# Introduction to Light – Reflection & Refraction

## Light: Definition

Light is a form of energy that enables us to see things. Light starts from a source and bounces off objects which are perceived by our eyes and our brain processes this signal, which eventually enables us to see.

## Nature of Light

Two theories about nature of light

Wave Theory

According to **Wave Theory,** Light consists of Electromagnetic waves which do not require a material medium ( like Solid, Liquid and Gas ) for their propagation.

Particle Theory

According to **Particle Theory,** Light is composed of particles which travel in a straight line at very high speed.

The elementary particle that defines Light is the "**PHOTONS**" (**are particles which transmit light**. )

**Light exhibit Dual Nature: Means it exhibits properties of both wave and particle.**

This Modern Theory of Light is called **QUANTUM THEORY OF LIGHT** . **It Combines both wave and particle theory of light**

## Characteristics of light

1. **Light is an Electromagnetic wave. Light travels in a straight line.**
2. **Light is transverse wave, and does not need any medium to travel. Light can travel through Vacuum.**
3. **The velocity of light changes when it travels from one medium to another.**
4. **The wavelength of light changes when it goes from one medium to another.**
5. **The frequency of the light wave remains the same in all media.**
6. **Light gets reflected back from polished surfaces, such as mirror, etc.**
7. **Light undergoes refraction (bending) when it travels from one transparent medium to another.**

| **Speed of light** | |
|---|---|
| Air/Vacuum | **$3 \times 10^8$ m/s** |
| Water | **$2.25 \times 10^8$ m/s** |
| Glass | **$2 \times 10^8$ m/s** |

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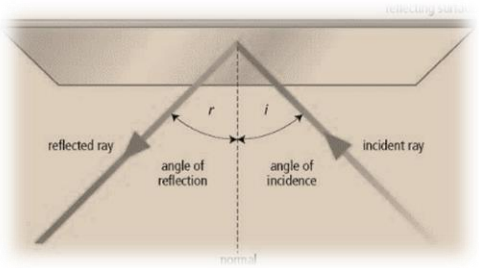
## Reflection of light




When light rays are incident on an opaque polished surface, these are returned back

in the same medium. This phenomenon of returning of ray of light in the same medium, is called Reflection of Light.

**Important Terms**

**Reflecting Surface** : The surface from which the light is reflected.

**Point of Incidence** : The point on the reflecting surface at which a ray of light strikes.

**Normal** : A perpendicular drawn on the reflecting surface at the point of incidence.

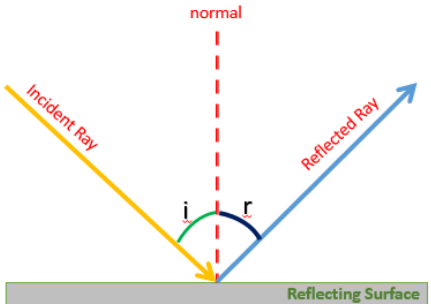
**Incident Ray** : The ray of light which strikes the reflecting surface at the Point of Incidence.

**Reflected Ray** : The ray of light which get reflect from the reflecting surface at the Point of Incidence.

**Angle of Incidence (i)** : The angle formed by incident ray with the normal.

**Angle of Reflection (r)** : The angle formed by reflected ray with the normal.

## Laws of Reflection




1st Law: The incident ray, the reflected ray and the normal at the point of incidence, all lies on the same plane.

2nd Law: The angle of reflection (r) is always equal to the angle of incidence (r) .

## Types of Mirror

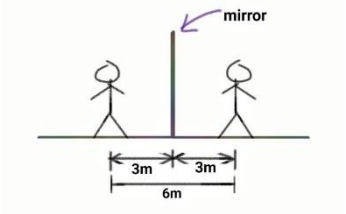
1. **Plane Mirror**
2. **Spherical Mirror**

## Plane mirror

Any flat and polished surface that has almost no irregularities on its surface that reflect light is called as a plane mirror.

## Characteristics of images

- The image formed by a plane mirror is always virtual and erect.
- Object and image are equidistant from the mirror.
- Size of the image is same as that of the object
- Image formed is a laterally inverted image i.e.,right hand side of the object seems to be the left hand side and vice-versa.

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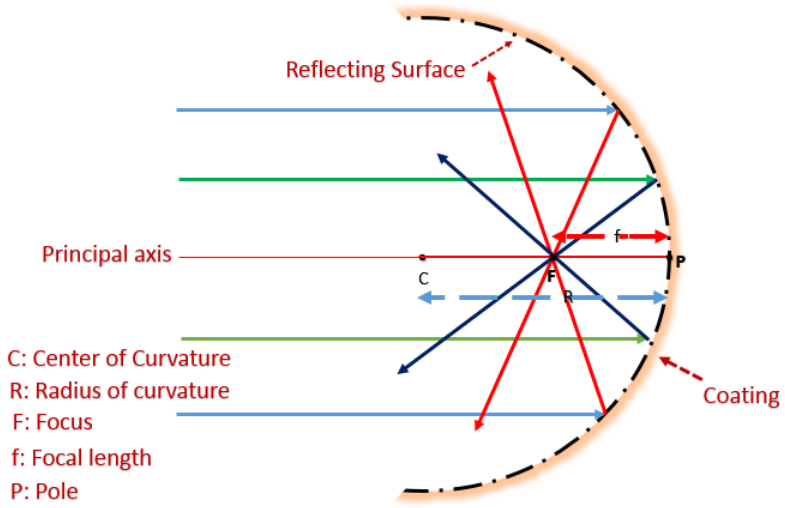
# Spherical Mirrors

Consider a hollow sphere with a very smooth and polished inside surface and an outer surface with a coating ,so that no light can come out. Then if we cut a thin slice out of the shell, we get a curved mirror, which is called a spherical mirror.




**Important terms**

**Aperture :** The diameter of the circular rim of the mirror. In diagram **MN** is the aperture of the mirror

**Pole :** The centre of the spherical surface of the mirror is called the pole of the mirror. It lies on the surface. In diagram**, P** is the pole of the mirror.

**Centre of curvature :** The centre of the spherical shell, of which the mirror is a section, is called centre of curvature of the mirror. It lies outside the surface. Every point on mirror surface lies at same distance from it. In diagram, **C** is the centre of curvature of the mirror.

**Principal axis :** The straight line passing through the pole and the centre of curvature of the mirror, is called principal axis of the mirror.

**Principal focus :** It is a point on the principal axis of the mirror, such that the rays incident on the mirror parallel to the principal axis after reflection, actually meet at this point (in case of a concave mirror) or appear to come from it (in case of a convex mirror).

**Radius of curvature :** The distance between the pole and the centre of curvature of the mirror, is called the radius of curvature of the mirror.

**Focal length :** The distance between the pole and principal focus of the mirror, is called the focal length of the mirror.

- **Concave Mirror**: A spherical mirror with the reflecting surface that bulges inwards.
- **Convex Mirror**: A spherical mirror with the reflecting surface that bulges outwards.

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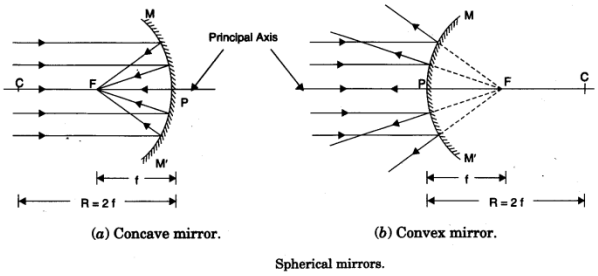
## Relationship between focus and radius of curvature

Focal length is half the distance between pole and radius of curvature.

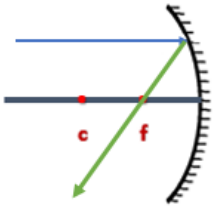
F = R/2



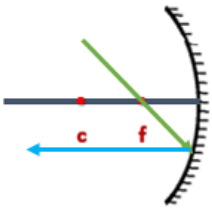
Spherical mirrors.

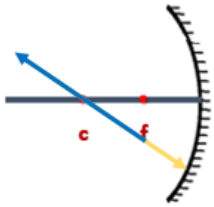
# RULES FOR IMAGE FORMATION (CONCAVE MIRROR)

Ray parallel to principal axis , after reflection passes through focus.



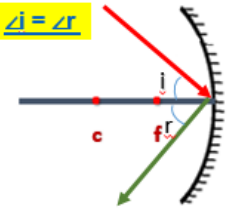

A ray passing through focus , after reflection will become parallel to principal axis.



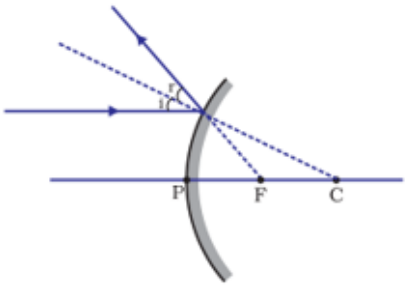

A ray passing through the center of curvature, after reflection will follow the same path.

∠i = ∠r

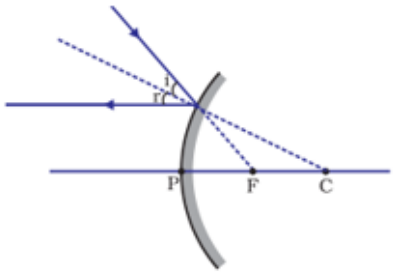



Ray incident at pole is reflected back making same angle with principal axis.

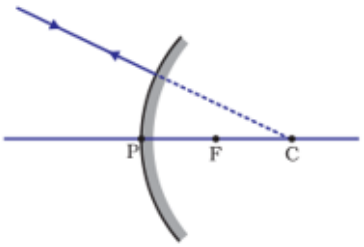
# RULES FOR IMAGE FORMATION (CONVEX MIRROR)



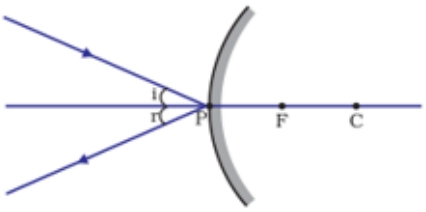

Rule 1




Rule 2




Rule 3




Rule 4

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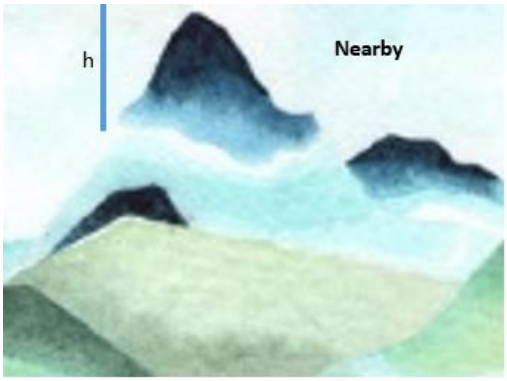
# IMAGE FORMATION BY SPHERICAL MIRROR IN DIFFERENT CASES




## CONCAVE MIRROR (or CONVERGING MIRROR)

By changing the position of the object from the concave mirror, different types of images can be formed. Different types of images are formed when the object is placed:

a) At the infinity
b) Beyond the centre of curvature
c) At the centre of curvature
d) Between the centre of curvature and principal focus
e) At the principal focus
f) Between the principal focus and pole

**Case 1**

**Position of Object** At Infinity

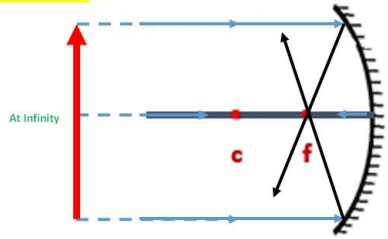



**Image size** Highly Diminished
**Position of Image** At focus
**Nature of Image** Real and Inverted

**Case 3**

**Position of Object** At the centre of curvature

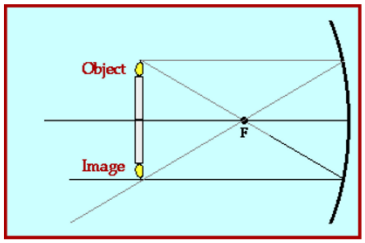



**Image size** Same size of object
**Position of Image** At C
**Nature of Image** Real and Inverted

**Case 2**

**Position of Object** Beyond the centre of curvature C

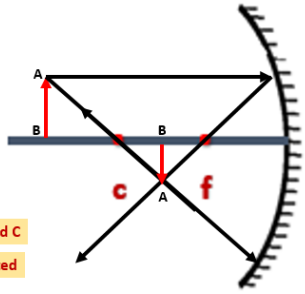



**Image size** Diminished
**Position of Image** Between F and C
**Nature of Image** Real and Inverted

**Case 4**

**Position of Object** Between the centre of curvature and principal focus

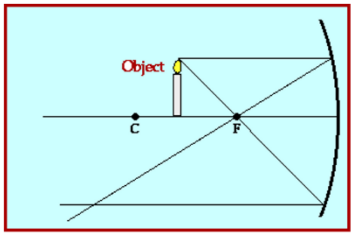



**Image size** Enlarged
**Position of Image** Beyond C
**Nature of Image** Real and Inverted

**Case 5**

**Position of Object** At the principal focus

**Case 6**

**Position of Object** Between the Pole and principal focus

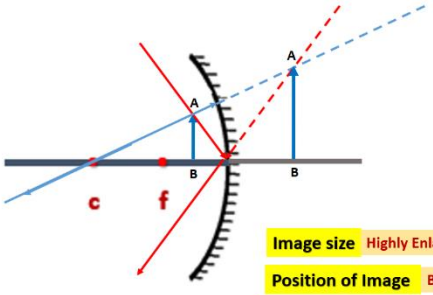
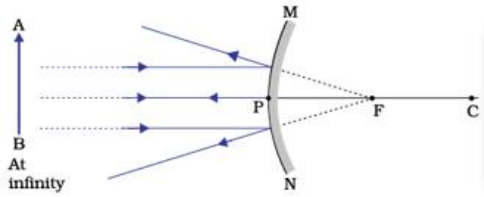



**Image size** Highly Enlarged
**Position of Image** Behind the mirror
**Nature of Image** Virtual and erect

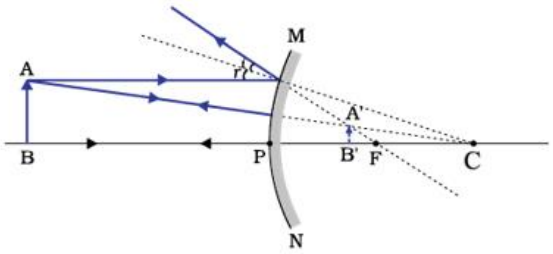
## TRY YOURSELF

## IMAGE FORMATION BY CONVEX MIRROR or DIVERGING MIRROR



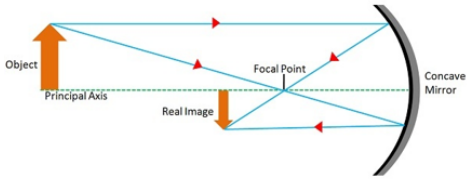
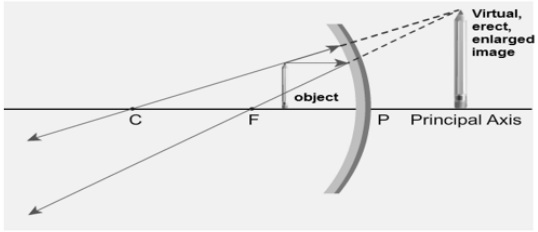

(a)

| Position of the object | Position of the image | Size of the image | Nature of the image |
|---|---|---|---|
| At infinity | At the focus F, behind the mirror | Highly diminished, point-sized | Virtual and erect |
| Between infinity and the pole P of the mirror | Between P and F, behind the mirror | Diminished | Virtual and erect |




(b)

# Difference Between Real and Virtual Image

| REAL IMAGE | VIRTUAL IMAGE |
|---|---|
| Image which can be obtained on Screen | Image which cannot be obtained on Screen |
| Image is formed in front of a mirror | Image is formed behind the mirror |
| Rays of light after reflection/refraction actually meet at a point | Rays of light after reflection/refraction actually meet at a point |
|   |   |
| Image is always Inverted | Image is always erect (upright) |
| Magnification is Negative | Magnification is Positive |

## Uses Of Spherical Mirror

**Use of Concave Mirror**: It is used as a makeup mirror, the reflector in torches, in headlights of cars and searchlights, doctor's head-mirrors, solar furnace, etc.

**Use of Convex Mirror**: Convex mirror used as rear view mirror in vehicles, **We prefer a** convex mirror **as a** rear-view mirror **in vehicles because it gives a wider field of** view**, which allows the driver to see most of the traffic behind him.** Convex mirrors **always form a virtual, erect, and diminished image of the objects placed in front of it**

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# Mirror formula and Magnification

**Sign Conventions of Spherical Mirror**

- All the distances are measured from the pole of the mirror as the origin.
- Distances measured in the direction of incident rays are taken as positive.
- Distances measured opposite to the direction of incident rays are taken as negative.
- Distances measured upward and perpendicular to the principal axis are taken as positive.
- Distances measured downward and perpendicular to the principal axis are taken as negative.

$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ ...where f, v and u are focal length, image distance, object distance

**Linear Magnification:** This is the ratio of the height of the image to the height of the object.

$m = \frac{h'}{h}$ ...where m = magnification, h = height of image, h' = height of object

**$m = \frac{-v}{u}$, v=image distance, u= object distance**

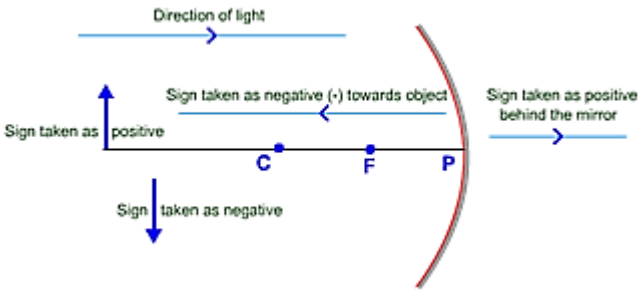
| SIGN CONVENTION | | |
|---|---|---|
| | **CONCAVE MIRROR** | **CONVEX MIRROR** |
| Object Distance, **u** | **-ve** | **-ve** |
| Image Distance, **v** | **-ve** | **+ve** |
| Focal Length, **f** | **-ve** | **+ve** |
| Object Height, **h'** | **+ve** | **+ve** |
| Image Height, **h** | **-ve** | **-ve** |

Magnification

Real image ⟶ m= -ve

Virtual image ⟶ m= +ve

If **m = +1** , it means **image is of same size of the object and is virtual in nature.**




**Numerical**

Q. An object is placed in front of a convex mirror of radius of curvature 40 cm at a distance of 10 cm. Find the position, nature and magnification of mirror.

Answer:
Here u = -10 cm, R = -40 cm

Then f = R/2 = - 20 cm

From the mirror formula 1/v = 1/f – 1/ u = -1/20 + 1/10 = 1/20.

V= 20 cm so v is positive , a virtual and erect image will be formed on the other side of the object, i.e; behind the mirror.

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M=-v/u = -20/-10 = 2

Q. An object is kept in front of a concave mirror of focal length of 15 cm. the image formed is 3 times the size of the object. Calculate the two possible distances of the object from the mirror.
Answer:

**Case:1. Image is real. M = -3**

Here f= -15 cm

Now m=-v/u = -3

Or , V = 3u

From the mirror formula

1/f = 1/u+1/v

-1/15 = 1/u + 1/3u

U= - 20 cm.

**Case:2. When the image is virtual m = 3**

Now m = -v/u = 3

Or, V=-3

From the mirror formula

1/f=1/u+1/v

Then -1/15 = 1/u-1/3u

2/3u = -1/15

U= -10cm.

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