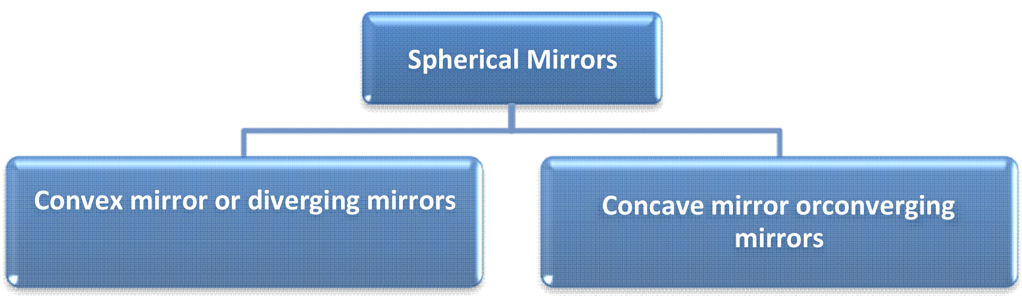
Light – Reflection and Refraction

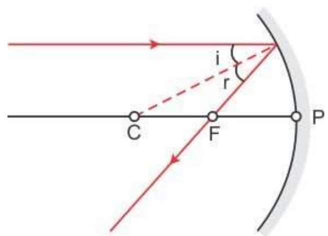
Reflection of Light

- Reflection is the phenomenon of bouncing back of light into the same medium on striking the surface of any object.
- **Laws of Reflection**
  - First law: The incident ray, the normal to the surface at the point of incidence and the reflected ray, all lie in the same plane.
  - Second law: The angle of reflection (r) is always equal to the angle of incidence(i).
    $\angle i = \angle r$
- The image formed by a **plane mirror** is always
  - virtual and erect
  - of the same size as the object
  - as far behind the mirror as the object is in front of it
  - laterally inverted
- **Spherical mirrors** are of two types:

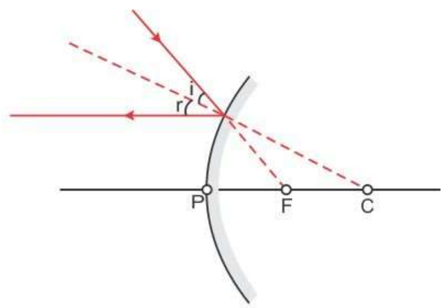


  - **Convex mirrors or diverging mirrors** in which the reflecting surface is curved outwards.
  - **Concave mirrors or converging mirrors** in which the reflecting surface is curved nwards.
- Some terms related to spherical mirrors:
  - The **centre of curvature (C)** of a spherical mirror is the center of the hollow sphere of glass, of which the spherical mirror is apart.
  - The **radius of curvature (R)** of a spherical mirror is the radius of the hollow sphere of glass, of which the spherical mirror is apart.
  - The **pole (P)** of a spherical mirror is the centre of themirror.
  - The **principal axis** of a spherical mirror is a straight line passing through the centre of curvature C and pole P of the sphericalmirror.
  - The **principal focus (F) of a concave mirror** is a point on the principal axis at which the rays of light incident on the mirror, in a direction parallel to the principal axis, actually meet after reflection from themirror.
  - The **principal focus (F) of a convex mirror** is a point on the principal axis from which the rays of light incident on the mirror, in a direction parallel to the principal axis, appear to diverge after reflection from themirror.
  - The **focal length (f)** of a mirror is the distance between its pole (P) and principal focus(F).
  - For spherical mirrors of small aperture, **R =2f**.

- **Sign Conventions for Spherical Mirrors**
  According to **New Cartesian Sign Conventions**,
  - All distances are measured from the pole of the mirror.
  - The distances measured in the direction of incidence of light are taken as positive and *vice versa*.
  - The heights above the principal axis are taken as positive and *vice versa*.
- **Rules for tracing images formed by spherical mirrors**
  Rule 1: A ray which is parallel to the principal axis after reflection passes through the principal focus in case of a concave mirror or appears to diverge from the principal focus in case of a convex mirror.

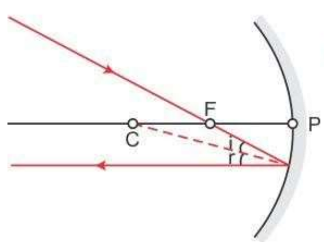


Concave Mirror

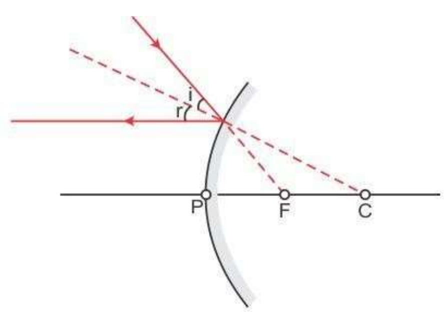


Convex Mirror

Rule 2: A ray passing through the principal focus of a concave mirror or a ray which is directed towards the principal focus of a convex mirror emerges parallel to the principal axis afterreflection.

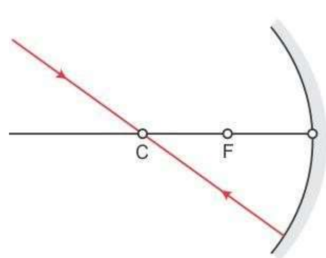


Concave Mirror

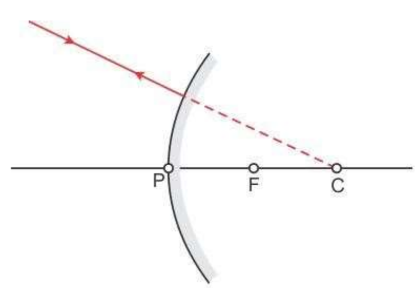


Convex Mirror

Rule 3: A ray passing through the centre of curvature of a concave mirror or directed towards the centre of curvature of a convex mirror is reflected back along the same path.

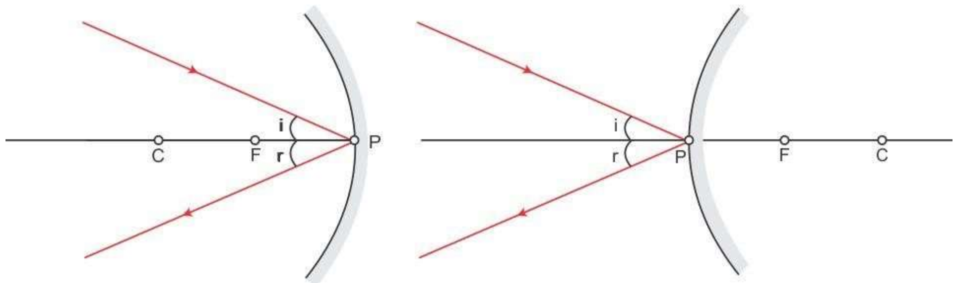


Concave Mirror

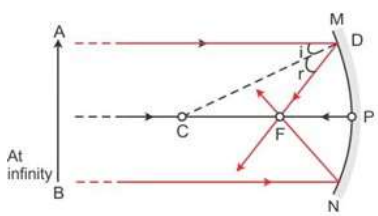


Convex Mirror

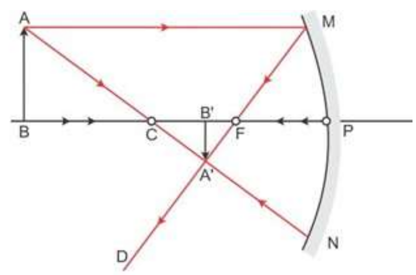
Rule 4: A ray incident obliquely towards the pole of a concave mirror or a convex mirror is reflected obliquely as per the laws of reflection.



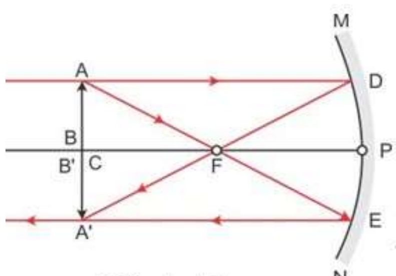
- **Image formation by a concavemirror**
  - **RayDiagrams**



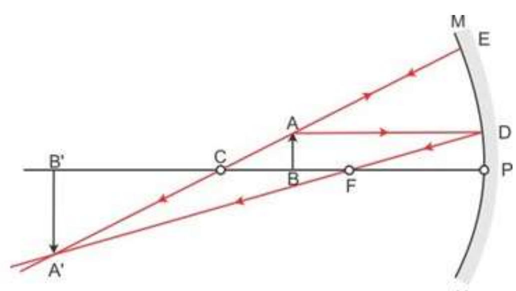
Object at infinity



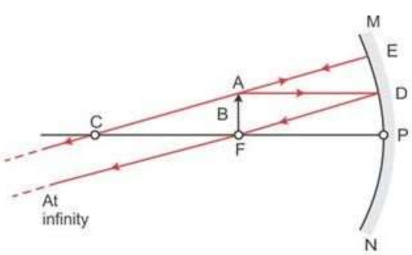
Object beyond C



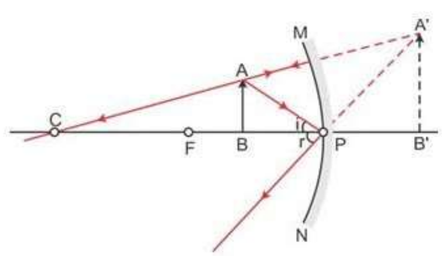
Object at C



Object between C and F



Object at F



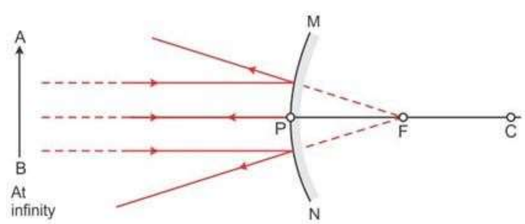
Object between F and P

Anodiam
Education that enlightens!

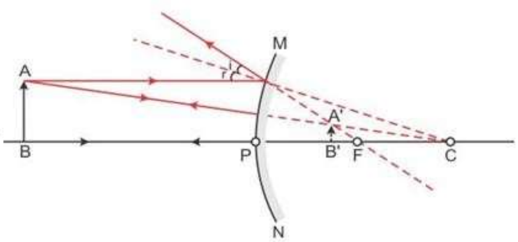
- **Characteristics of imagesformed**

Position of object	Position of image	Size of image	Nature of image
At infinity	At focus F	Highly diminished	Real and inverted
Beyond C	Between F and C	Diminished	Real and inverted
At C	At C	Equal to size of object	Real and inverted
Between C and F	Beyond C	Enlarged	Real and inverted
At F	At infinity	Highly enlarged	Real and inverted
Between F and P	Behind the mirror	Enlarged	Virtual and erect

- **Image formation by a convexmirror**
  - **RayDiagrams**



Object at infinity



Object anywhere between infinity and P

  - **Characteristics of imagesformed**

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

- **MirrorFormula**
The object distance (u), image distance (v) and focal length (f) of a spherical mirror are related as

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

- **Linear Magnification (m)** produced by a spherical mirroris

$$\mathbf{m = \frac{size\ of\ image\ (h_2)}{size\ ofobject(h_1)} = -\frac{image\ distance\ (v)}{object\ distance(u)}}$$

m is **negative** for real images and **positive** for virtual images.

Refraction of Light

- The phenomenon of change in the path of a beam of light as it passes from one medium to another is called refraction oflight.
- The **cause of refraction** is the change in the speed of light as it goes from one medium toanother.
- **Laws ofRefraction**
  - FirstLaw:Theincidentray,therefractedrayandthenormaltotheinterfaceoftwomediaat the point of incidence, all lie in the sameplane.
  - Second Law: The ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant for a given pair ofmedia.

    $$\frac{\sin i}{\sin r} = \text{constant} = {}^1n_2$$

    This law is also known as **Snell's law.**

    The constant, writtenas ${}^1n_2$ is called the **refractive index** of the secondmedium (in which the refracted ray lies) with respect to the first medium (in which the incident ray lies).
- **Absolute refractive index (n)** of a medium is givenas

$$\mathbf{n} = \frac{\textbf{speed of lightinvacuum}}{\textbf{speed of light inthemedium}} = \frac{\mathbf{c}}{\mathbf{v}}$$

- When a beam of light passes from medium 1 to medium 2, the refractive index of medium 2 with respect to medium 1 is called the **relative refractive index**, represented by ${}^1n_2$,where

$${}^1n_2 = \frac{n_2}{n_1} = \frac{c/v_2}{c/v_1} = \frac{v_1}{v_2}$$

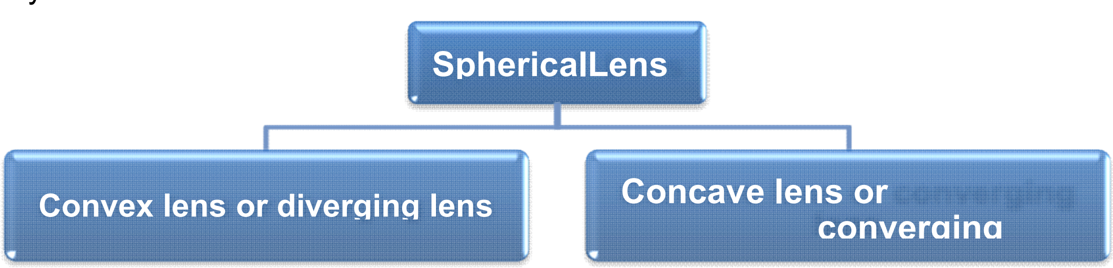
Similarly, the refractive index of medium 1 with respect to medium 2 is

$${}^2n_1 = \frac{n_1}{n_2} = \frac{c/v_1}{c/v_2} = \frac{v_2}{v_1}$$

$$\Rightarrow \quad {}^1n_2 \times {}^2n_1 = 1$$

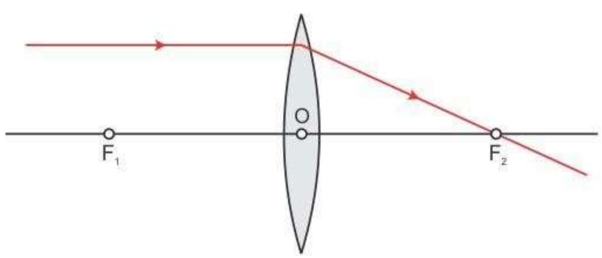
$$\text{or,} \quad {}^1n_2 = \frac{1}{{}^2n_1}$$

- While going from **a rarer to a denser medium**, the ray of **light bends towards the normal.** While going from **a denser to a rarer medium**, the ray of **light bends away from thenormal.**
- **Conditions for norefraction**
  - When light is incident normally on aboundary.
  - When the refractive indices of the two media areequal.
- In the case of a **rectangular glass slab**, a ray of light suffers **two refractions**, one at the air–glass interface and the other at the glass–air interface. The emergent ray is **parallel** to the direction of the incidentray.

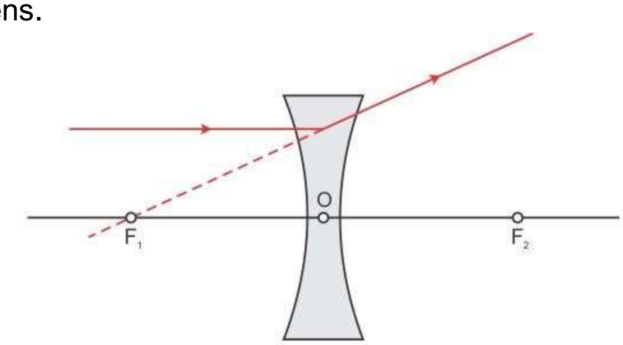


- **Convex lens or converging lens** which is thick at the centre and thin at theedges.
- **Concave lens or diverging lens** which is thin at the centre and thick at theedges.

- Some terms related to sphericallenses:
  - The central point of the lens is known as its **optical centre(O)**.
  - Each of the two spherical surfaces of a lens forms a part of a sphere. The centres of these spheres are called **centres of curvature** of the lens. These are represented as **C_1**and**C_2**.
  - The **principal axis** of a lens is a straight line passing through its two centres ofcurvature.
  - The **principal focus of a convex lens** is a point on its principal axis to which light rays parallel to the principal axis converge after passing through thelens.
  - The **principal focus of a concave lens** is a point on its principal axis from which light rays, originally parallel to the principal axis appear to diverge after passing through thelens.
  - The **focal length (f)** of a lens is the distance of the principal focus from the opticalcentre.
- **Sign Conventions for SphericalLenses**
  According to **New Cartesian Sign Conventions**,
  - All distances are measured from the optical centre of thelens.
  - The distances measured in the direction of incidence of light are taken as positive and *viceversa*.
  - The heights above the principal axis are taken as positive and *viceversa*.
- **Rules for tracing images formed by sphericallens**
  Rule 1: A ray which is parallel to the principal axis, after refraction passes through the principal focus on the other side of the lens in case of a convex lens or appears to diverge from the principal focus on the same side of the lens in case of a concave lens.

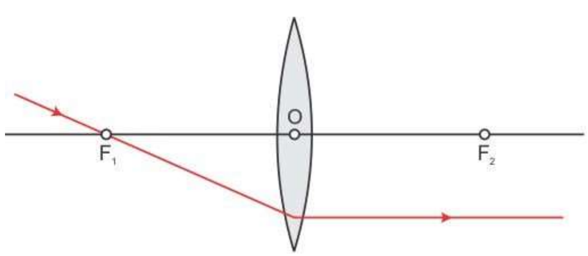


Convex Lens

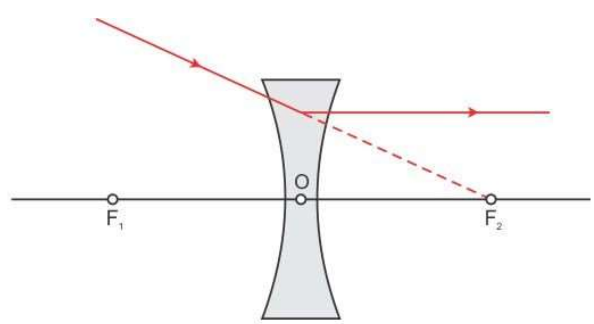


Concave Lens

Rule 2: A ray passing through the principal focus of a convex lens or appearing to meet at the principal focus of a concave lens after refraction emerges parallel to the principalaxis.

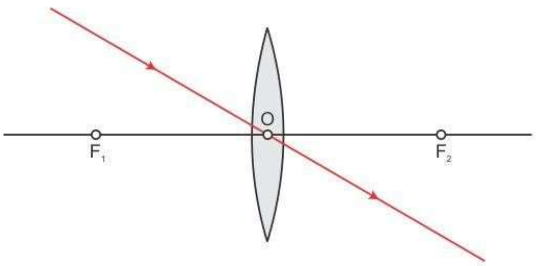


Convex Lens

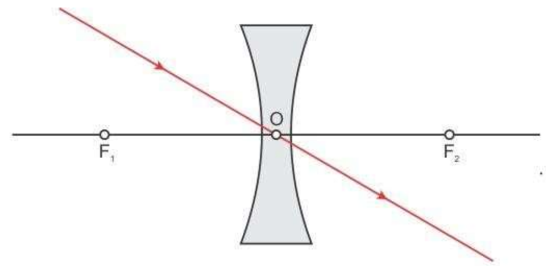


Concave Lens

Rule 3: A ray passing through the optical centreof a convex lens or a concave lens emerges without any deviation.

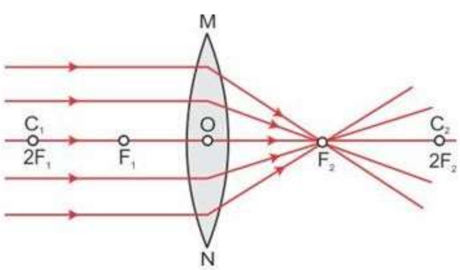


Convex Lens

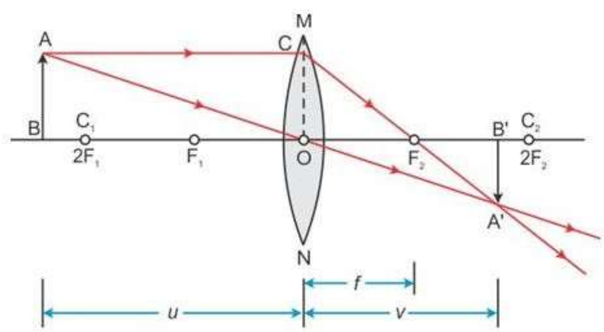


Concave Lens

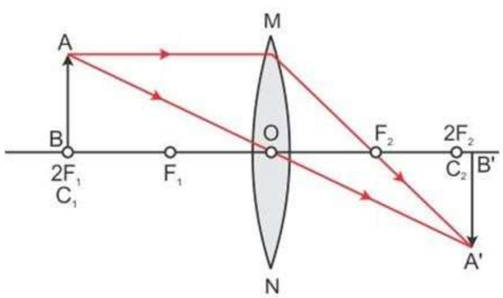
- **Image formation by a convexlens**
  - **RayDiagrams**



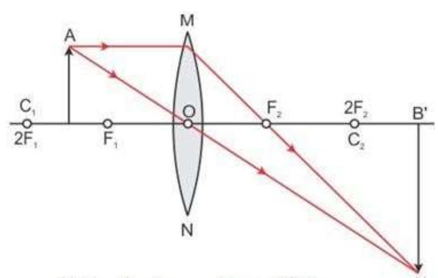
Object at infinity



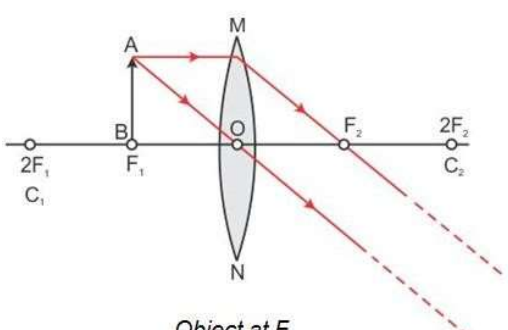
Object beyond $2F_1$



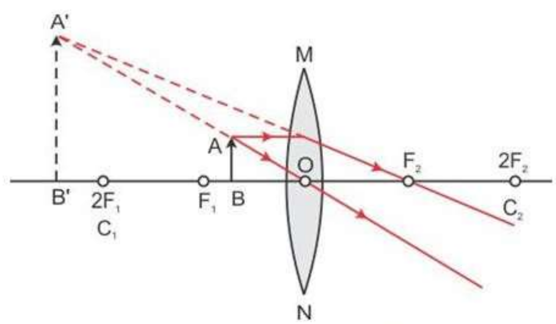
Object at $2F_1$



Object between F_1 and $2F_1$



Object at F_1

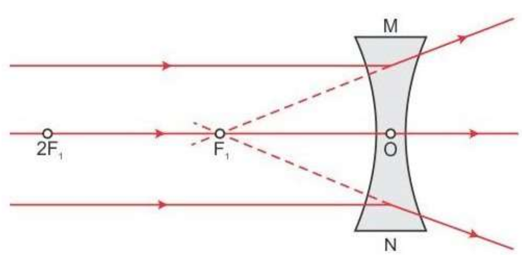


Object between F_1 and C

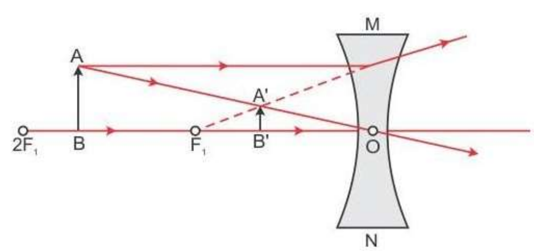
- **Characteristics of imagesformed**

Position of object	Position of image	Size of image	Nature of image
At infinity	At focus F_2	Highly diminished	Real and inverted
Beyond $2F_1$	Between F_2 and $2F_2$	Diminished	Real and inverted
At $2F_1$	At $2F_2$	Equal to size of object	Real and inverted
Between F_1 and $2F_1$	Beyond $2F_2$	Enlarged	Real and inverted
At focus F_1	At infinity	Highly enlarged	Real and inverted
Between F_1 and O	Beyond F_1 on the same side as the object	Enlarged	Virtual and erect

- **Image formation by a concavelens**
  - **RayDiagrams**



Object at infinity



Object between infinity and optical centre

- **Characteristics of imagesformed**

Position of object	Position of image	Size of image	Nature of image
At infinity	At focus F_1	Highly diminished	Virtual and erect
Between infinity and O	Between focus F_1 and O	Diminished	Virtual and erect

- **LensFormula**
  Object distance (u), image distance (v) and focal length (f) of a spherical lens are related as
  $$\frac{1}{u}-\frac{1}{u}=\frac{1}{f}$$
- **Linear Magnification (m)** produced by a spherical lensis
  $$m=\frac{\text{sizeofimage}(h_2)}{\text{size of object}(h_1)}=\frac{\text{imagedistance}(v)}{\text{object distance}(u)}$$
  m is **negative** for real images and **positive** for virtual images.

- **Power of alens**
  - Power of a lens is the reciprocal of the focal length of the lens. Its S.I. unit is **dioptre(D)**.

    $$\mathbf{P\ (dioptre)} = \frac{\mathbf{1}}{\mathbf{f\ (metre)}}$$

  - Power of a **convex lens** is **positive** and that of a **concave lens** is**negative**.
  - When several thin lenses are placed in contact with one another, the **power of the combination of lenses** is equal to the algebraic sum of the powers of the individuallenses.

    $$\mathbf{P = P_1 + P_2 + P_3 + P_4 + ...}$$