Î¸ from its old direction.

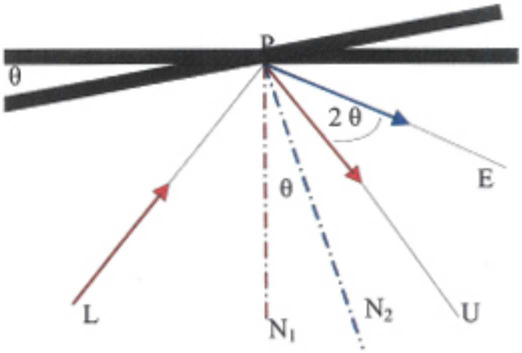


Figure 12.16b: Rotation of plane mirror

Images formed by inclined mirrors

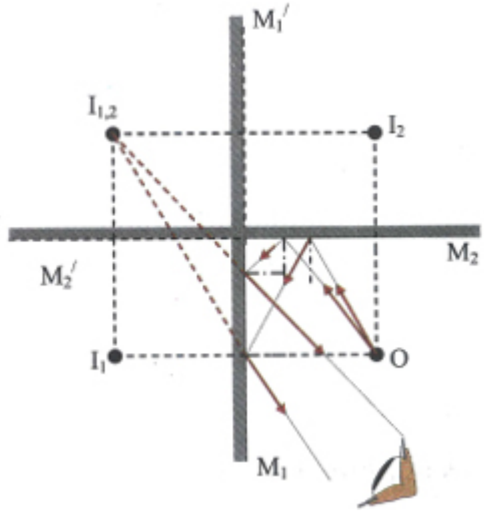


Figure 12.17: Image formation in inclined mirrors

The number of images formed by two mirrors inclined at an angle to each other depends on the angle between the mirrors. If two mirrors M_1 and M_2 are inclined at 90Â°, three images are formed. Figure 12.17 shows how the images are formed. Mirror M_1 forms the image I_1 and mirror M_2 forms the image I_2. The two mirrors combine to form the third image $I_{1,2}$ if the observer E is looking into the mirror M_1 or $I_{2,1}$ if the eye E is viewing the images through the mirror M_2.

The number of images formed by an inclined mirror is given by:

$$n = \frac{360}{\theta} - 1$$

n = the number of images formed by two inclined mirrors.
Î¸ = angle of inclination between the mirrors.
The number of images formed by two inclined mirrors increases as the angle between the mirrors is reduced.
For *Î¸* = 90Â°

$$n = \frac{360}{\theta} - 1 = \frac{360}{90} - 1 = 4 - 1 = 3 \text{ images}$$

For $\theta = 60°$

$$n = \frac{360}{\theta} - 1 = \frac{360}{60} - 1 = 6 - 1 = 5 \text{ images}$$

Images formed by two parallel mirrors

The number of images formed between two parallel mirrors is uncountable (infinity). The angle between the mirrors *Î¸* = 0Â°, therefore, *n* the number of images in infinity.

$$n = \frac{360}{\theta} - 1 = \frac{360}{0} - 1 = \infty - 1 = \infty$$

The image $I_{1,2}$ is formed by double reflection from mirror M_2 to M_1. The images formed by the mirrors become fainter and smaller because absorption of light by the mirror and the distance between the images and the observer is increased for each successive reflection from the mirrors.

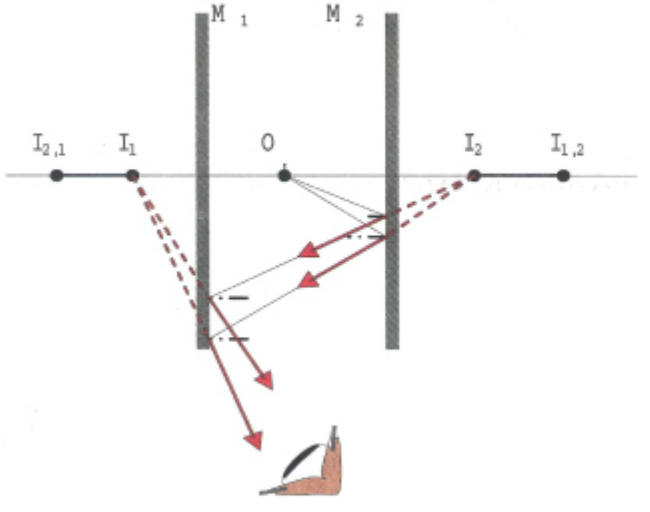


Figure 12.18: Images formed by two parallel mirrors

The number of images formed by two parallel mirrors is infinite.

Uses of plane mirrors

1. Kaleidoscope

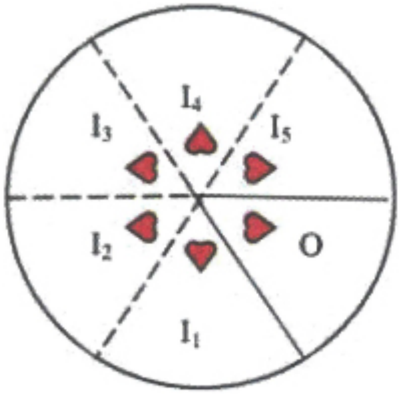


Figure 12.19: Kaleidoscope

A kaleidoscope consists of two plane mirrors inclined at an angle of 60Â°. When an object is placed between the mirrors, five images are formed, the object makes the sixth. If many coloured objects are placed between the mirrors beautiful symmetrical patterns are produced. Different beautiful symmetrical patterns are formed each time the housing of the mirrors is shaken. Kaleidoscopes are used in textile industry for designing beautiful patterns on textile materials.

2. Periscopes

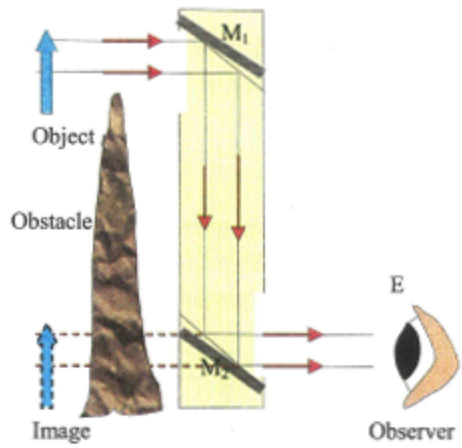


Figure 12.20: Periscope

A periscope consists of two parallel plane mirrors each inclined at 45Â° to the horizontal as shown in Figure 12.20. The mirror M_1 collects parallel light rays from the object and reflects them vertically downward to the second mirror M_2. The mirror M_2 reflects the light to the eye E. The eye E sees the virtual image of the object O at the position I. Periscopes are used by submarines to see ships and other objects floating on the sea.

3. Other uses of plane mirrors:

Plane mirrors are used in moving coil instruments to eliminate parallax error. The correct position of the point is where the point and its image in the plane mirror coincide. A plane mirror is used as a make-up (dressing) mirror.

Summary

â€¢ **Reflection** is the sending back of light waves when it strikes a smooth surface.

â€¢ **Regular reflection** is when all the incident light rays are reflected in the same direction.

â€¢ **Irregular or diffuse reflection** is when all the reflected rays are scattered in different directions. Rough surfaces like walls and papers produce diffuse reflection.

â€¢ **The laws of reflection state that:**

 â€¢ The incident ray, the normal and the reflected at the point of incidence all lie on the same plane.

 â€¢ The angle of incidence = angle of reflection.

â€¢ Turning a mirror through a small angle *Î¸* makes the reflected ray to shift through an angle twice the angle of rotation of the mirror.

â€¢ **The number of images** formed by an inclined mirror is given by:

$$n = \frac{360}{\theta} - 1$$

n = the number of images formed by two inclined mirrors

Î¸ = angle of inclination between the mirrors.

â€¢ **The number of images** formed between two parallel mirrors is uncountable (infinity).

Practice questions 12b

1. (a) State the laws of reflection of light;
   (b) Describe an experiment to verify the laws of reflection of light.
   (c) What precautions should be taken to ensure accurate results?
2. (a) Describe an experiment to locate the position of image formed in a plane mirror.
   (b) What are the characteristics of image formed by plane mirrors?
   (c) The distance between a man and his image in a plane mirror is 7 m. If the man moves 1.5 m away from the mirror, how far is he from his image?
3. (a) Explain the following terms as applied to image formed by plane mirrors:
   (i) virtual image (ii) lateral inversion.
   (b) A man standing 10 m away from a plane mirror moves toward the mirror along the line normal to the plane of the mirror with a speed of 2 ms^{-1}. Calculate:

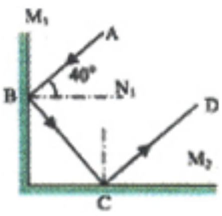
(i) the speed with which his image in the mirror approaches him.

(ii) how far is the man from his image after 3 s.

4. Distinguish between (i) **regular** and **diffuse reflections** (ii) **real** and **virtual images.**
5. (a) Draw a ray diagram showing how images are formed by two plane mirrors inclined at 90Â°.

   (b) Calculate the number of images formed by two plane mirrors inclined at 30Â°.
6. State **three** applications of plane mirror.
7. (a) State the laws of reflection

   (b) The diagram on the right shows a ray of light AB incident on mirror M_1 at an angle of 40Â°.
   Find the angle of reflection of the ray on mirror M_2.



CURVED MIRRORS

OBJECTIVE

At the end of this topic, students should be able to:

- identify curved mirrors and distinguish between convex and concave mirrors;
- draw ray diagrams to show the formation of images formed by curved mirrors;
- state the characteristics of image formed by curved mirrors;
- determine the focal length of concave mirrors;
- perform simple calculation on curved mirrors;
- state the uses of curved mirrors.

What is a curved mirror?

A mirror with its reflecting curved surface is called a **curved mirror**. Two types of curved mirrors are **spherical mirror** and **parabolic mirror**.

Spherical mirrors

The simplest form of a curved mirror is the spherical mirror. It is formed by cutting off part of a big sphere. The side of the carved out sphere, which curves inward, is **concave** while the side that curves outward is **convex**. If the convex side of the carved out sphere is coated, the concave side becomes the reflecting side and is called **concave mirror**. A **convex mirror** is produced if the concave side is coated, leaving the convex side to reflect light.

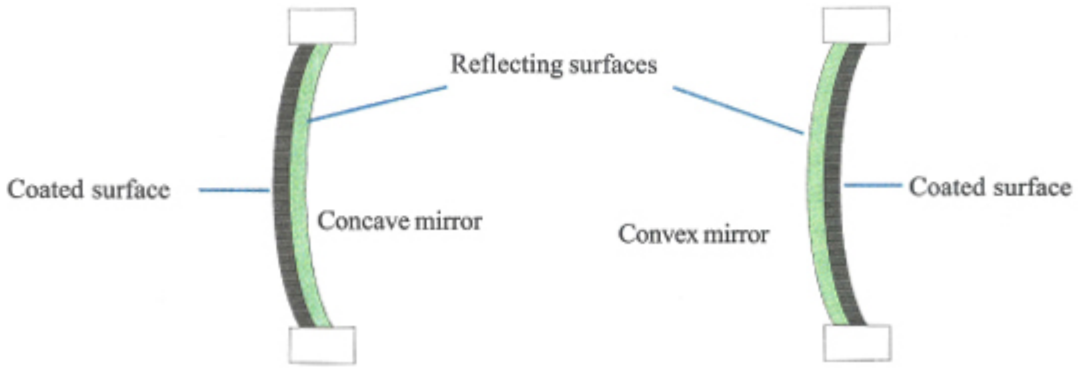


Figure 12.21a: Spherical mirrors

Terms and definitions applied to spherical mirrors

To understand the actions of spherical mirrors, the following terms and definitions should be known.

1. ***The pole (P):***
   The pole is midpoint of the spherical mirrors.
2. ***The aperture (LU):*** The aperture is the width or diameter of the mirror.
3. ***The centre of curvature (C)*** is the centre of the large sphere from which the spherical mirror is carved out.
4. ***The radius of curvature (r)*** is the distance CP between the centre of curvature (C) and the pole of the mirror (P). It is the radius of the large sphere from which the mirror is carved out.
5. ***The principal axis*** is the imaginary line passing through the pole (P) and the centre of curvature (C).
6. ***The secondary axes are*** the imaginary lines close to and parallel to the principle axis.
7. ***The principal focus*** (concave mirror) is the point F on the principal axis where incident parallel light close to the principal axis converges after reflection from a concave mirror.
8. ***The principal focus*** (convex mirror) is the point F on the principal axis where incident parallel light close to the principal axis appear to diverge from after reflection from a convex mirror.
9. ***The focal length*** (f) is the distance between the focus (F) and the pole (P) of a spherical mirror.

The focal length (f) and radius of curvature (r) are related by the equation below:

$$f = \frac{r}{2} \quad or \quad r = 2f$$

Actions of concave and convex mirrors on parallel light rays

Concave mirror

Concave mirrors reflect parallel beam of light to the focus (F). We say that the rays converge at the focus F of the mirror, therefore concave mirrors are called **converging mirrors**. The focus of a concave mirror is real because light truly passes through the point.

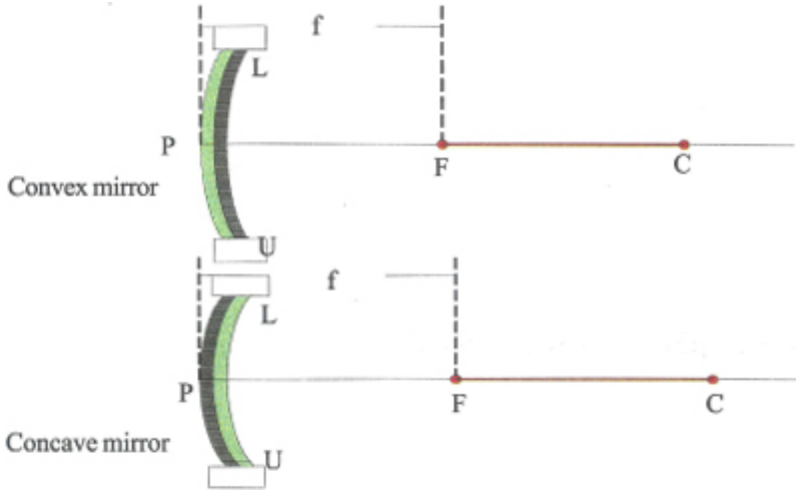


Figure 12.21b: Parts of spherical mirrors

Convex mirror

Convex mirrors reflect parallel beam of light as if they are coming from the focus behind the mirror. The reflected rays diverge or spread from the mirror in such a way that they appear to come from the point F. A convex mirror has a virtual focus since light does not really pass through the focus.

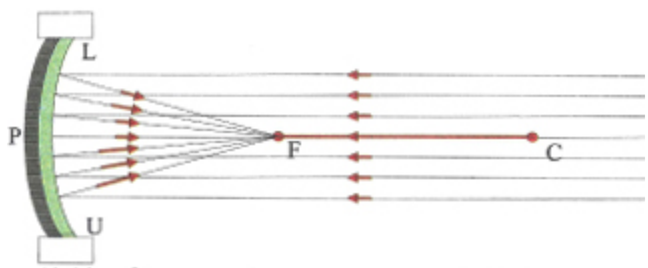


Figure 12.22a: Concave mirror converge parallel light to the focus (F)

Construction of ray diagrams

Location of images in **convex** and **concave mirrors** can be found by tracing the paths of two light rays coming from any point of the object. Four ray constructions are possible but only two are needed to find the position of the image.

(i) Light rays parallel to the principal axis are reflected through the focus.

(ii) A light ray passing through the centre of curvature is reflected back along the same path.

(iii) A light ray passing through the focus is reflected parallel to the principal axis.

(iv) Light rays striking the mirror at the pole P is reflected such that the angle of incidence is equal to the angle of reflection.

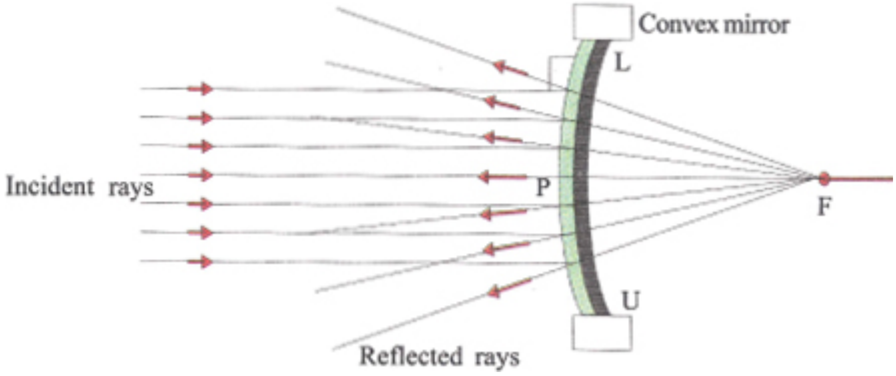


Figure 12.22b: Convex mirror diverges parallel light from the focus (F)

The point of intersection of two or more of these rays after reflection from a concave mirror is the position of **real image** of an illuminated object placed in front of the mirror. If the rays diverge after reflection from the mirror, they are produced backwards with dotted lines until they meet behind the mirror. The point where they intersect is the position of **virtual image** of the object placed in front of the mirror.

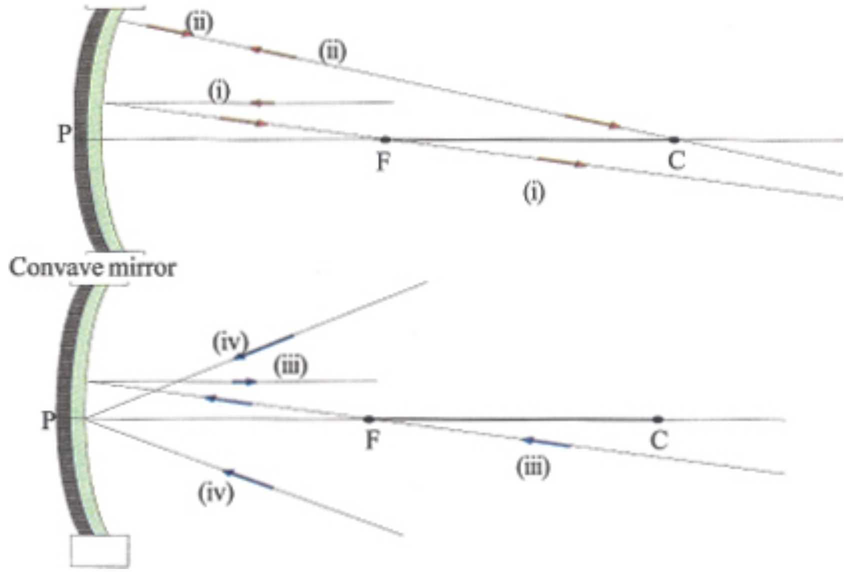


Figure 12.23a: Ray construction for concave mirrors

Hints for drawing good ray diagrams

(a) On a graph or plane paper, draw a line to represent the principal axis. A perpendicular line behind the curve mirror serves as the mirror.

(b) Choose a convinient scale and mark on the principal axis the focus F and the centre of curvature C. Make sure that PF = FC.

(c) Mark the position of the object O and draw the arrow representing the object perpendicular to the principal axis.

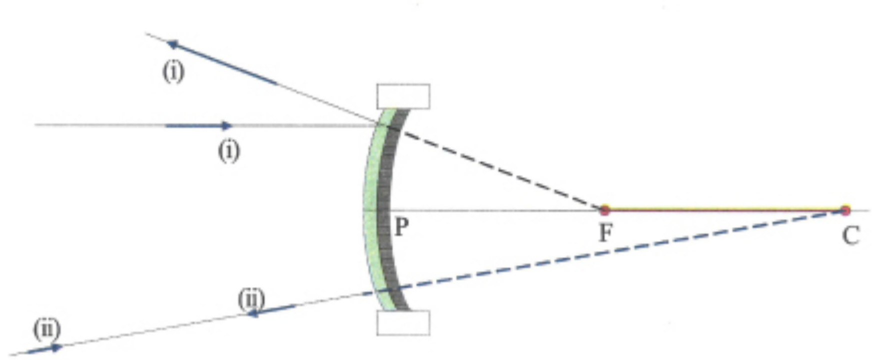


Figure 12.23b: Ray construction for convex mirrors

(d) Draw two rays from any part of the object which best suit its position to meet the mirror.

(e) The position of the image is where the reflected rays intercept each other. An arrow is drawn perpendicular to the principal axis to represent the image.

Location and characteristics of images formed by curved mirrors

I. Concave mirrors

Concave mirrors can form either **real** or **virtual images** depending on where the object is positioned. The characteristics of the image formed depend on where the object is positioned.

(a) Object positioned between the pole and the focus

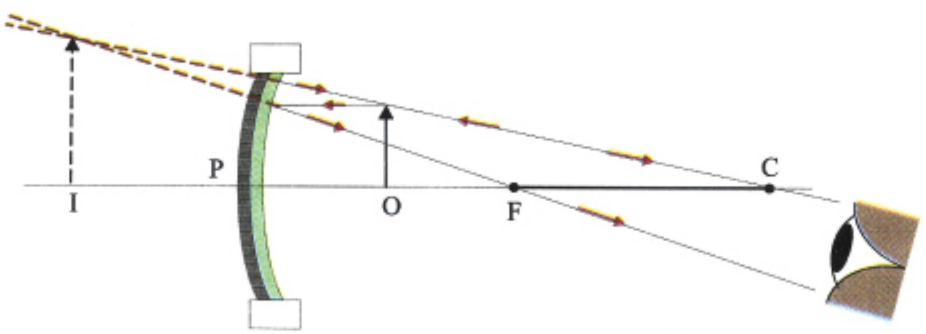


Figure 12.24a: Image formed by object placed between P and F is erect, magnified and formed behind the mirror

â€¢ **Size of image:** The image formed is magnified (bigger than the object).

â€¢ **Position of image:** Image is formed behind the mirror by apparent light intersection.

â€¢ **Nature of image:** An erect virtual image is formed.

A concave mirror with the object positioned between the pole and the focus is used as a **shaving or make up mirror** and also as a **dentist mirror**.

(b) Object positioned at the focus

The reflected rays from the mirror are **parallel**, therefore, the rays will not **intercept**. The image is said to be **formed at infinity**. We cannot state the size or the nature of the image since it is not visible. A source of light placed at the focus of a concave mirror will produce a parallel beam of light. **A concave mirror with a light source at the focus is used as car headlight, searchlight and torchlight used to produce a beam of nearly parallel light**.

(c) Object positioned between the focus and the centre of curvature

- â€¢ **Size of image:** The image formed is magnified (bigger than the object).
- â€¢ **Position of image:** The image is formed beyond the centre of curvature of the mirror by real light intersection.
- â€¢ **Nature of image:** An inverted real image is formed.

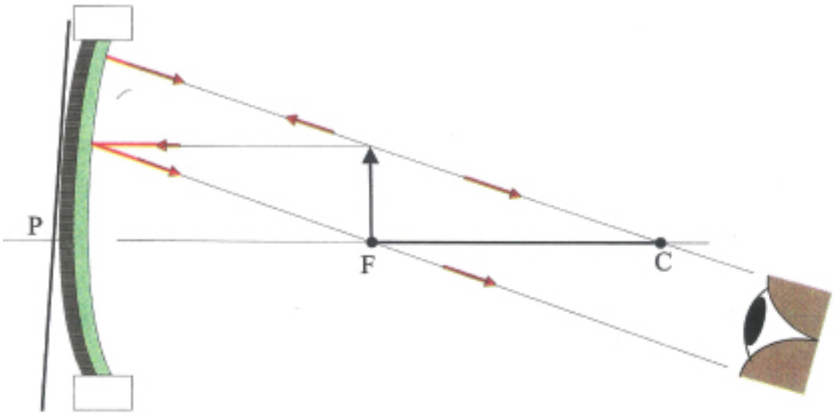


Figure 12.24b: When the objects is at F, the object is formed at infinity

A real image is formed by real intersection of light rays; it can be formed on a screen.

(d) Object positioned at the centre of curvature

- â€¢ **Size of image:** The image formed has the same size as the object.
- â€¢ **Position of image:** The image is formed at the centre of curvature mirror by real light intersection.
- â€¢ **Nature of image:** An inverted real image is formed.

Film or slide projectors use concave mirrors with the source of light at the centre of curvature to reflect light so that the object will be well illuminated.

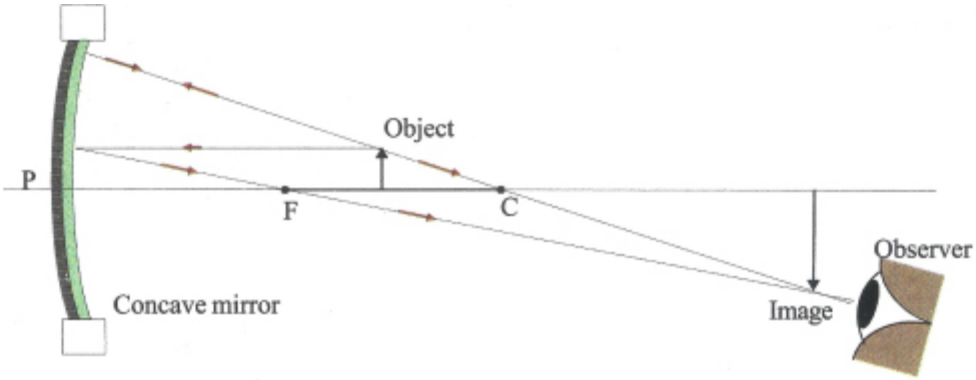


Figure 12.24c: Object between F and C produces real, inverted and magnified image beyond C

(e) Object positioned beyond the centre of curvature

â€¢ **Size of image**: The image formed is diminished (smaller than the object).

â€¢ **Position of image:** The image is formed between the centre of curvature and the focus of the mirror by real light intersection.

â€¢ **Nature of image:** An inverted real image is formed.

(f) Object at infinity

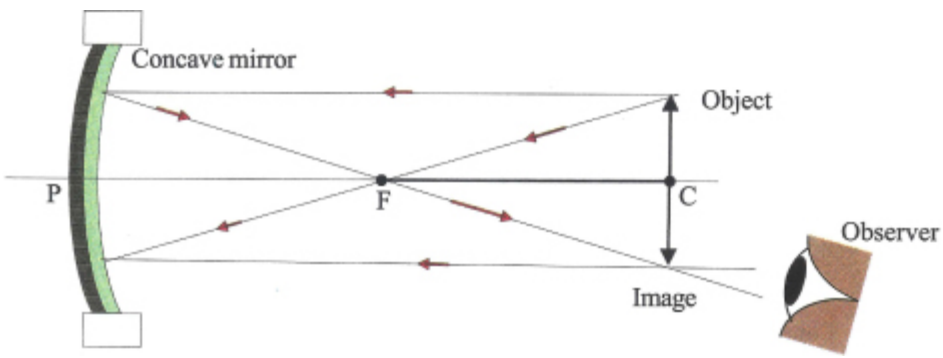


Figure 12.24d: Object at C produces a real inverted image which is same size as object

â€¢ **Size of image:** The image formed is diminished (smaller than the object).

â€¢ **Position of image:** The image is formed at the focus of the mirror by real light intersection.

â€¢ **Nature of image:** An inverted real image is formed.

A concave mirror with the object is at infinity, is used as the objective of a reflecting telescope to view distant objects like stars. It is also used to concentrate heat radiations to ignite a carbon paper, a match and also used to cook food as in solar cells.

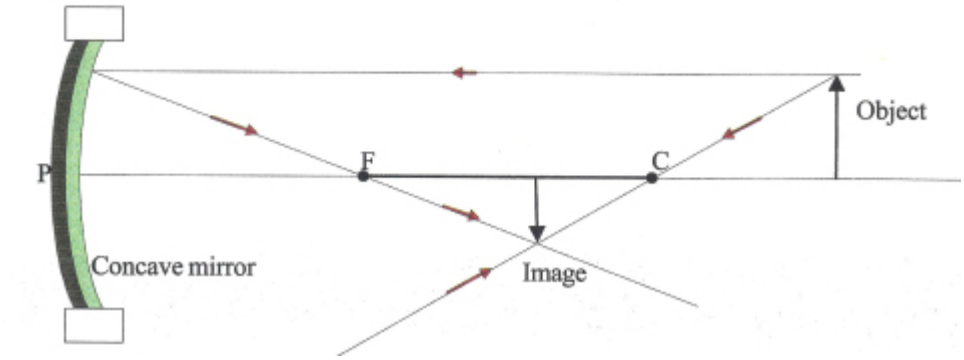


Figure 12.24e: Object positioned beyond the centre of curvature

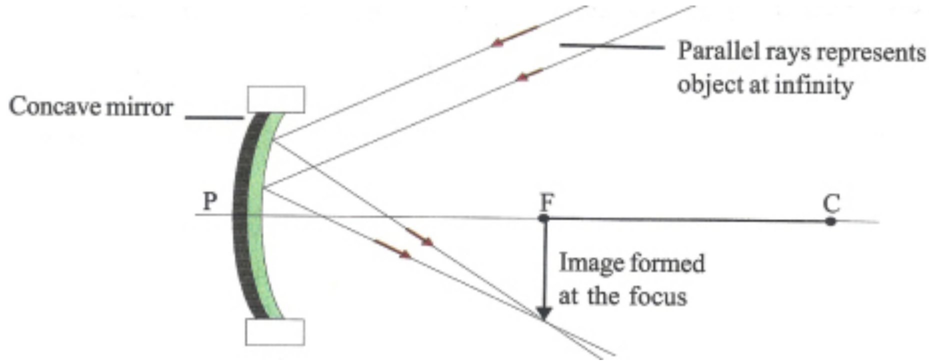


Figure 12.24f: Object at infinity produces a real, inverted and diminished object at focus

II. Convex mirrors

A convex mirror forms only a virtual image no matter the position of the object.

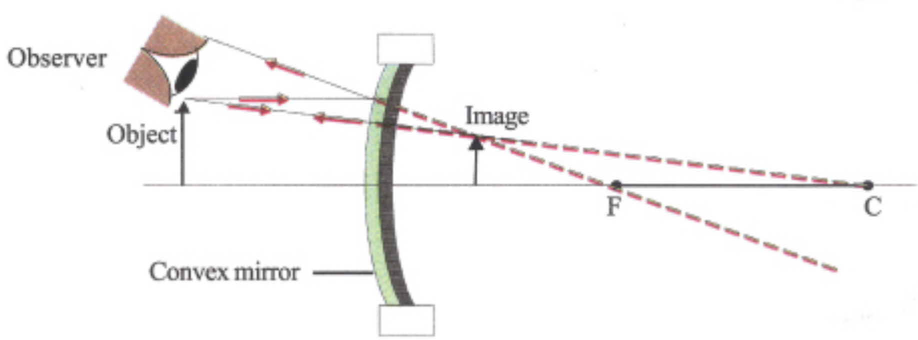


Figure 12.25: Convex mirror produces virtual images only

â€¢ **Size of image:** The image formed is diminished (smaller than the object).

â€¢ **Position of image:** The image is always formed between the focus and pole of the mirror by apparent light ray intersection.

â€¢ **Nature of image:** The image formed is always diminished, erect and virtual.

The ability of convex mirrors to produce erect and diminished images makes it suitable as driving or rear-view mirrors. This is because they are able to cover wider view of traffic behind.

Defects of spherical mirrors

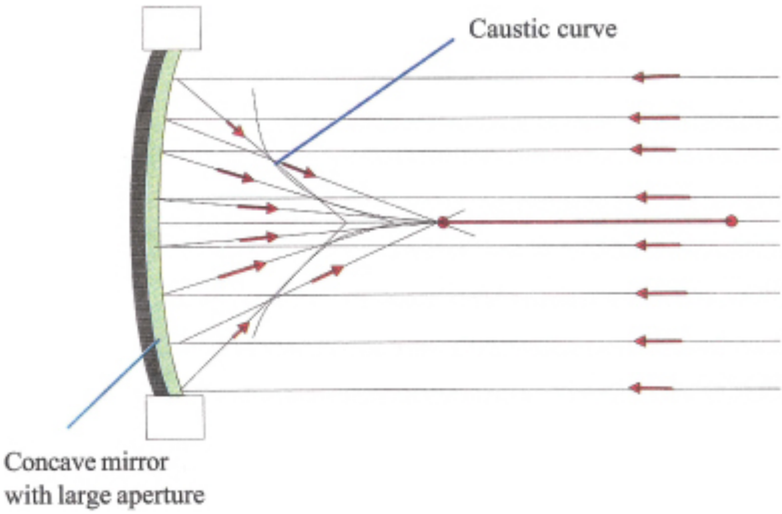


Figure 12.26: Spherical aberration

Concave mirrors of small aperture converge parallel beam of light to a single point or **focus**. For concave mirrors with large aperture, parallel beam of light do not all converge to a focus at one point on the principal axis but form a curve of light called **caustic curve**. The inability of spherical mirrors to converge parallel beam of light to a single focus is called **spherical aberration**.

Parabolic mirrors

Spherical aberration can be corrected by using concave mirrors with a small aperture or using a parabolic mirror. A parabolic mirror converges wide parallel beam of light to a single focus on its principal axis.

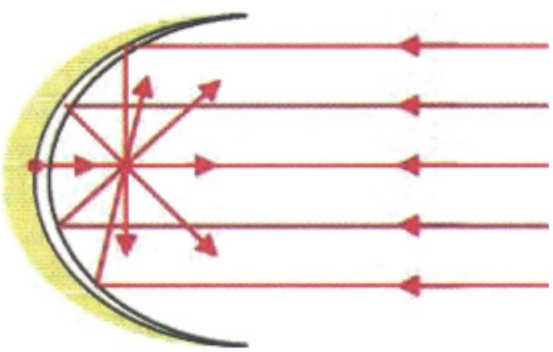


Figure 12.27: Parabolic mirror

Uses of parabolic mirrors

(a) Parabolic mirrors are used as a car headlight reflector or torchlight to produce beam of parallel light.

(b) Parabolic mirrors are used to converge parallel beam of light to a focus. This is used as dish aerials to bring microwaves signals from communication satellites.

Summary

â€¢ A virtual, magnified and erect image of an object is formed if the object is positioned at a distance less than the focal length of the mirror.

â€¢ At the focus, the image is formed at infinity.

â€¢ A magnified, real and inverted image is formed beyond the centre of curvature if the object is positioned between the focus and the centre of curvature.

â€¢ At the centre of curvature, a real inverted image, which is the same size as the object is formed.

â€¢ Beyond the centre of curvature, the image formed is real, inverted and diminished.

â€¢ As the object moves closer to the focus of the mirror, the image moves away from the mirror.

Mirror formula

The position of the image formed in a curved mirror depends on the position of the object and the **focal length** (f) of the mirror. The position of the object from the pole of the mirror is called **object distance** (u) and the position of the image from the pole of the mirror is called **image distance** (v). The object distance (u), the image distance (v) and focal length (f) of the mirror are related by the formula:

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

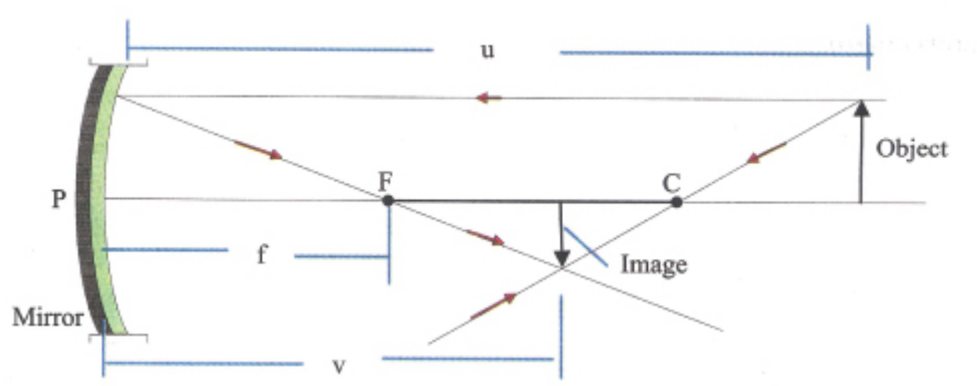


Figure 12.28: Object placed beyond C produces a real, inverted and diminished image between F and C

Magnification

The image formed by concave mirrors are magnified or diminished while convex mirrors always form diminished images.

Linear magnification is the ratio of image size (height) to the object size (height).

$$\text{Linear magnification} = \frac{\text{Image height}}{\text{Object height}}$$

$$m = \frac{h_i}{h_0}$$

When $m < 1$ or $h_i < h_0$, a diminished image is formed. An enlarged image is formed if $m > 1$ or $h_i > h_0$ and if $m = 1$ or $h_i = h_0$, the object is at the centre of curvature.

$$\text{Linear magnification} = \frac{\text{Image distance}}{\text{Object distance}}$$

$$m = \frac{v}{u}$$

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

Linear magnification can also be defined in terms of image distance *(v)* and object distance *(u)*.

Multiplying the equation above by v (image distance);

$$\frac{v}{f} = \frac{v}{u} + \frac{v}{v} \text{ but } \frac{v}{u} = m \text{ (magnification)}$$

$$\therefore \frac{v}{f} = m + 1$$

$$\therefore \frac{v}{f} = m + 1$$

Sign convention

To calculate the position, and to know the nature of image formed by curved mirrors a convention assigning a sign to the image distance and focal length of the mirror is adopted. Two of such sign conventions are:

(i) The new Cartesian convention

In this convention all distance measured to the left of the mirror from the pole are negative. Distances measured to the right of the mirror from the pole are positive.

(ii) Real is positive and virtual is negative sign convention

This sign convention is widely accepted and used. All calculations in this topic and lenses will be based on this sign convention. In this sign convention:

(i) All distances are measured from the pole of the mirror either to the left or right.

(ii) The distances of real objects and real images from the pole of the mirror are positive.

(iii) The distances of virtual images from the pole of the mirror are negative.

(iv) The focal length of concave mirror is positive while the focal length of convex mirror is negative.

Worked examples

1. A small pin is placed 10 cm in front a concave mirror of focal length 15 cm.
   (i) Calculate the image distance and magnification of the image.
   (ii) What is the nature of the image?

Solution

Focal length of concave mirror (f) = +15 cm, object distance (u) = 10 cm and v =?

(i) $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

$$\frac{1}{15} = \frac{1}{10} + \frac{1}{v}$$

$$\frac{1}{v} = \frac{1}{15} - \frac{1}{10} = \frac{2-3}{30} = -\frac{1}{30}$$

$\therefore$ v = - 30 cm

(ii) $m = \frac{v}{u} = -\frac{30}{10} = -3$

These values of m and v indicate that an **erect virtual image** three times the size of the object is formed 30 cm behind the mirror.

2. A concave mirror of focal length 15 cm forms an image of a pin 12 cm high at 20 cm in front of the mirror. Find the:
   (a) object distance;
   (b) magnification;
   (c) size of the image.

Solution

Focal length of concave mirror = +15 cm, image distance (v) = 20 cm and u =?

(a) $\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \Rightarrow \frac{1}{15} = \frac{1}{u} + \frac{1}{20}$

$$\frac{1}{u} = \frac{1}{15} - \frac{1}{20} = \frac{4-3}{60} = \frac{1}{60}$$

$\therefore$ u = 60 cm

(b) $m = \frac{v}{u} = \frac{20}{60} = \frac{1}{3}$

(c) $m = \frac{h_i}{h_0} \Rightarrow \frac{1}{3} = \frac{h_i}{12}$

$h_i = 4$ cm.

3. A *magnified erect image* four times the size of the object is formed by a concave mirror of focal length 12 cm. What is the distance of the image from the pole of the mirror?

Solution

Magnification (m) = - *4 since the image is virtual*.

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

$$\frac{v}{12} = -4 + 1 = -3$$

$\therefore$ v = -36 cm

4. A man 1.8 m stands 4.50 m in front of a convex mirror of focal length 15 cm. Calculate the image distance and its size.

Solution

Focal length (f) = -15 cm, object distance (u) = 4.50 m = 450 cm.

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \quad \Rightarrow -\frac{1}{15} = \frac{1}{450} + \frac{1}{v}$$

$$\frac{1}{v} = -\frac{1}{15} - \frac{1}{450} = \frac{-30-1}{450} = -\frac{31}{450}$$

$$v = -\frac{450}{31} = -14.5\ cm$$

$$m = \frac{v}{u} = \frac{-14.5}{450} = -0.0322$$

$$-0.0322 = \frac{h_i}{180}$$

h_i = 5.796 cm.

Methods of measuring focal length of a concave mirror

(a) Quick and approximate method

A concave mirror is used to collect parallel light rays from a distant (far) object. The screen or a sheet of white paper is moved forward and backward until a sharp image is formed on it. Where the sharp image is formed is the focus of the mirror. The distance between the mirror and the screen is measured and recorded as the approximate focal length of the mirror.

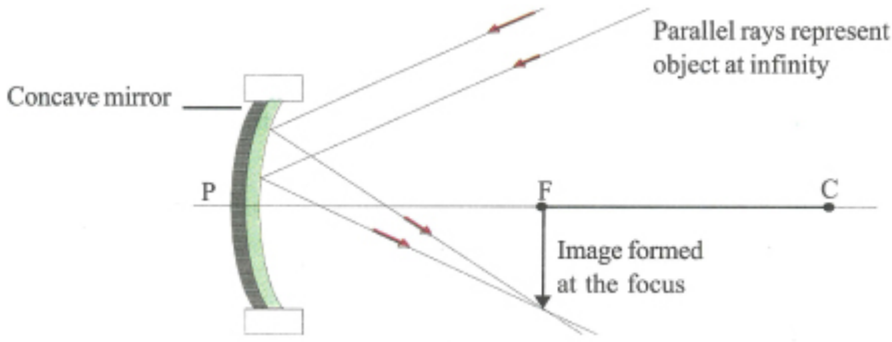


Figure 12.29: Quick and approximate method of measuring focal length of a concave mirror

(b) Finding focal length using an illuminated object placed at the centre of curvature(C)

When an object is placed at the centre of curvature, the image is also formed at the centre of curvature. A ray box or an illuminated object and mirror are arranged as shown in Figure 12.29. The mirror is adjusted until a sharp image of the cross wire representing the object is formed near it. The distance between the screen (ray box) and the mirror is measured and recorded. This is the radius of curvature of the mirror (r).

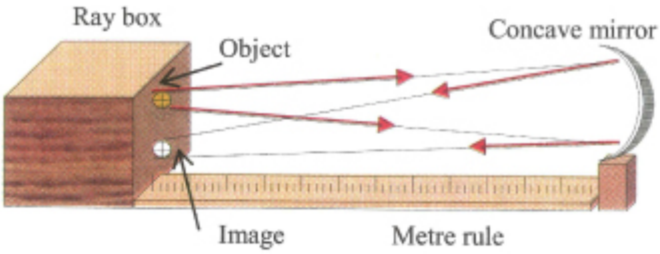
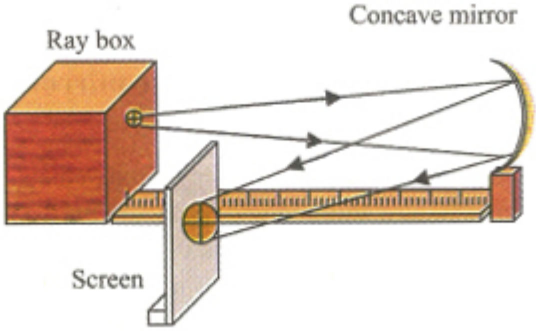


Figure 12.30: Finding the focal length

The focal length of the mirror is half the radius of curvature.

$$f = \frac{r}{2} \quad or \quad r = 2f$$

(c) Determination of focal length by measuring image distance and object distance



An illuminated object (ray box) is placed at a distance *(u)* from a concave mirror mounted on a mirror stand. A screen *(S)* is moved forward and backward until a sharp image of the crosswire *(O)* is formed on the screen. The distance of the screen from the pole of the mirror is measured and recorded as the image distance *(v).*

The experiment is repeated for five more times using different object distances and the corresponding image distances are measured and recorded as shown in the table below,

(a)

u cm^{-1}	v cm^{-1}	$\frac{1}{u}$ (cm^{-1})$^{-1}$	$\frac{1}{v}$ (cm^{-1})$^{-1}$

(The graph of $\frac{1}{u}$ plotted against $\frac{1}{v}$ is a straight line with double intercepts as illustrated in Figure 11.30.

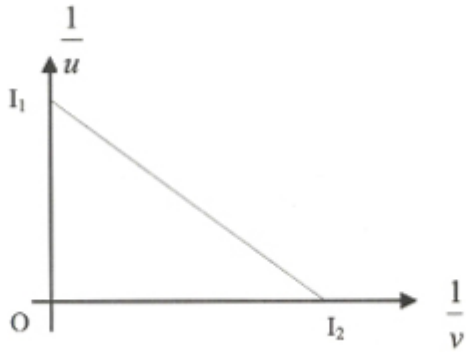


Figure 12.31: Graph of $\frac{1}{u}$ *plotted against* $\frac{1}{v}$

The intercept on the vertical axis = I_1 and the intercept on the horizontal axis = I_2. The average of the two intercepts is given by:

$$I = \frac{I_1 + I_2}{2}$$

The focal length of the mirror is the reciprocal of the average intercept I,

$$f = \frac{1}{I} = \frac{2}{I_1 + I_2}$$

(b) Another way of determining the focal length of the mirror is shown in the table below.

u cm^{-1}	v cm^{-1}	uv cm^{-2}	(u+v) cm^{-1}

When the graph of **uv** is plotted against **u+v**, a straight line passing through the origin is obtained as shown in Figure 12.31.

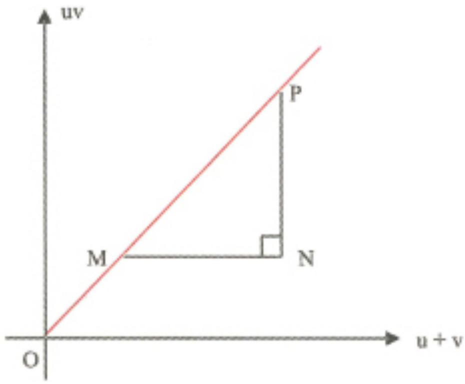


Figure 12.32: Graph of uv plotted against u + v

The slope (s) of the graph represents the focal length of the mirror.

$$\text{Slope (s)} = \text{focal length}(f) = \frac{uv}{u+v}$$

(c) The third method of finding the focal length of the mirror is shown in the table below.

u cm^{-1}	v cm^{-1}	$m = \frac{v}{u}$

The graph of magnification (m) plotted against the image distance (v) is a straight line intercepting the m axis at – 1 as shown in Figure 11.32. The intercept on the v – axis is the focal length of the mirror. The focal length of the mirror is also the reciprocal of the slope of the graph.
The magnification equation is given by:

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

$$m = \frac{v}{f} - 1$$

$$\text{Slope (s)} = \frac{1}{f} \therefore f = \frac{1}{slope(s)}$$

The intercept on the **v** – axis is I. The value of **m** is zero at **I**, therefore

$$m = \frac{v}{f} - 1 = 0$$

$$\therefore \frac{v}{f} = 1 \Rightarrow f = v$$

(v = image distance when m = 0)

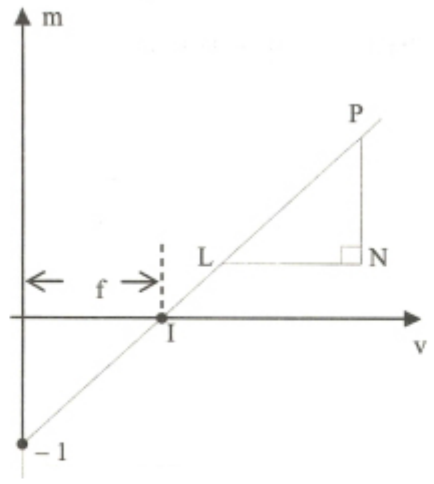


Figure 12.33: m plotted against v

Summary

â€¢ **A curved mirror** has its reflecting surface curved.

- â€¢ A **concave mirror** has its reflecting surface curved inward and is called converging mirror.
- â€¢ A **convex mirror** has its reflecting surface curved outward. It is called diverging mirror.

â€¢ The **principal focus** is the point F on the principal axis where incident parallel rays of light close to the principal axis converge or appear to diverge after reflection from the mirror.

â€¢ The **focal length** (f) is the distance between the focus (F) and the pole (P) of a spherical mirror.

â€¢ A **real image** is formed by real intersection of light rays; it can be formed on a screen. A **virtual image** is formed by apparent intersection of light rays; it cannot be formed on a screen.

â€¢ **Spherical aberration** is the inability of spherical mirrors to converge parallel beam of light to a single focus.

â€¢ **The mirror formula** is given by: $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$
u = object distance, v = image distance and f = focal length of the mirror.

â€¢ **Linear magnification** is the ratio of image size (height) to the object size (height).

$$\text{Linear magnification} = \frac{\text{Image height}}{\text{Object height}}$$

$$\text{Linear magnification} = \frac{\text{Image distance}}{\text{Object distance}}$$

$$\therefore \frac{v}{f} = m+1$$

Practice questions 12c

1. (a) Define the following terms as applied to curved mirrors: *radius of curvature, focal length and principal focus.*
   (b) Draw ray diagrams to illustrate the action of *concave* and *convex mirrors* on parallel beam of light.
   (c) A small pin is positioned 12 cm in front of (i) a concave mirror (ii) a convex mirror each of focal length 15 cm. Draw a ray diagram to show how the image is formed.
   (d) State **two** characteristics common to the two images.
2. (a) Define *real* and *virtual* images.
   (b) By means of ray constructions, show how a concave mirror

can produce each type of images.

(c) Using your sketches, (b) in differentiate between the two types of images.

(d) An object of height 2 cm is placed in front of a concave mirror and a real image of height 8 cm is formed 75 cm from the mirror. Calculate:

(i) the focal length of the mirror;

(ii) the distance of the object from the mirror.

3. (a) Explain what is meant by the statement, *â€œthe focal length of a concave mirror is 20 cm.â€*

(b) Describe an experiment to determine the focal length of concave mirror. Sketch the graph expected from the experiment and explain clearly how the focal length may be obtained from the graph.

(c) State **two** precautions you must observe to obtain accurate result if you were to perform the experiment in the laboratory.

4. (a) Define the **principal focus** of a convex mirror.

(b) Draw ray diagrams to illustrate how a convex mirror and a plane mirror form an image of an object placed some distance from them.

(c) Explain why a convex mirror is preferred to a plane mirror as a driving mirror.

(d) A bus driver views a car 50 m away in a convex mirror of focal length 25 cm. Calculate distance of the image of the car from the mirror.

5. (a) Differentiate between *real* and *virtual* images.

(b) Draw a ray diagram to show how a concave mirror can form a magnified real image of an object placed perpendicularly to its principal axis.

(c) An arrow of height 5cm is placed 20 cm in front of a concave mirror and an image is formed 60 cm from the pole of the mirror. Find the

(i) focal length of the mirror;

(ii) magnification of the image;

(ii) height of the image formed.

Past questions

1. Which of the following observations is **not** a consequence of the principle of the rectilinear propagation of light?

A. diffraction patterns.

B. shadows.

C. eclipses.

D. images in a pinhole camera.
E. images in mirror.

2. Virtual image is one
A. formed by the intersection of actual rays.
B. which is not visible to the eye.
C. through which rays of light do not pass.
D. which can be formed on a screen.

WASSCE

3. An opaque object can be seen because of the amount of light it
A. emits from its surface.
B. disperses to the observer.
C. reflects to the observer.
D. transmits through it.

WASSCE

4. When the moon comes between the sun and the earth such that they are collinear, there is
A. eclipse of the moon.
B. eclipse of the earth.
C. eclipse of the sun.
D. total darkness on the earthâ€™s surface.

WASSCE

5. An object 3.00 m high is placed at a distance of 7.50 m from a pinhole camera. If the image height is 6.00cm, what is the distance of the film from the pinhole?
A. 3.75 cm
B. 7.50 cm
C. 15.00 cm
D. 30.00 cm
E. 150.00 cm.

NECO

6. Which of the following statements about a pinhole camera is correct? It
A. operates on the principle of rectilinear propagation of light.
B. can be used to form images of moving objects.
C. always produces real and erect images of objects.
D. produces a magnification which depends on the size of the pinhole.

WASSCE

7. A body that produces its own light is said to be
A. luminous.
B. non-incandescent.
C. opaque.

D. translucent.

E. transparent.

NECO

8. A boy walks away from a plane mirror at a constant speed of 2.5 ms^{-1} in a direction normal to the surface of the mirror. At what speed does his image move away from him?

A. 5.00 ms^{-1}.

B. 2.50.

C. 1.25 ms^{-1}.

D. 0.00 ms^{-1}.

WASSCE

9. An object 8 cm in front of a plane mirror moves at a speed of 6 cms^{-1} away from the mirror. What will be the distance separating the object and the image after 2 s?

A. 8 cm

B. 12 cm

C. 20 cm

D. 28 cm

E. 40 cm.

NECO

10. A ray of light strikes a plane mirror normally. If the mirror is rotated through an angle of 20Â°, what is the angle through which the reflected ray rotates?

A. 10Â°

B. 20Â°

C. 40Â°

D. 60Â°.

WASSCE

11. An incident ray is reflected normally by a plane mirror onto a screen where it forms a bright spot. The mirror and the screen are parallel and 1 m apart. If the mirror is rotated through 5Â°, calculate the displacement of the spot.

A. 8.7 cm.

B. 10.0 cm.

C. 15.4 cm.

D. 17.6 cm.

WASSCE

12. A plane mirror gives a spot of light on a screen which is 3 m from the mirror. The screen is perpendicular to the initial direction of the ray of light. When the mirror is rotated, the spot of light moves a distance of 4 m across the screen. Calculate the angle of rotation of the mirror.

A. 53.1Â°.

B. 36.9Â°.
C. 26.2Â°.
D. 18.5Â°.

WASSCE

13. A man 1.74 m tall stands 3 m in front of a mirror 1 m long. What is the size of his image?
    A. 5.22 m.
    B. 1.74 m.
    C. 0.74 m.
    D. 0.58 m.

WASSCE

14. An object is placed on the principal axis and at the centre of curvature of a concave mirror, the image of the object formed by the mirror is
    A. real and magnified.
    B. real and inverted.
    C. erect and magnified.
    D. erect and virtual.

WASSCE

15. An object is placed 30 cm in front of a concave mirror of focal length 20 cm. Calculate the distance between the object and the image.
    A. 90 cm
    B. 40 cm
    C. 30 cm
    D. 20 cm
    E. 10 cm

NECO

16. An object is placed at the centre of curvature of a converging mirror. Its image is
    A. at the centre of curvature. B. at the principal focus.
    C. inverted and virtual.
    D. magnified and real.
    E. virtual and the same size as the object.

NECO

17. Convex spherical mirrors are preferred to plane mirrors as driving mirrors because
    A. the image produced is upright and clearly visible.
    B. it provides a wider field of view.
    C. the image produced is erect and magnified.
    D. the image produced is not laterally inverted.

WASSCE

18. An object is placed 15 cm in front of a concave mirror of focal length 20 cm. the image formed is
A. real, inverted and diminished.
B. real, inverted and magnified.
C. virtual, erect and diminished.
D. virtual, erect and magnified.
E. virtual, inverted and magnified.

NECO

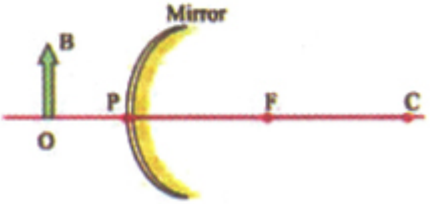
19. A concave mirror used as a shaving mirror should
A. have a virtual focal length.
B. be narrow.
C. have small curvature.
D. have a long focal length.

WASSCE

20. A concave mirror can be used to produce a parallel beam of light if a lighted bulb is placed
A. between its focus and the pole.
B. at its focus.
C. at its centre of curvature.
D. between its focus and centre of curvature.

WASSCE

21. In the diagram above, P, F and C represent respectively the pole, focus and centre of curvature of a convex mirror. Where will the image of the object OB be formed by the mirror?



A. Between F and C.
B. Between P and F.
C. Between O and P.
D. At F.

WASSCE

22. The image of an object is located 6 cm behind a convex mirror. If its magnification is 0.6, calculate the focal length of the mirror.
A. 3.75 cm
B. 6.60 cm
C. 10.00 cm
D. 15.00 cm.

WASSCE

23. The simple periscope is an optical instrument which

I. comprises two parallel mirrors, suitably arranged.

II. magnifies images of objects.

III. is used for viewing objects behind obstacles.

Which of the statements above is/are correct?

A. I, II and III.

B. I and III only.

C. I and II only.

D. II only.

E. I only.

WAEC

24. An object is placed in front of a concave mirror of radius of curvature 12 cm. If the height of the real image formed is three times that of the object, calculate the distance of the object from the mirror.

A. 24 cm

B. 16 cm

C. 12 cm

D. 8 cm

E. 4 cm.

WAEC

25. (a) (i) Illustrate, using a ray diagram, how an image is formed by a convex mirror.

(ii) State **one** advantage and **one** disadvantage of using a convex mirror as a driving mirror.

WASSCE

26. (a) Define the following terms as applied to a convex mirror:

(i) principal focus (ii) pole (iii) radius of curvature,

(b) State **one** advantage and **one** disadvantage of using a convex mirror as a driving mirror.

WASSCE

27. (a) (i) Distinguish between a real and a virtual image.

(ii) Draw ray diagrams to show how a concave mirror can be used to produce each type of image.

(iii) State **ONE** practical application of a concave mirror where these two types of images are produced.

NECO

28. (a) What is a virtual image?

(b) (i) Draw a ray diagram showing how a virtual image of an object is formed by a concave mirror, indicating the position of the eye when viewing such an image.

(ii) State two applications of concave mirror.

WASSCE

29. (a) Explain with the aid of a diagram, how total, partial and annular

eclipses of the sun are formed.

(b) What is the effect of increasing the size of the hole of a pinhole camera on:

(i) the size of the image;

(ii) the brightness of the image;

(iii) the sharpness of the image?

(c) The screen of a pinhole camera is a square of side 160 mm and it is 150 mm behind the pinhole. The camera is placed 11m from a flag staff and positioned so that the image of the flag staff is formed centrally on the screen. The image occupies three-quarters of the screen. What is the length of the flag staff?

WAEC

30. (i) Explain with the aid of a ray diagram, how the image of an object is formed by a plane mirror.

(ii) State **four** characteristics of the image.

NECO