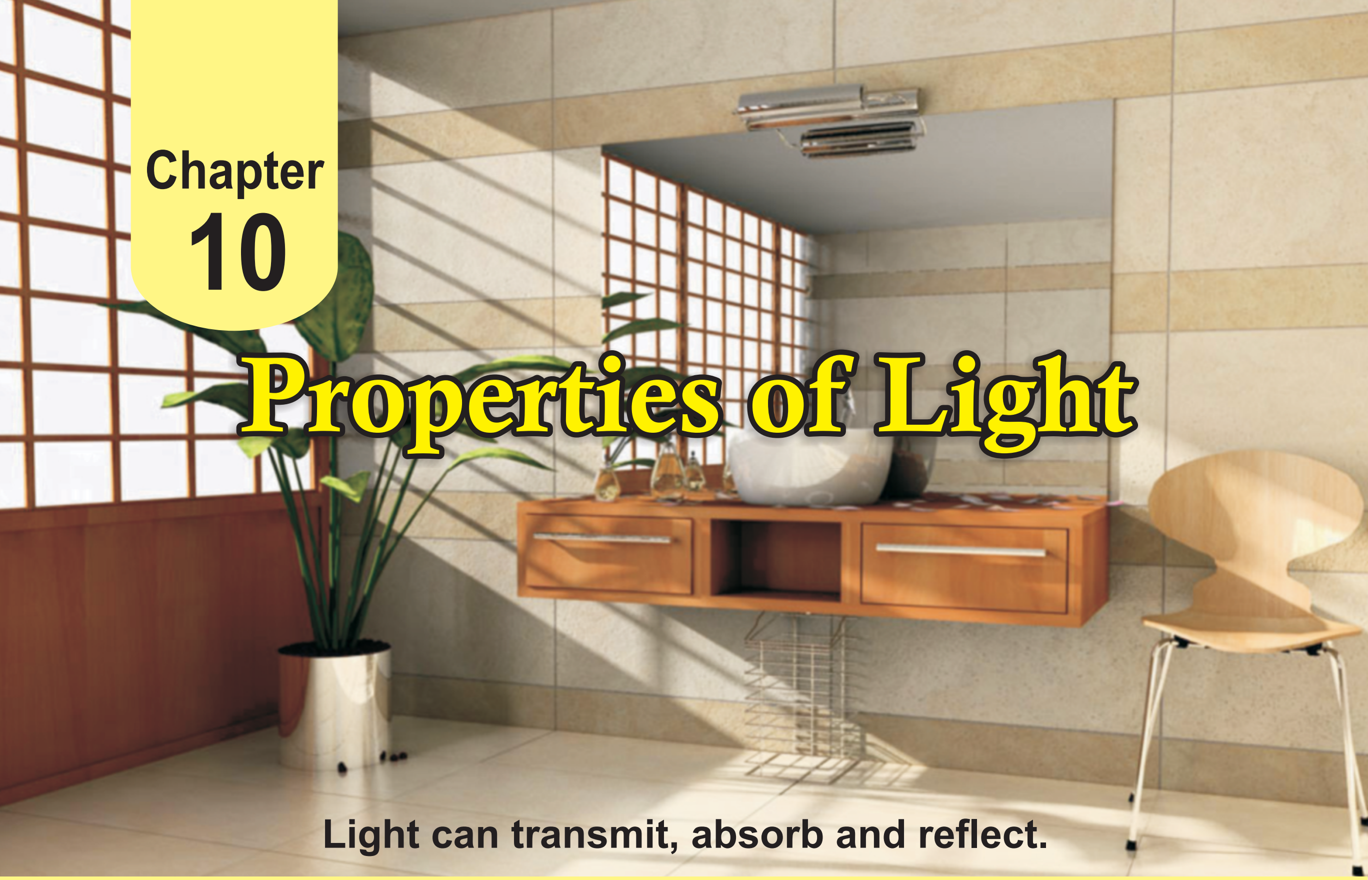
Chapter 10

Properties of Light



Light can transmit, absorb and reflect.

Student Learning Outcomes

After completing this chapter, you will be able to:

- Differentiate between transmission, absorption and reflection of light.
- Demonstrate the laws of reflection.
- Demonstrate the difference between smooth, shiny, and rough surfaces.
- Compare the regular and diffuse reflection.
- Identify everyday applications, which involve regular reflection and diffuse reflection.
- Draw ray diagrams for light reflected from a plane mirror at different angles of incidence.
- Describe image formation by a plane mirror.
- Compare characteristics of the images formed by a plane mirror and a pinhole camera.
- Explain the use of reflecting surfaces in different devices.
- Design an experiment to make an optical instrument using mirrors.
- Explain the principle of reflection in a kaleidoscope.
- Describe the relationship of angles between two mirrors and the number of images you can see in a kaleidoscope.
- Explain types of mirror and their uses in our daily life.
- Investigate the image formation by convex and concave mirrors.

Light is a form of energy which is given out by **luminous objects**. The Sun, bulb, candle, etc. are luminous objects. Other objects which do not give out light are called **non-luminous**.

Light can pass through **transparent** materials. Glass, water, clear plastic and air are transparent materials. Light can not pass through **translucent** materials. A tracing paper, frosted glass and waxed paper are translucent materials.

Transmission, Absorption and Reflection of Light

Light behaves differently when it falls on different objects. When light falls on the surface of a non-luminous object, it can behave in three ways (Fig.10.1):

1. When light falls on transparent objects, it is **transmitted** to the other side. That is why, we can see across transparent objects.
2. When light falls on rough opaque objects, most part of this light is **absorbed** and changed into heat energy. A black surface absorbs most of the light.
3. When light falls on a smooth shiny surface, it bounces off in one particular direction. This bouncing off of light is called **reflection** of light.

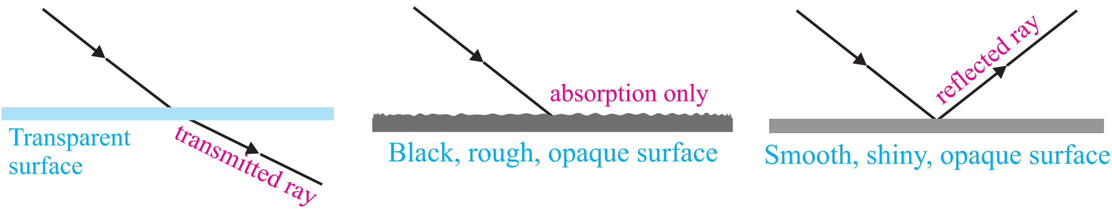


Fig.10.1: Behaviour of light on different surfaces

A part of light passes through a surface (windscreen of a car), some part is reflected and rest of light is absorbed in the surface. It means transmission, reflection and absorption occur at the same time.

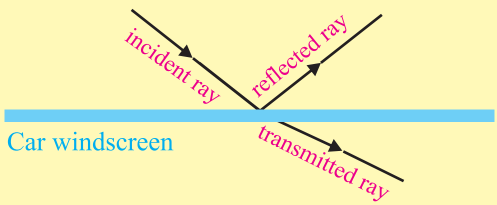


Fig.10.2: Identify transmission, absorption and reflection of light in the picture.

How Reflection Occurs

Reflection occurs when a light ray strikes a shiny surface (mirror) and bounces off (Fig. 10.3). The ray that strikes the shiny surface is called **incident ray**. The ray that bounces off is called **reflected ray**. The point at which incident ray strikes is called **point of incidence**. The line perpendicular on the point of incidence is called **normal.** Incident ray forms **angle of incidence** with the normal. It is denoted by 'i'. The angle that reflected ray forms with the normal is called **angle of reflection**. It is denoted by 'r'.

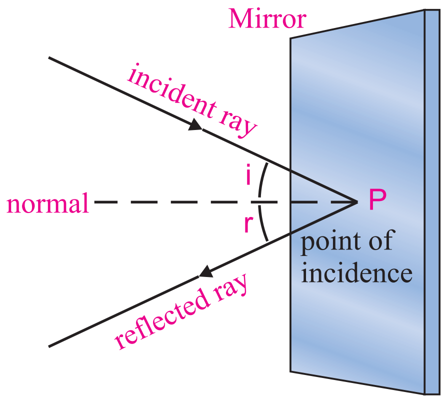


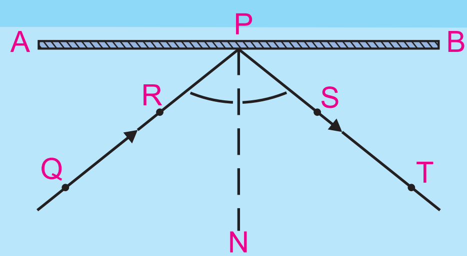
Fig.10.3: Reflection of light

Laws of Reflection

It has been found experimentally that reflection of light obeys certain laws as:

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

These are called the **laws of reflection**.



1. Fix a white paper on a drawing board using the drawing pins.
2. Place a mirror strip AB (fixed in a stand) on the paper.
3. Fix two common pins Q and R before the mirror in a line.
4. See the images of the pins in the mirror and fix two more common pins S and T in such a way that images of pins Q and R and pins S and T lie on the same straight line.
5. Join the points Q, R, S, and T with the AB (strip) on point P. Draw a perpendicular line on P. It is normal.

Observe the **angle of incidence** QPN that incident ray QR forms with the normal and the **angle of reflection** NPT that reflected ray ST forms with the normal. We will observe that:

_ The angle of incidence is equal to the angle of reflection.
_ The incident ray, the reflected ray and the normal on the point of incidence all lie on the same plane.

Types of Reflecting Surfaces

Some surfaces reflect more light than the others. A reflecting surface may be smooth or rough.

Smooth Surface

A plane surface is called a smooth surface. When parallel light rays hit a smooth shiny surface, all the rays are reflected at the same angle. It is called **regular reflection** of light (Fig.10.4).

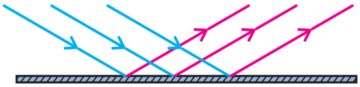


Fig. 10.4: Regular reflection of light from a smooth shiny surface

Rough Surface

An uneven surface is called a rough surface. When parallel light rays hit a rough surface, all the rays are reflected at different angles. It is called **diffused reflection** of light (Fig.10.5).

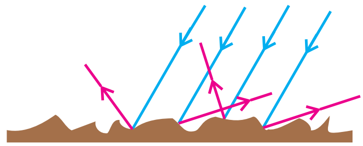


Fig. 10.5: Diffused reflection of light from a rough surface

Applications of Regular and Diffused Reflection in Everyday Life

Regular and diffused reflections of light have many applications in our everyday life:

- Due to the regular reflection of light we look our image in the plane mirror.
- We can turn the sunlight towards dark places by the regular reflection of light with the help of a shiny surface.
- Sunlight does not reach directly in our rooms, but we can see things in our rooms. This is because of diffused reflection of light. The light scatters in different directions when it shines on dust particles.
- We can see things just before the sunrise and just after the sunset due to the diffused reflection of light.

Images Formed By a Plane Mirror

A shiny surface is called a **mirror**. A plane mirror has a smooth and flat surface. We see images in a **plane mirror** when light reflected by the mirror enters our eyes. We use a plane mirror to see our faces. We observe that;

Fig.10.6: Reflection in a plane mirror

1. The image formed by a plane mirror is **upright** (straight upward).
2. The image is **equal in size** to the object.

3. The image is **laterally inverted**. It means your right becomes left in the image.

4. The image in the plane mirror is **virtual**. It means the image disappears on removing the object.

5. The image is as far behind the mirror as the object is in front of it.

Ray Diagram For Light Reflected From a Plane Mirror

Take a sheet of white paper and fix it on a drawing board. Draw a line MR on the sheet and put a plane mirror vertically along the line. Now fix a pin O, serving as the object before the mirror (Fig.10.7).

View the image I of pin O from left side of the object pin and fix two pins P and Q in such a way that both of these pins and image I lie in the straight line. Now view the image from the right of the pin O and fix two pins S and T in the same way.

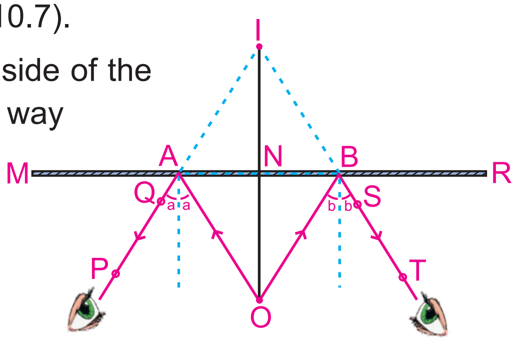
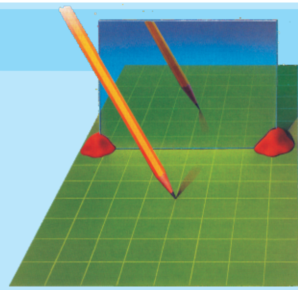


Fig.10.7: Ray diagram for plane mirror

Remove all the pins and put cross (x) to mark each pin hole. Draw lines PQ and ST beyond the mirror line MR till both lines intersect each other. Draw a vertical line from O to I which meets MR at N. Also join O to the points A and B where lines PQ and ST meet the line MR. Measure ON and IN. ON is the distance of the object from the mirror and IN is the distance of the image from the mirror. Both will be equal.

Draw perpendiculars on A and B to prove the laws of reflection. At each point of incidence, the angle of incidence should be equal to the angle of reflection.



To prove that a plane mirror forms the image as far behind as the object is in front of it.

1. Take a piece of graph paper and spread it on a table. Mark over one of the horizontal lines on this piece.
2. Put a mirror along the marked line in vertical position with the help of modeling clay.
3. Put your pencil in front of the mirror and observe its image.
4. Now place the pencil six squares far in front of the mirror. The image in the mirror will also be six squares behind the mirror.
5. Repeat the image formation by placing the pencil 8 squares far in front of the mirror. How many squares behind the mirror is the image now?

The word 'Ambulance' is often written laterally inverted on the front of ambulances. Why? In fact, such writing can be easily read by drivers ahead from their side mirrors.

A Pin-hole Camera

We know that light travels in straight lines. A device which makes use of this fact is called a **pin-hole camera**. A Muslim scientist Al-Haithem invented the pin-hole camera.

A pin-hole camera simply consists of a cardboard or a metal box with a very small pin-hole in the middle of its one of the faces. All inside the camera is made black so that light can not enter the camera. A white screen is placed along the opposite face of the pin-hole (Fig.10.8).

Image Formation by the Pin-Hole Camera

When a brightly lit object is placed in front of the hole of a pin-hole camera, an inverted (upside down) image of small or large size and of same colour as that of the object is obtained on the white screen of the camera. This image is real as it can be made on a screen.

We can obtain good pictures with our pin-hole camera by pasting some photographic film instead of a white screen.

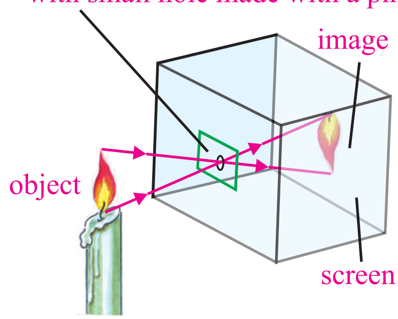


Fig.10.8: A pin hole camera

Comparison of Images Formed by a Plane Mirror and a Pin-hole Camera

- A plane mirror forms a virtual image while a pin-hole camera forms a real image.
- A plane mirror forms the image of equal size as of the object. A pin-hole camera mostly forms enlarged or diminished images.
- The image formed by a plane mirror is upright. A pin-hole camera forms an inverted image.

Do you know?

An image which we can obtain on a screen is called a **real image**.
An image which we cannot obtain on a screen is called a **virtual image**.

Uses of Reflecting Surfaces

Reflecting surfaces help to change the direction of light in many optical instruments like periscope, telescope and microscope.

Periscope

A **periscope** helps us to see on the other side of the wall. We can make a periscope.

A simple periscope consists of a long tube which bends at right angle on both ends. A plane mirror is fitted on either end in such a way that the mirror makes an angle of 45° with the walls of the tube (Fig.10.9).

The top mirror reflects the light to the bottom mirror which then reflects it to our eyes.

- Periscopes are used in submarines. People in a submarine can watch the objects above the water surface.
- Battle tanks are also fitted with periscopes. The crew inside the tank can see every thing outside of the tank.

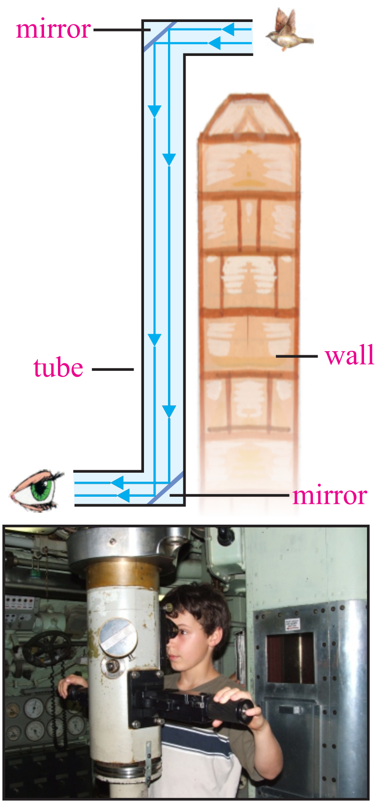


Fig.10.9: A periscope

Reflecting Telescope

A reflecting telescope produces images of distant objects like the moon, stars and planets.

A plane mirror is used to reflect light into the **reflecting telescope** (Fig.10.10).

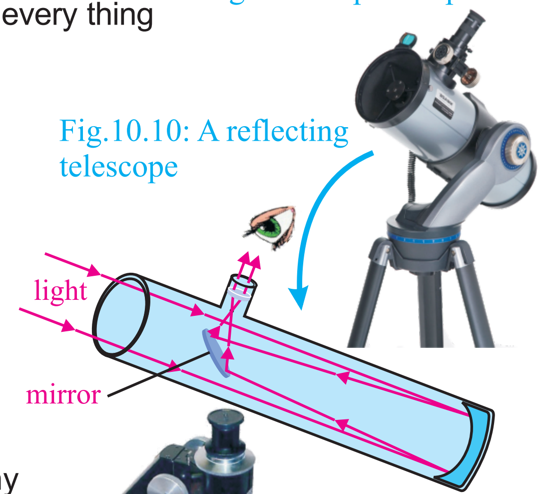


Fig.10.10: A reflecting telescope

Microscope

A **microscope** is used to see tiny objects like bacteria. A lens system works in it. However, a mirror is also used to reflect light into the microscope, otherwise you will be unable to view the image in it (Fig.10.11).

Fig.10.11: A microscope

Multiple Reflections

A **kaleidoscope** is an optical instrument in which we can see changing patterns of a simple design.

A kaleidoscope is a hollow tube containing two or more rectangular plane mirrors (Fig.10.12). The mirrors are fixed at an angle of 60° or 45° with each other. At the far ends of the kaleidoscope are two more plates, one made of clear glass and the other of ground glass. The clear glass is closer to the eye hole. Small pieces of coloured objects are placed between the plates and are reflected in the mirrors.

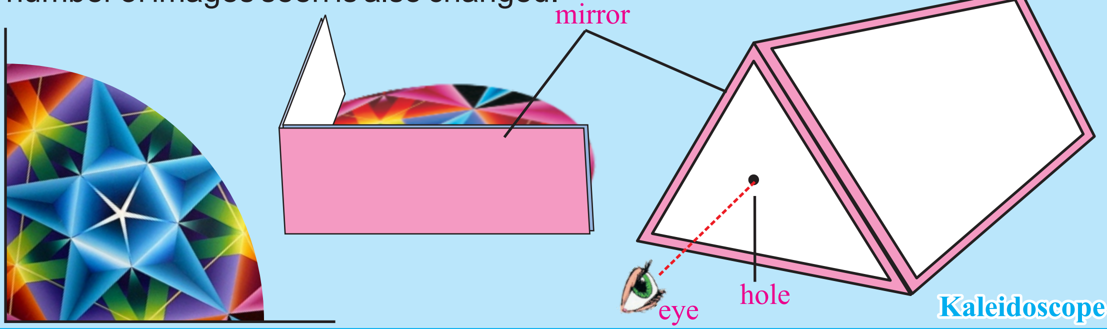
Fig.10.12: A kaleidoscope

The plate of ground glass throws the reflections in different directions. It makes a beautiful design. When the viewer turns the kaleidoscope, the coloured pieces shift position and the reflected patterns change. The constantly changing patterns are formed by the multiple reflections of the loose coloured pieces through mirrors.

Experiments have proved that the angles between the two mirrors of a kaleidoscope affect the number of images seen.

Draw two mutually perpendicular lines on a sheet of white paper. Draw some design with colour pencils between these lines. Place two mirror strips vertically on these lines with the help of modeling clay. Observe the images of the design in one of the mirrors. The number of images seen is 3. Now change the angle between the two mirrors, for example 60°. The number of images now seen is 5.

It proves that when angle between mirrors of a kaleidoscope changes, the number of images seen is also changed.



Types of Mirrors

Fig.10.13: Image in the spoon bowl

All the reflecting surfaces are not flat like the plane mirror. Some are curved in shape. Mirrors are of two types, i.e. **plane mirror and curved mirror.**

The plane mirror has been discussed in the early part of this chapter. A curved mirror is a part of a curve.

Curved mirrors are of two types, i.e. concave mirror and convex mirror.

Concave Mirror

A curved mirror whose inner curved surface is reflecting is called a concave mirror. It is like the inside of the bowl of a spoon.

Convex Mirror

A curved mirror whose outer curved surface is reflecting is called a convex mirror. It is like the outside of the bowl of a spoon.

Uses of Mirrors

Plane, concave and convex mirrors form different images.

Fig.10.14: Image in a plane mirror

A **plane mirror** forms an upright virtual image which is same in size as that of the object.

It is used as a looking glass. It is also used in periscopes, telescopes and microscopes to reflect light.

A **convex mirror** forms an upright virtual image which is smaller in size.

Convex mirrors are used as; security mirrors in shops, car wing mirrors and blind corner mirrors on roads especially on mountains.

Fig.10.15: Image in a curved mirror

A **concave mirror** forms a real upside down image on a screen. It forms an upright virtual and very big image if the object is very close to the mirror.

Concave mirrors are used as; a dentist's mirror, a cosmetic mirror , a headlight mirror, a torch and search light mirror.

Point to think!
Have you ever visited Sozo Water Park, Lahore? You can observe your amusing images in strange mirrors here. Can you explain these mirrors?

Terms Related to Curved Mirrors

A curved mirror is a part of a curve or sphere. The center of the curve is called as the centre of curvature and is denoted by 'C'. The center of the mirror is called the pole and is denoted by 'P'. The line joining the 'C' to 'P' is called the principal axis.

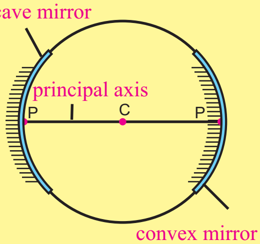


Image Formation in Concave and Convex Mirrors

A concave mirror can form real as well as virtual image, but a convex mirror only forms a virtual image.

Images with a Concave Mirror

When light rays strike a concave mirror parallel to its principal axis, after reflection they pass through a common point in front of the mirror. This common point is called the **principal focus**. It is denoted by 'F' (Fig.10.16). A concave mirror has an original principal focus 'F'. That is why it can form real images on a screen.

The characteristics of an image depend upon the distance between the object and the mirror.

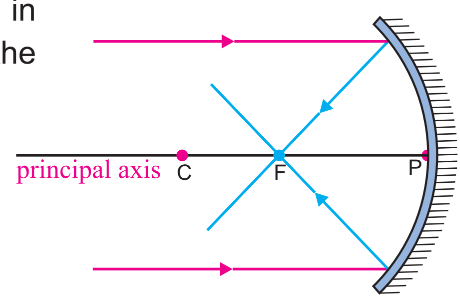
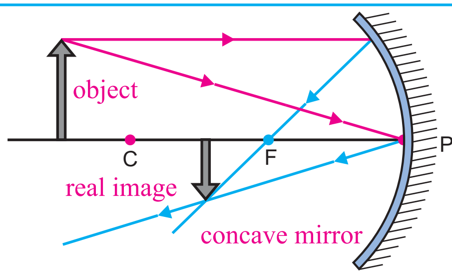


Fig.10.16: Reflection of light from a concave mirror

1. If the object is beyond the principal focus (F), the image formed is real and upside down.



2. If the object is very near to the concave mirror, the image forms behind the mirror. It is virtual, upright and bigger in size.

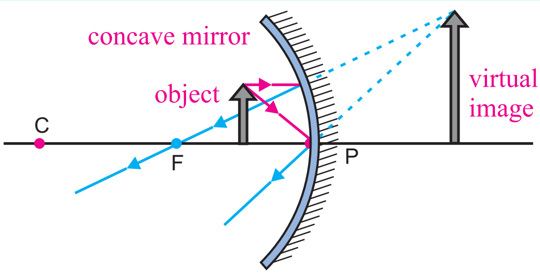


Image With a Convex Mirror

Convex mirror always spreads light rays. When light rays parallel to the principal axis strike a convex mirror, after reflection they spread in such a way that they appear to come from a point behind the mirror. This common point is called the **principal focus** 'F' of the convex mirror (Fig.10.17).

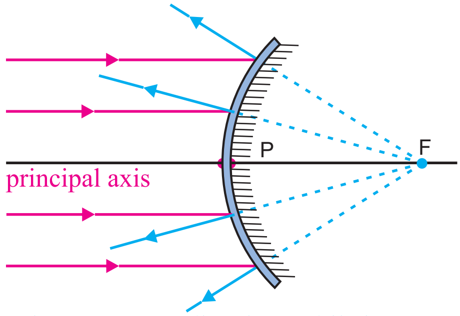
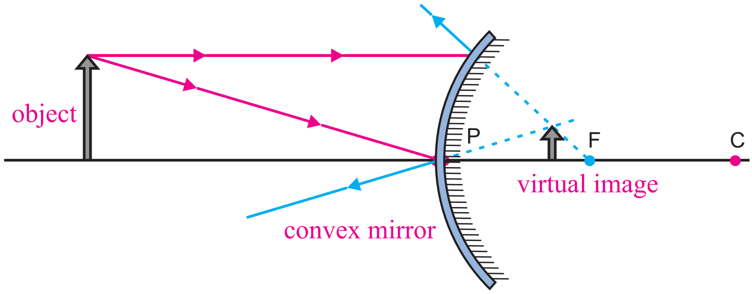


Fig.10.17: Reflection of light from a convex mirror

A convex mirror always produces a **virtual**, **upright** and **smaller** image of the object at any distance in front of it. The image is located behind the mirror.



1. Light behaves differently when it falls on different objects.
2. Whenever light reflects, it obeys 'Laws of Reflection'.
3. Transparent objects transmit, rough opaque objects absorb and shiny surfaces reflect the light.
4. Smooth surfaces reflect all rays of light in a regular pattern and rough surfaces reflect light rays in different directions.
5. A plane mirror has a smooth and flat surface to reflect the light regularly.
6. A periscope, a telescope, a microscope and a kaleidoscope are devices which use reflection for their working.
7. We can view different designs in a kaleidoscope.
8. A curved mirror is a part of a curve. Curved mirrors are of two types: concave mirror, convex mirror.
9. A convex mirror forms a virtual image while a concave mirror mostly forms real images.

1. **Write proper term/word against each statement.**

i. Helps see things before the sunrise and after sunset ________

ii. Used to see very small things ________

iii. A mirror that forms mostly real images ________

iv. The angle of incidence is equal to the angle of reflection ________

2. **Circle the letter of the best answer.**

i. When light rays bounce off from a shiny surface:
   (a) reflection occurs (b) absorption occurs
   (c) bending of light occurs (d) nothing happens

ii. Light reflects regularly from a surface which is:
   (a) opaque and rough (b) rough
   (c) black (d) smooth and shiny

iii. We can see things around us even on cloudy days due to:
   (a) regular reflection of light (b) irregular absorption of light
   (c) regular transmission of light (d) diffused reflection of light

iv. One statement is not correct for the plane mirror:
   (a) the image formed is upright (b) the image is equal in size to the object
   (c) the image is real (d) the image is laterally inverted

v. Your friend wants to see over a wall. What would you suggest him to use?
   (a) telescope (b) kaleidoscope
   (c) periscope (d) microscope

vi. Which device uses the fact that light travels in straight lines?
   (a) telescope (b) kaleidoscope
   (c) pin-hole camera (d) microscope

3. **Answer the following questions in detail.**

i. Define the transmission, absorption and reflection of light.

ii. Prove the laws of reflection through an activity.

iii. Draw a ray diagram for light reflected from a plane mirror.

iv. How does multiple reflection occur in a kaleidoscope?

v. Describe in detail the image formation in a concave mirror.

4. **Extend your thinking.**

i. Is a shiny metal plate also said to be a mirror?

ii. How does the surface of a still pond or puddle behave when light falls on it?

iii. How can a scientist see the details of the Moon?

iv. White surfaces reflect most of the light that strikes them. Why are people used to wear dark coloured dresses in winter?

v. Can you obtain a virtual and upright image from a concave mirror? Draw a ray diagram.

vi. Can a plane mirror ever produce a real image? Explain.

vii. If you look directly at a highway it looks black. If, however, you look at it at an angle, it looks shiny. Why is it look so?

1. Look at the back of a shiny spoon. What kind of image do you see? How does changing the distance between your eyes and the spoon affect what you see? What kind of mirror does the back of the spoon represent? Now look at the front of the spoon. What kind of mirror is the front of the spoon? What kind of image do you see?

2. Take two 1-litre milk or juice cartons, two small square mirrors, scissor and tape. Cut around the top of each carton and remove the roof. Cut a window in the front at the bottom of each carton. Fix a mirror in the window of each carton at 45° angle. Tape the open parts of both the cartons in such a way that one window faces you and other on the opposite side. Use your periscope to see over an obstacle or wall.

3. Take three long mirrors, tape them along the length with their coated sides outside. Insert these mirrors in a tightly rolled cardboard tube. Cover one end of the tube with clear plastic. Put some pieces of broken bangles, silver glitter and coloured paper over the plastic sheet. Cover them with another layer of plastic. Tape a circular piece of card with a hole in the centre on the other end of the tube. Look through the hole and rotate the tube to see beautiful patterns made by multiple reflections.

The Sun has produced energy for billions of years. Solar energy is the Sun's light rays that reach the Earth. This energy can be converted into other forms of energy, such as heat and electricity. Why do you think solar energy can help us overcome the severe problem of electricity shortage?

Computer Links

- http://www.physchem.co.za/OB12-mat/transmission.htm
- http://www.physicsclassroom.com/class/refln/u13l4a.cfm