# Light: 2/2
## Refraction

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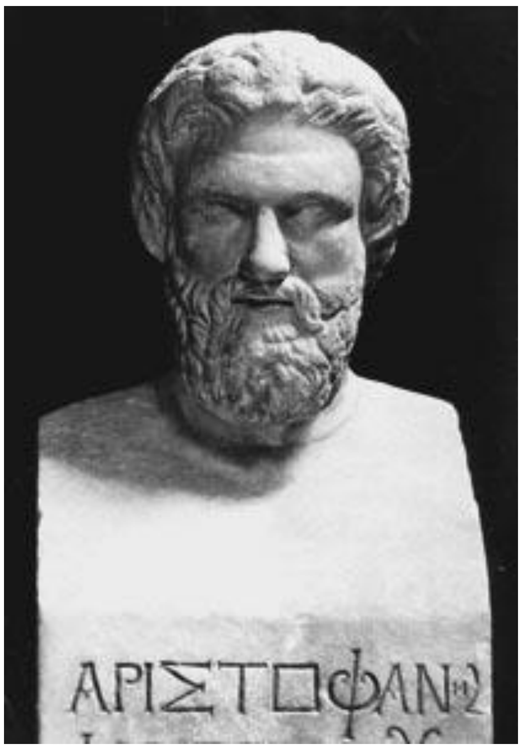
# The History of Lens

- A simple magnifier or microscope is  a converging lens of small focal length.
- A **lens** is a transmissive optical device that focuses or disperses a light beam by means of **refraction.**
- The word ***lens*** comes from ***lēns*** , the Latin name of the **lentil**, because a double-convex lens is lentil-shaped.

X: Light-Refraction

# The History of Lens

- The oldest certain reference to the use of lenses is from **Aristophanes**' play ***The Clouds*** (424 BC) mentioning a **burning-glass**.



A **burning glass** or **burning lens** is a large convex lens that can concentrate the sun's rays onto a small area, heating up the area and thus resulting in ignition of the exposed surface: Museum of American History - Smithsonian Institution-

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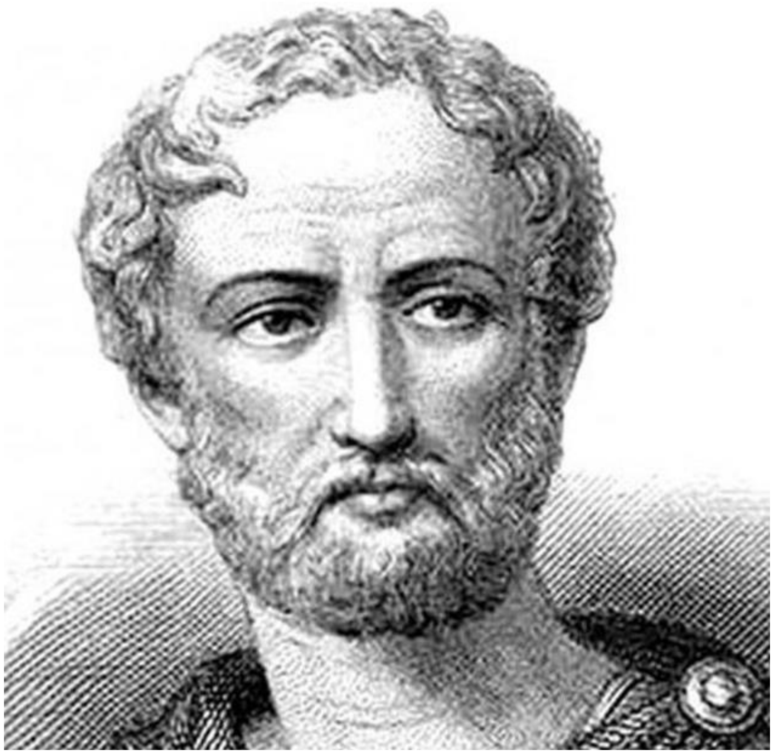
# The History of Lens

- **Pliny the elder** also has the earliest known reference to the use of a corrective lens when he mentions that Nero was said to watch the **gladiatorial games (in Rome)** using an **emerald** (presumably concave to correct for near-sightedness).



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**Pliny the elder**

# The History of Lens

- Pliny the elder also has the earliest known reference to the use of a corrective lens when he mentions that **Nero** was said to watch the **gladiatorial games (in Rome)** using an **emerald** (presumably concave to correct for near-sightedness).

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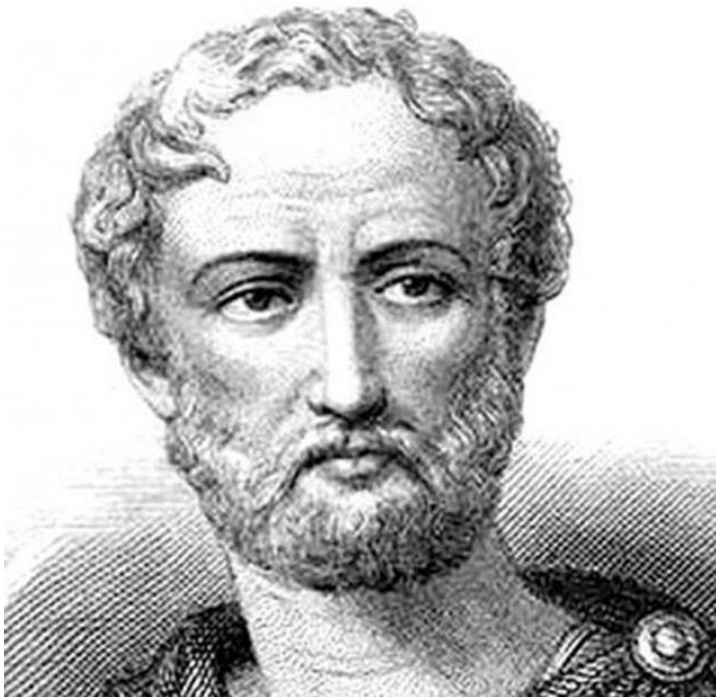
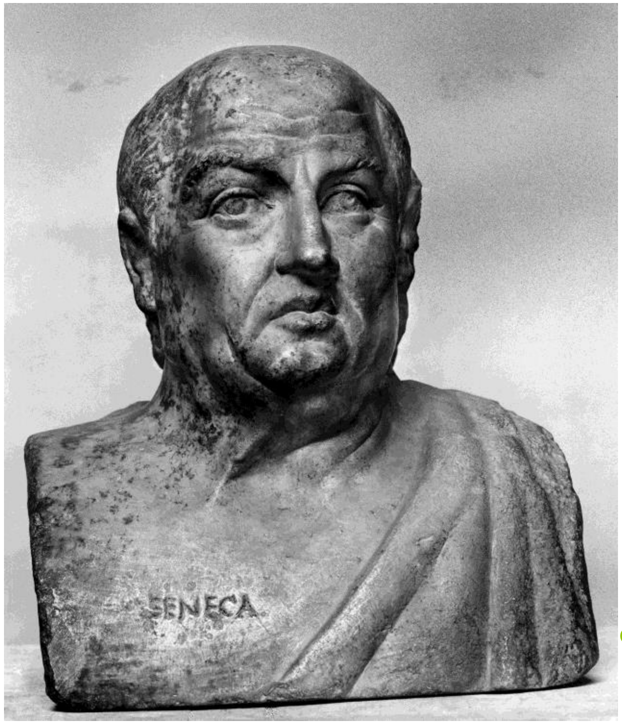
**Nero**

# The History of Lens

- Both **Pliny** and **Seneca** (3 BC–65 AD) described the magnifying effect of a **glass globe** filled with water.



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# Refraction:

- Light does not travel in the same direction in all media. It appears that when travelling obliquely from one medium to another having different optical densities, the direction of propagation of light in the second medium changes.

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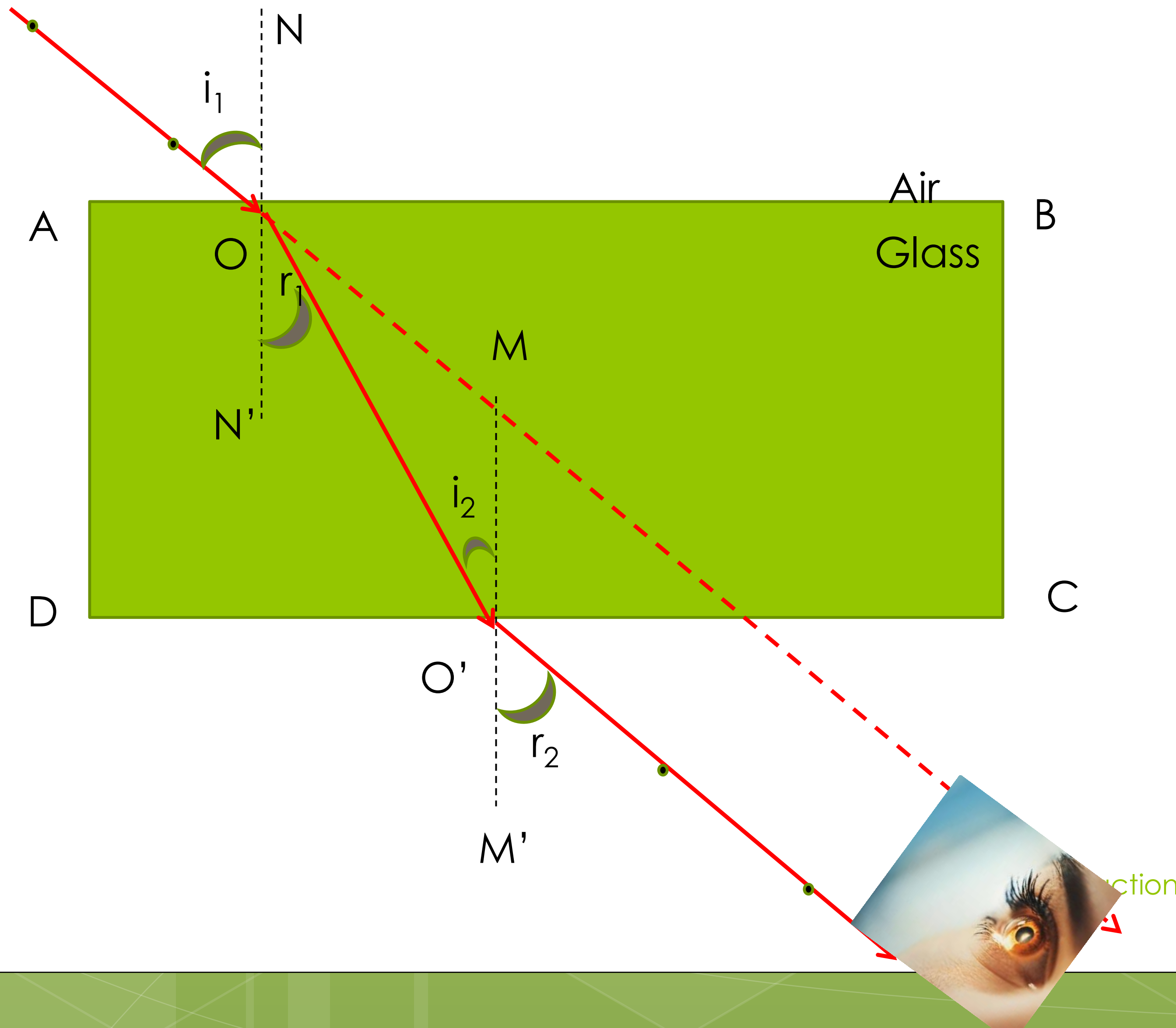
# Refraction through a rectangular glass slab



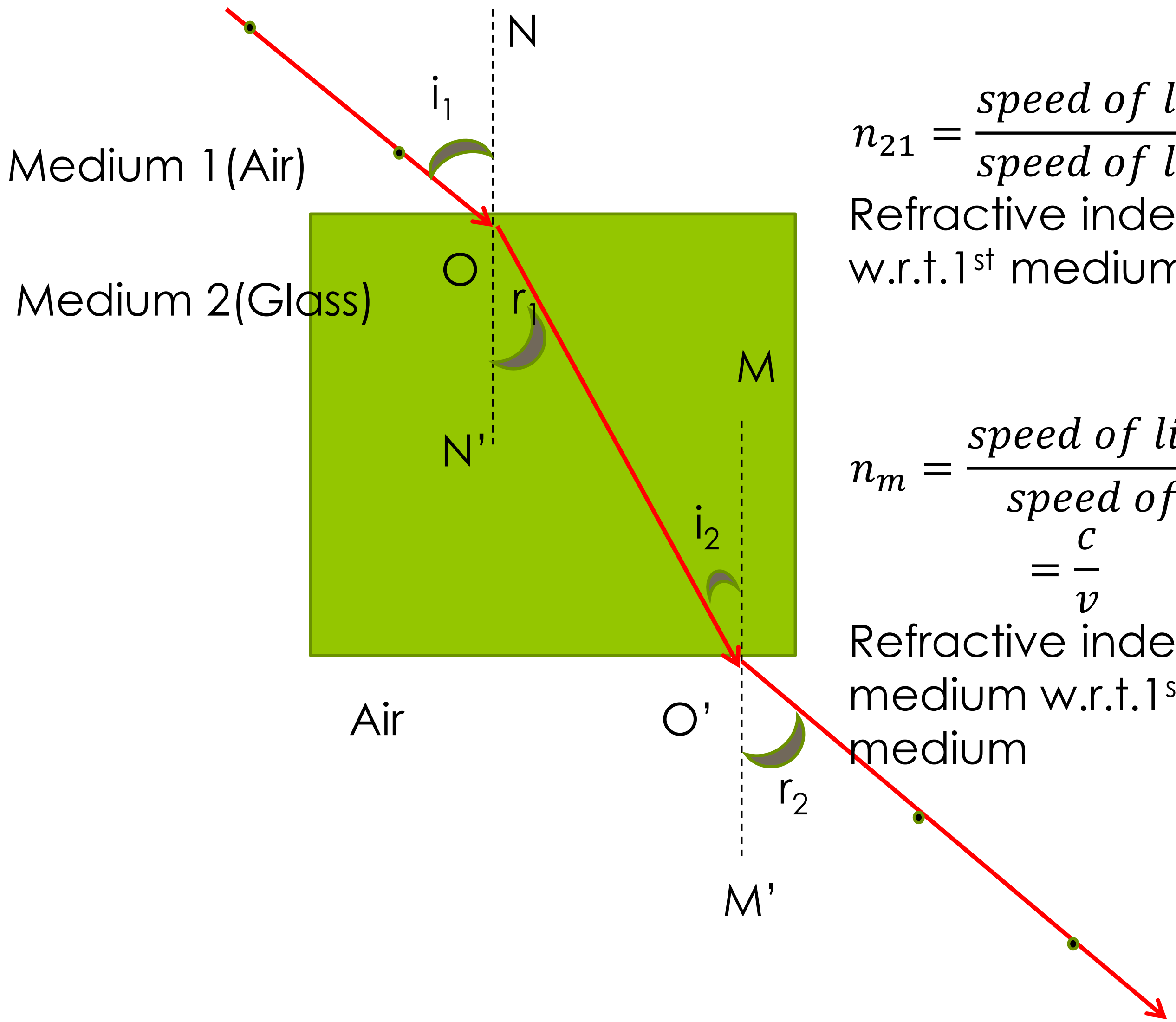
# Laws of Refraction:

- (i) *The incident ray, the refracted ray and the normal to the interface of two transparent media at the point of incidence, all lie in the same plane.*
- (ii) *The ratio of sine of angle of incidence to the sine of angle of refraction is a constant, for the light of a given colour and for the given pair of media.*
- This law is also known as **Snell's law of refraction**. (This is true for angle 0 < *i* < 90º) If *i* is the angle of incidence and *r* is the angle of refraction, then
- $\frac{\sin i}{\sin r} = constant = {}_1n_2$ or $n_{21}$
- i.e., refractive index of the second medium w.r.t. first medium

# Refractive Index

- The refractive index can be linked to an important physical quantity, the relative speed of propagation of light in different media.
- It turns out that light propagates with different speeds in different media.
- Light travels fastest in vacuum with speed of $3 \times 10^8$ m/s.
- In air, the speed of light is only marginally less, compared to that in vacuum. It reduces considerably in glass or water.
- The value of the refractive index for a given pair of media depends upon the speed of light in the two media

# Refraction through a rectangular glass slab




$$n_{21} = \frac{speed\ of\ light\ in\ med.1}{speed\ of\ light\ in\ med.2} = \frac{v_1}{v_2}$$

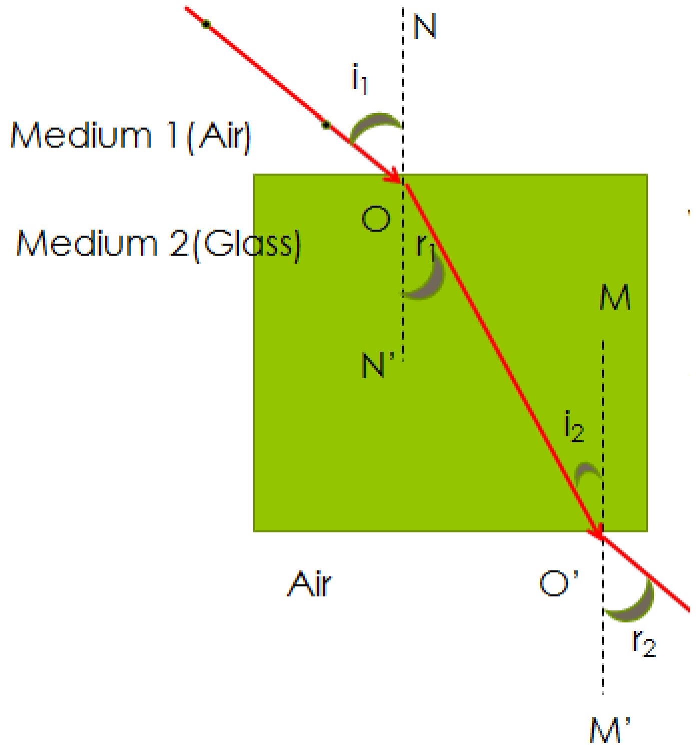
Refractive index of 2nd medium w.r.t.1st medium

$$n_m = \frac{speed\ of\ light\ in\ air/vacuum}{speed\ of\ light\ in\ medium} = \frac{c}{v}$$

Refractive index of the given medium w.r.t.1st air/vacuum medium

# Bending of Light

- When light travels from Rarer (Air) medium to denser medium (glass/water) it bends towards the normal
- When light enters from denser (glass/water) to rarer (Air) it bends away from the normal.

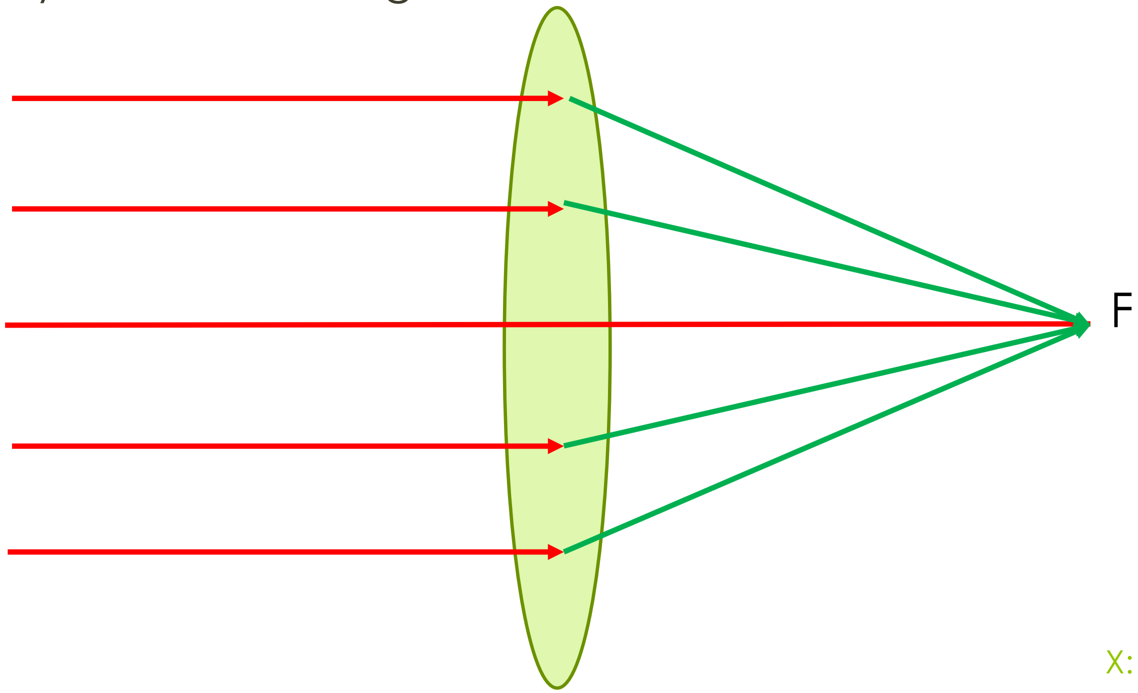


# Refractive Index

| Material medium | Refractive index | Material medium | Refractive index |
|---|---|---|---|
| Air | 1.0003 | Canada Balsam | 1.53 |
| Ice | 1.31 | | |
| Water | 1.33 | Rock salt | 1.54 |
| Alcohol | 1.36 | | |
| Kerosene | 1.44 | Carbon disulphide | 1.63 |
| Fused quartz | 1.46 | Dense flint glass | 1.65 |
| Turpentine oil | 1.47 | Ruby | 1.71 |
| Benzene | 1.50 | Sapphire | 1.77 |
| Crown glass | 1.52 | Diamond | 2.42 |

# Image formation by Convex Lens

- A transparent material bound by two surfaces, of which one or both surfaces are spherical, forms a lens. This means that a lens is bound by at least one spherical surface. In such lenses, the other surface would be plane. A lens may have two spherical surfaces, bulging outwards. Such a lens is called a double convex lens. It is simply called a **convex lens**. It is thicker at the middle as compared to the edges. Convex lens converges light rays as shown in Fig

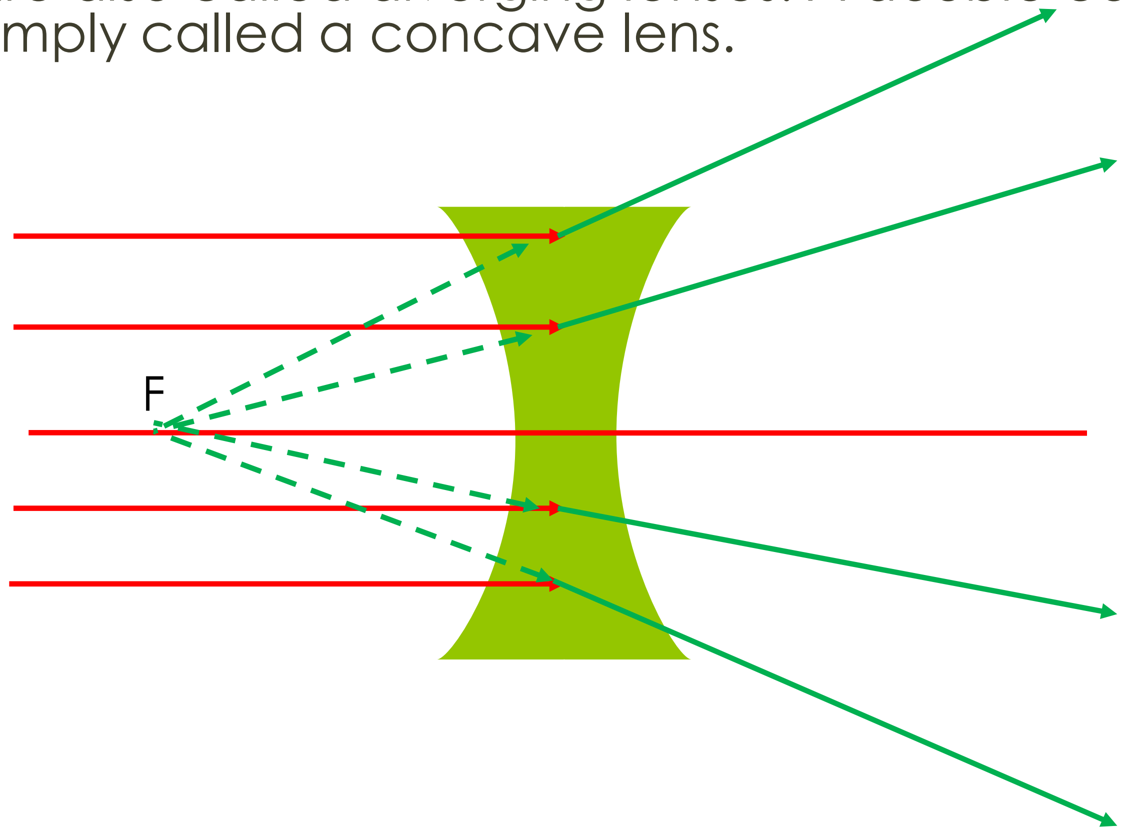





Hence convex lenses are also called **converging lenses**.

# Image formation by Concave Lens

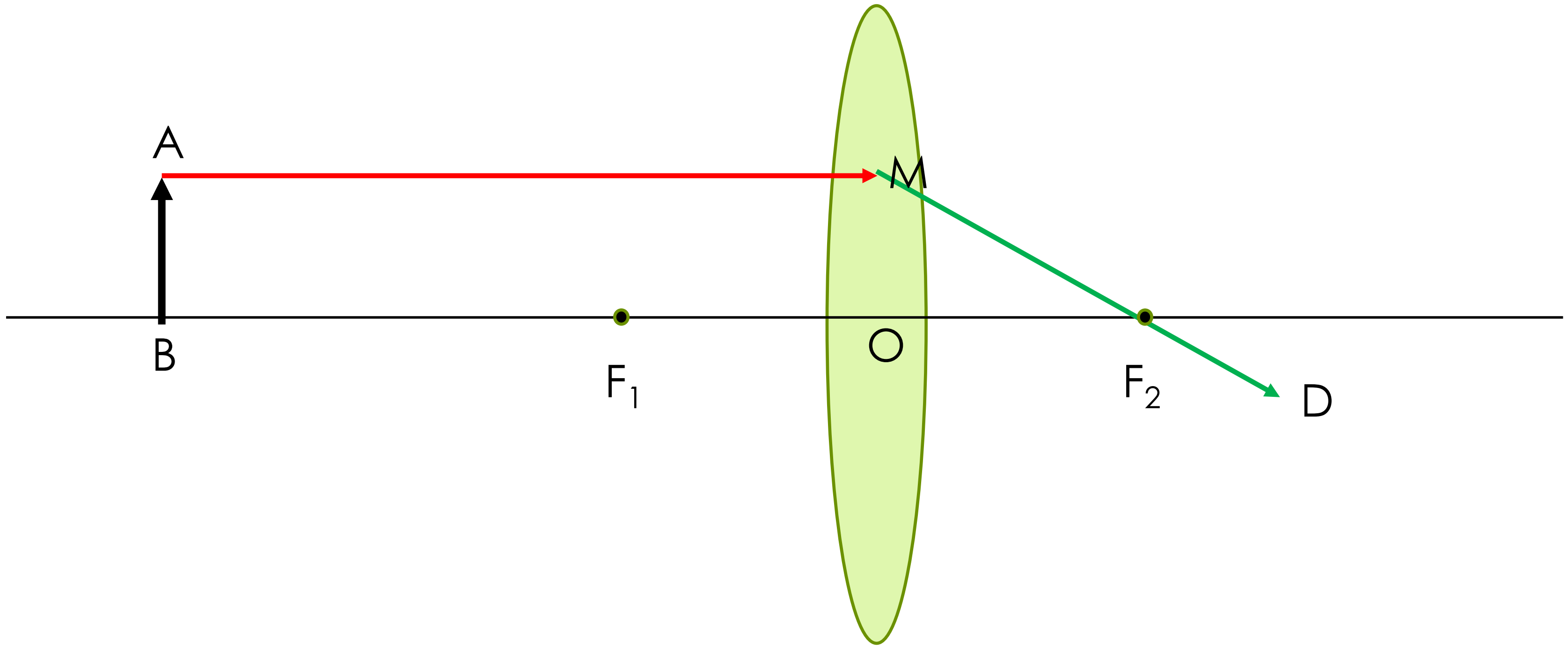
- Double concave lens is bounded by two spherical surfaces, curved inwards. It is thicker at the edges than at the middle. Such lenses diverge light rays as shown in Fig. Such lenses are also called diverging lenses. A double concave lens is simply called a concave lens.




X: Light-Refraction

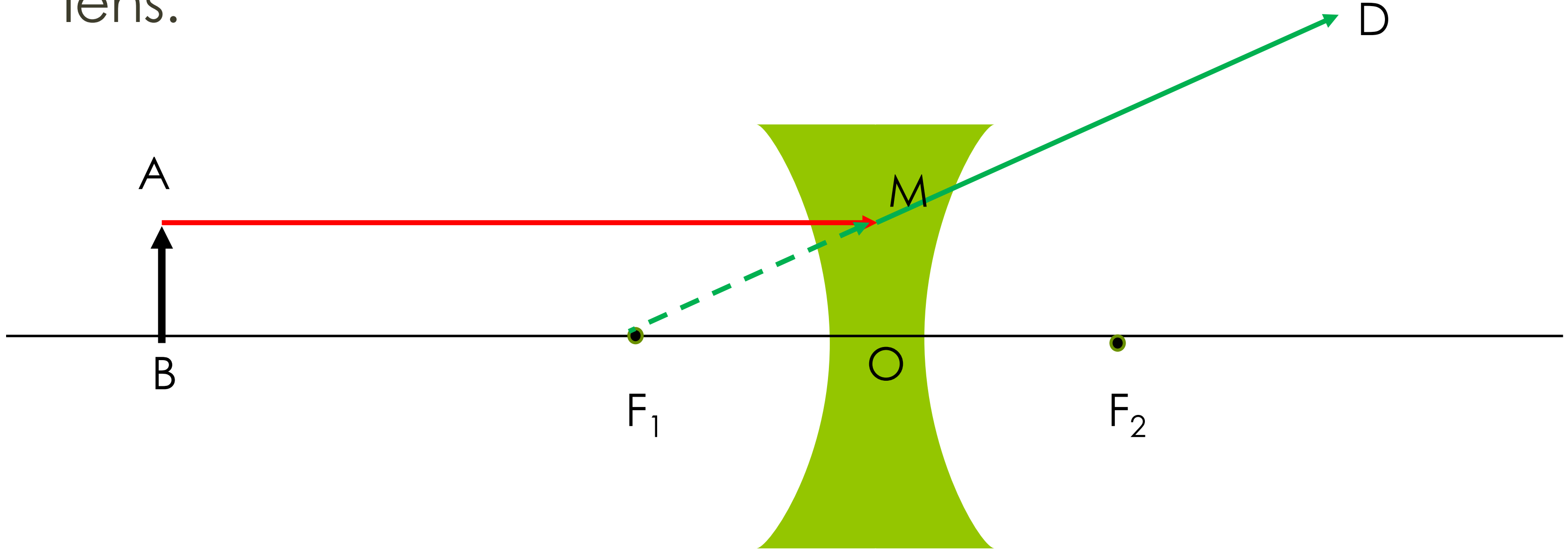
# Image formation by Convex Lens

- (i) ray of light from the object, parallel to the principal axis, after refraction from a convex lens, passes through the principal focus on the other side of the lens.



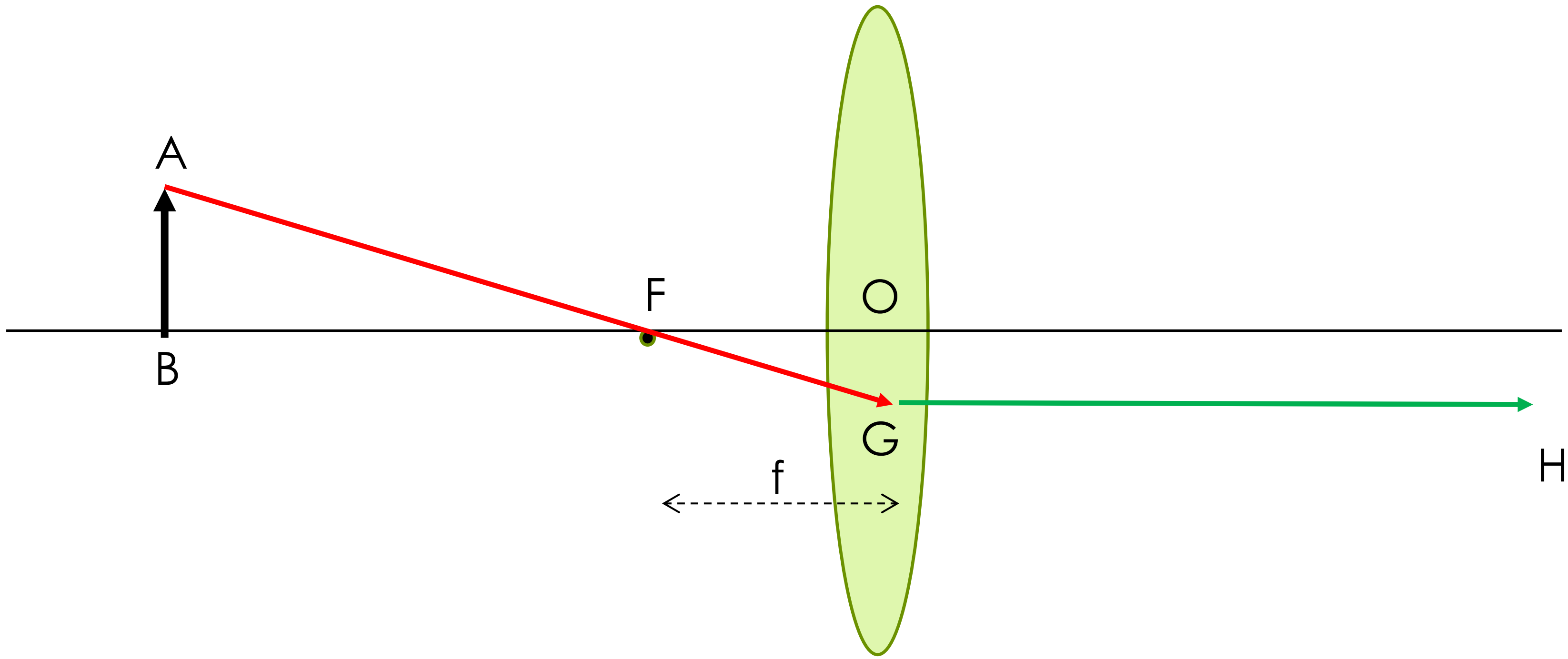
# Image formation by Concave Lens

- (i) In case of a concave lens, the ray appears to diverge from the principal focus located on the same side of the lens.



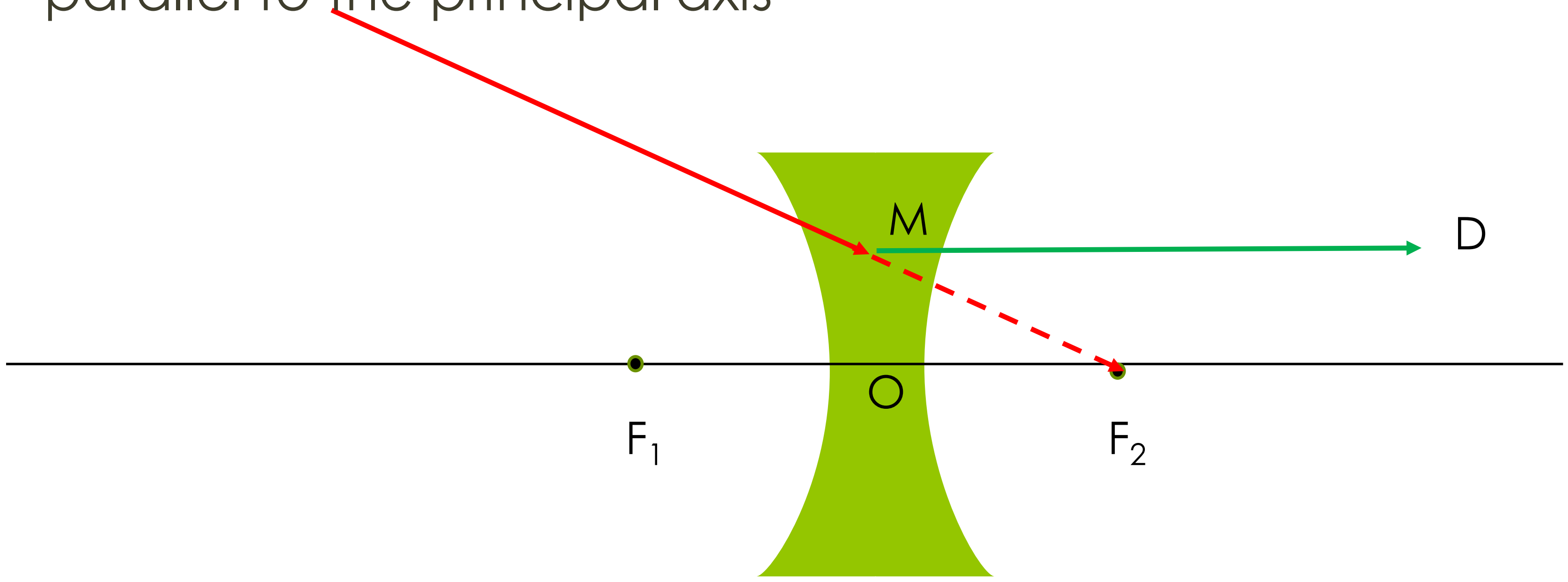
# Image formation by Convex Lens

- (ii) A ray of light passing through a principal focus, after refraction from a convex lens, will emerge parallel to the principal axis.



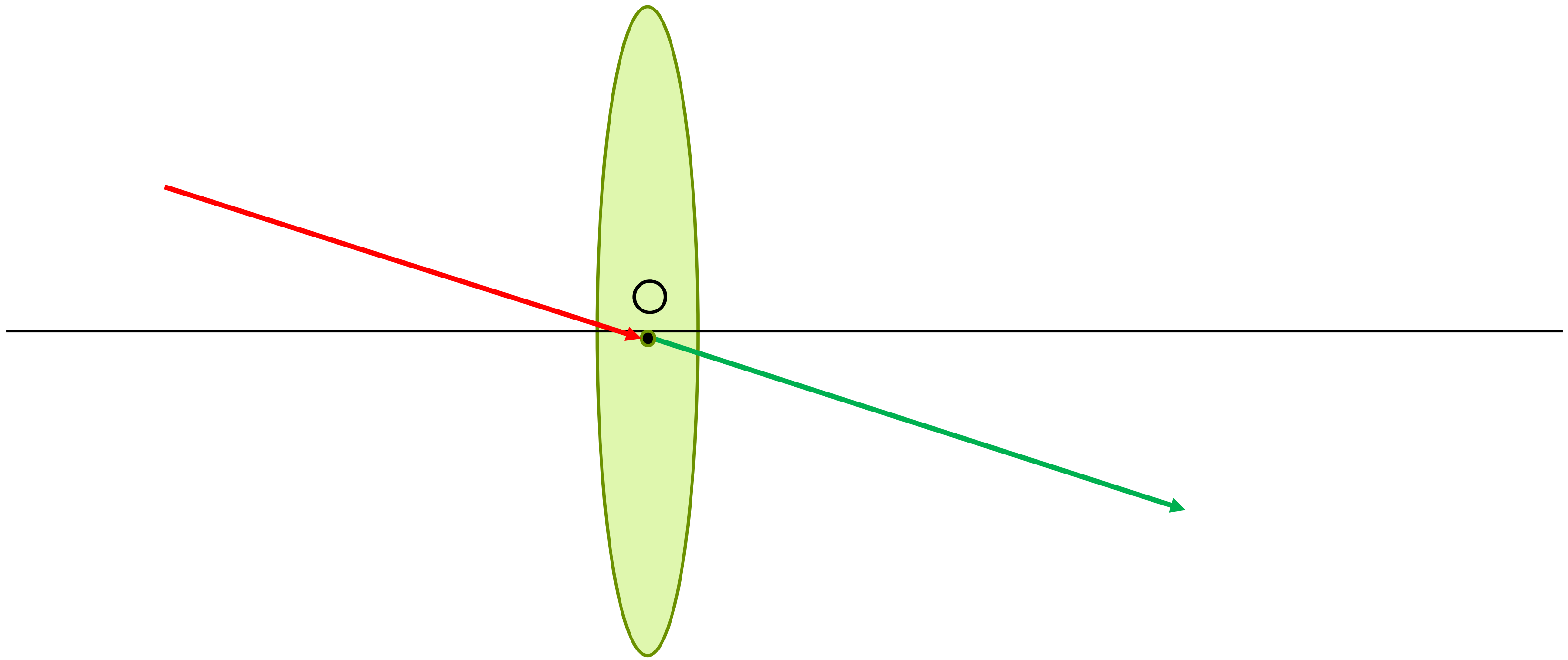
# Image formation by Concave Lens

- (ii) A ray of light appearing to meet at the principal focus of a concave lens, after refraction, will emerge parallel to the principal axis



# Image formation by Convex Lens

- (iii) A ray of light passing through the optical centre of a convex lens will emerge without any deviation.



# Image formation by Concave Lens

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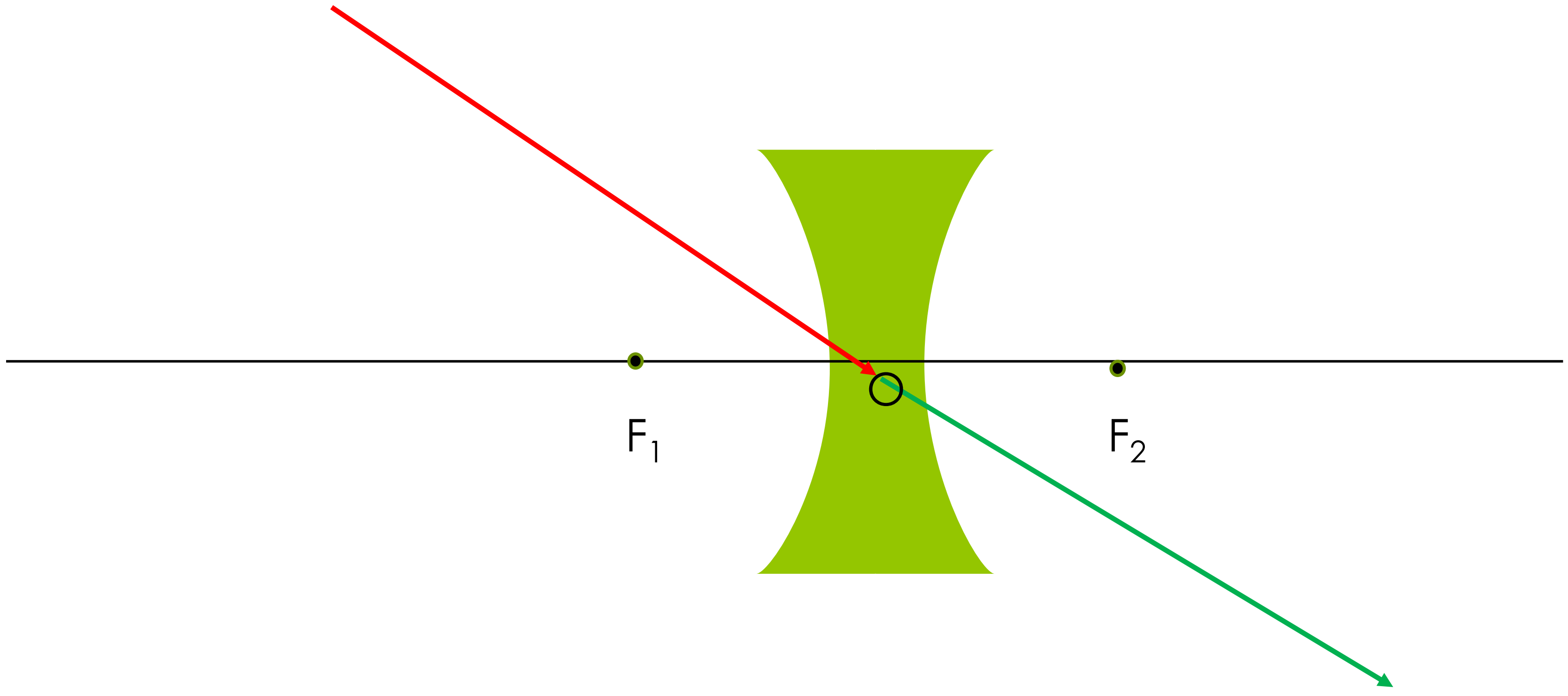
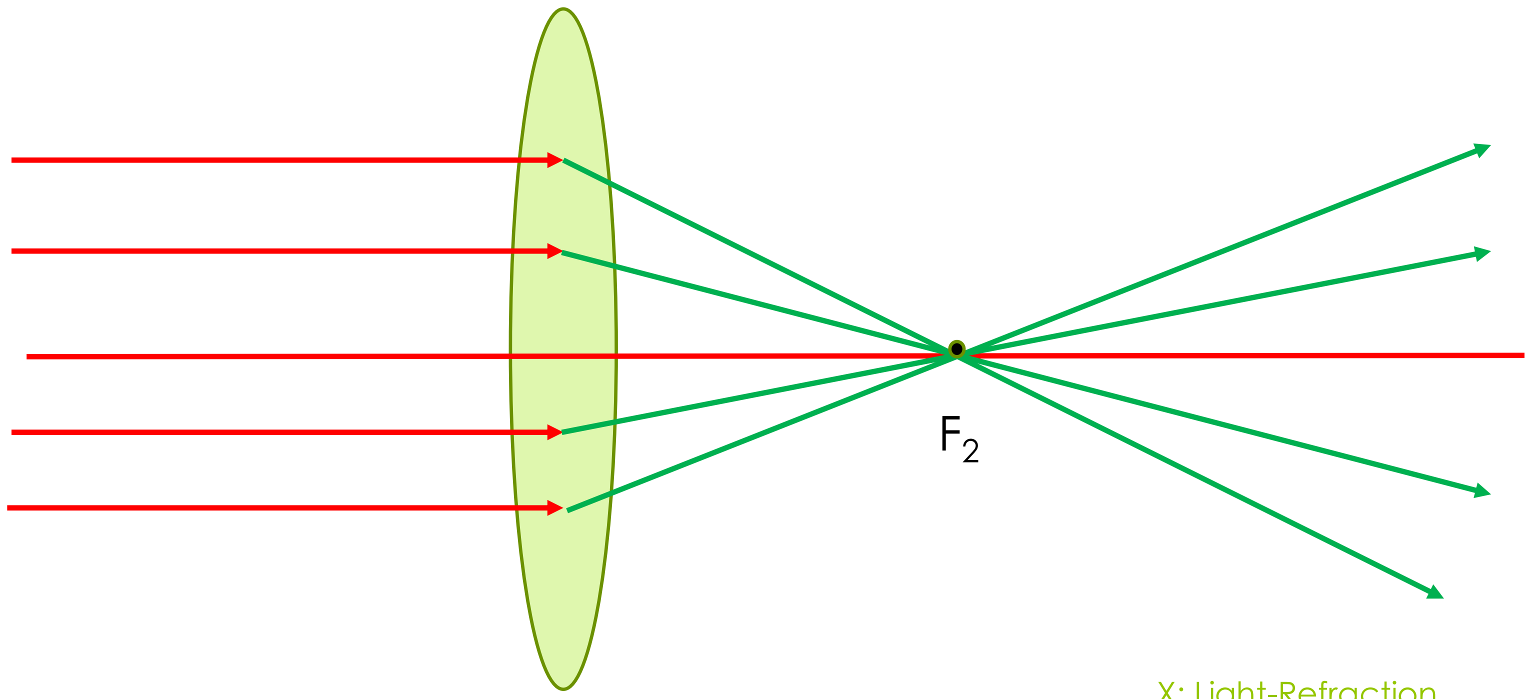


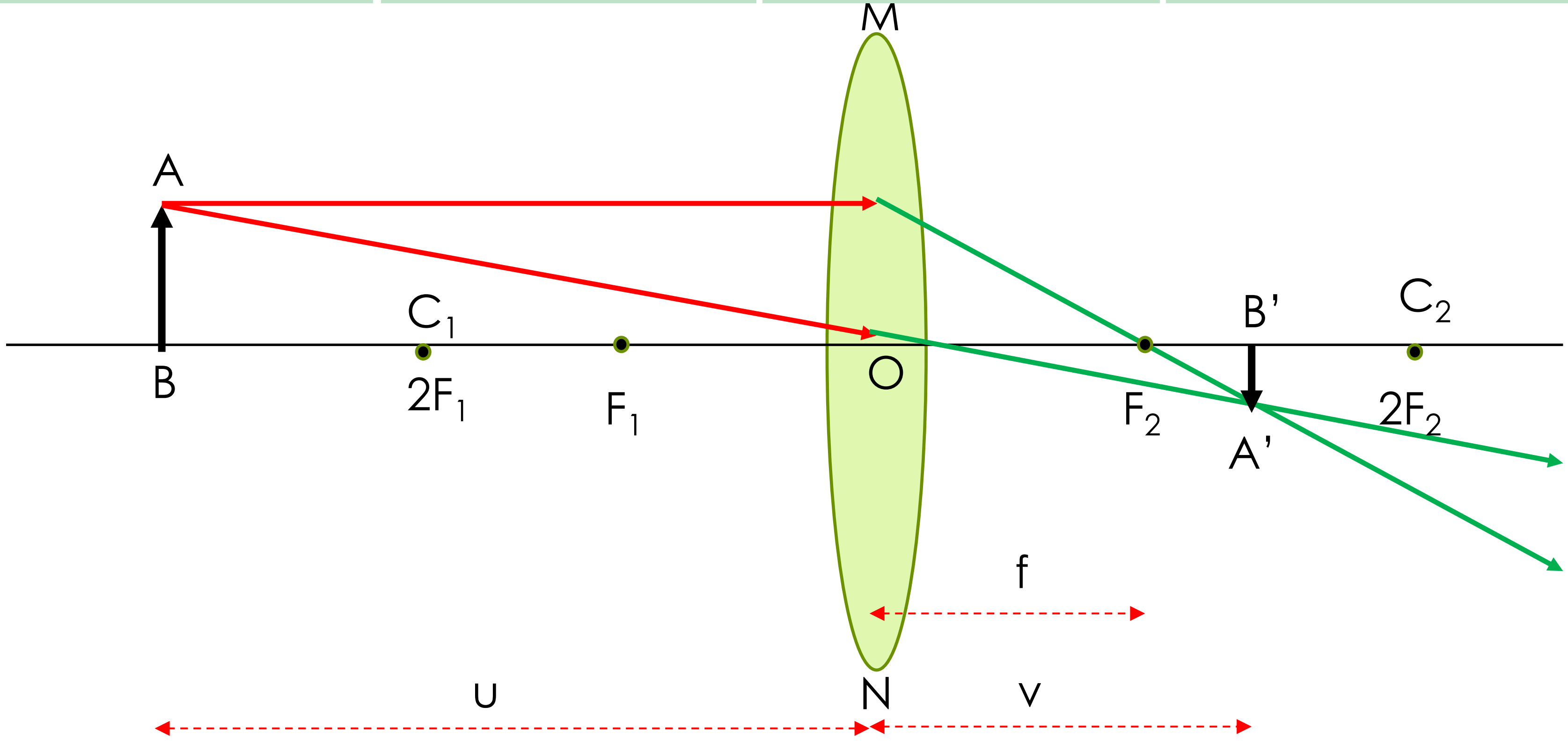
# Image formation by Convex Lens (i)

| Position of the object | Position of the image | Relative size of the image | Nature of the image |
|---|---|---|---|
| At infinity | At focus $F_2$ | Highly diminished, point-sized | Real and inverted |



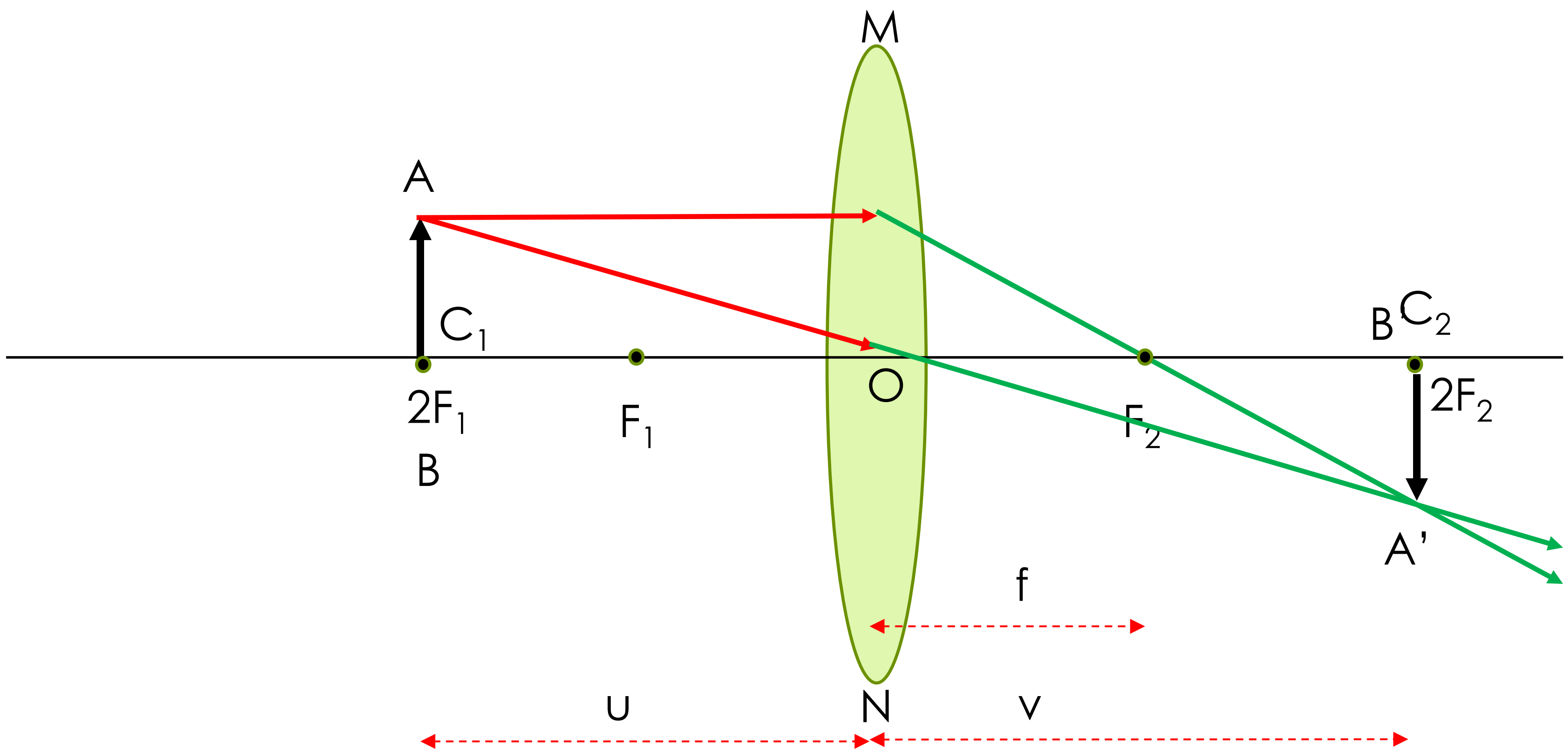
# Image formation by Convex Lens (ii)

| Position of the object | Position of the image | Relative size of the image | Nature of the image |
|---|---|---|---|
| Beyond $2F_1$ | Between $F_2$ and $2F_2$ | Diminished | Real and inverted |



# Image formation by Convex Lens (iii)

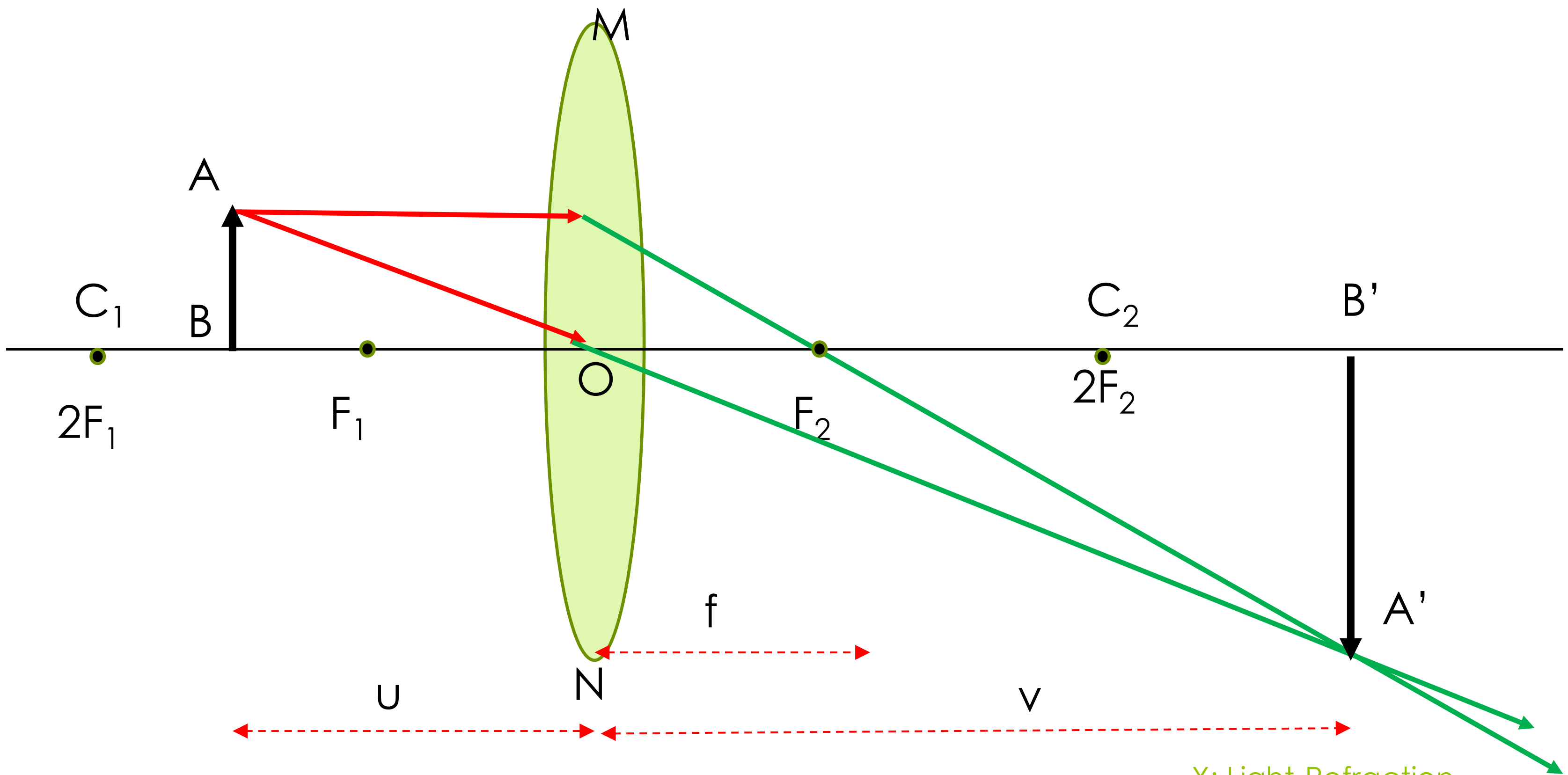
| Position of the object | Position of the image | Relative size of the image | Nature of the image |
|---|---|---|---|
| At $2F_1$ | At $2F_2$ | Same size | Real and inverted |




X: Light-Refraction

# Image formation by Convex Lens (iv)

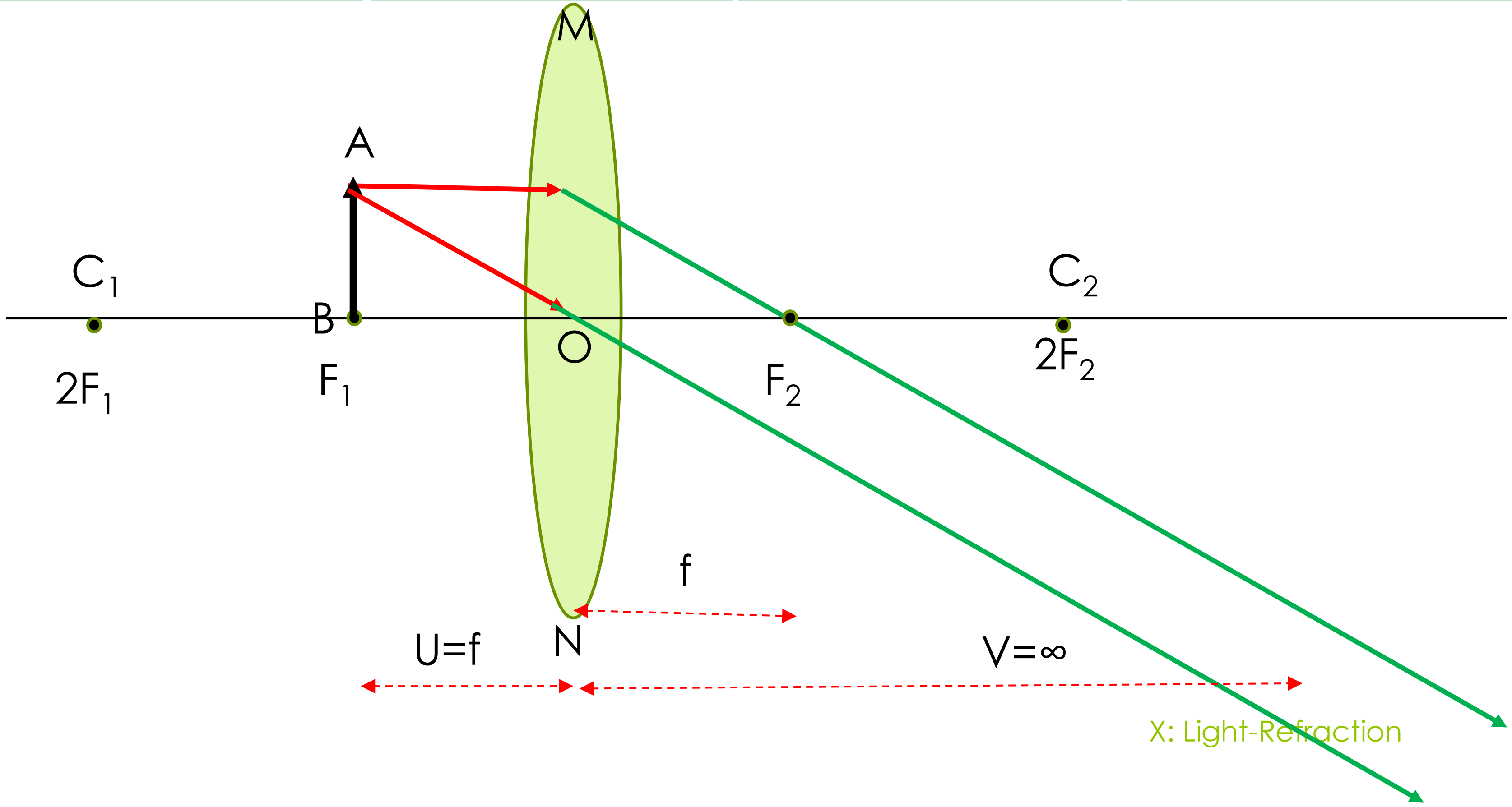
| Position of the object | Position of the image | Relative size of the image | Nature of the image |
|---|---|---|---|
| Between $F_1$ and $2F_1$ | Beyond $2F_2$ | Enlarged | Real and inverted |




X: Light-Refraction

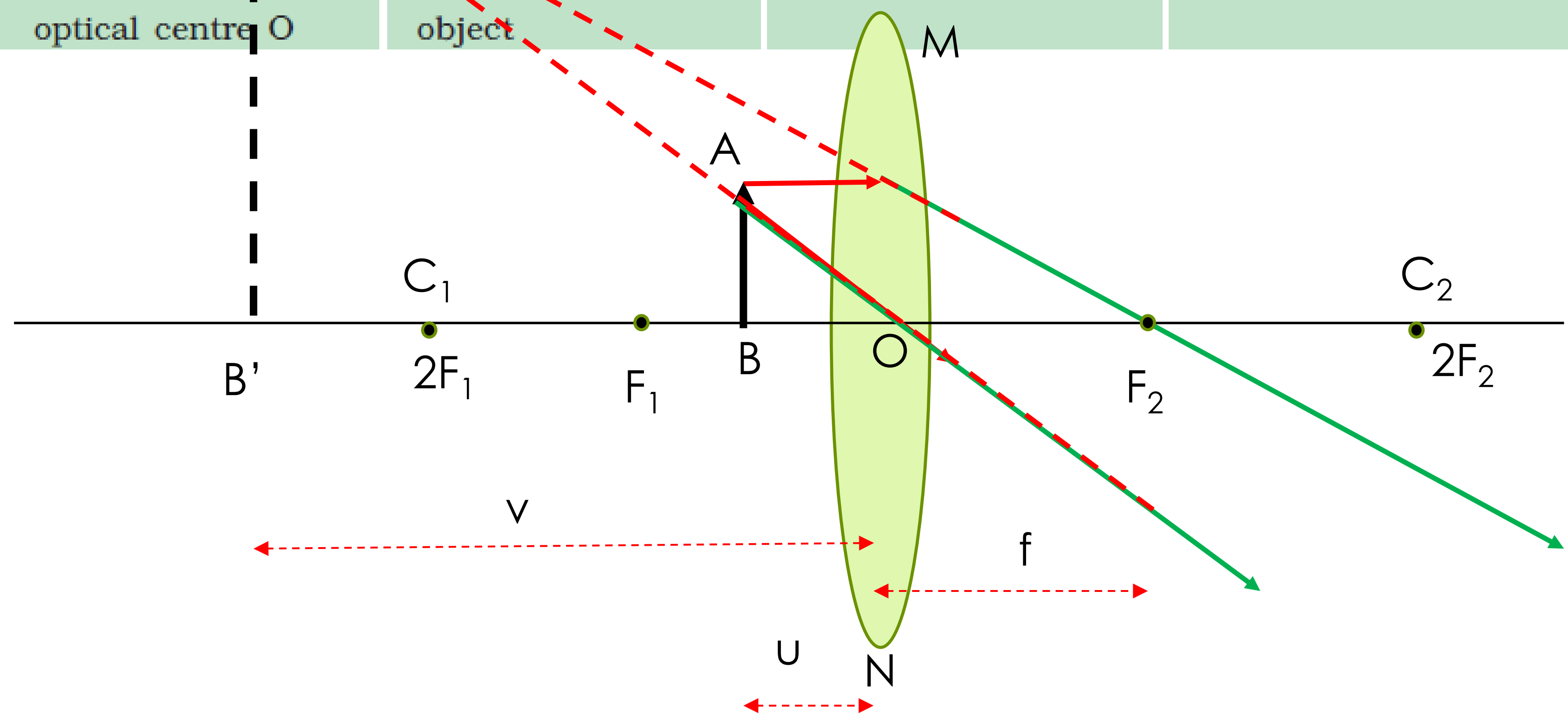
# Image formation by Convex Lens (v)

| Position of the object | Position of the image | Relative size of the image | Nature of the image |
|---|---|---|---|
| At focus $F_1$ | At infinity | Infinitely large or highly enlarged | Real and inverted |



# Image formation by Convex Lens (vi)

| Position of the object | Position of the image | Relative size of the image | Nature of the image |
|---|---|---|---|
| Between focus $F_1$ and optical centre O | On the same side of the lens as the object | Enlarged | Virtual and erect |

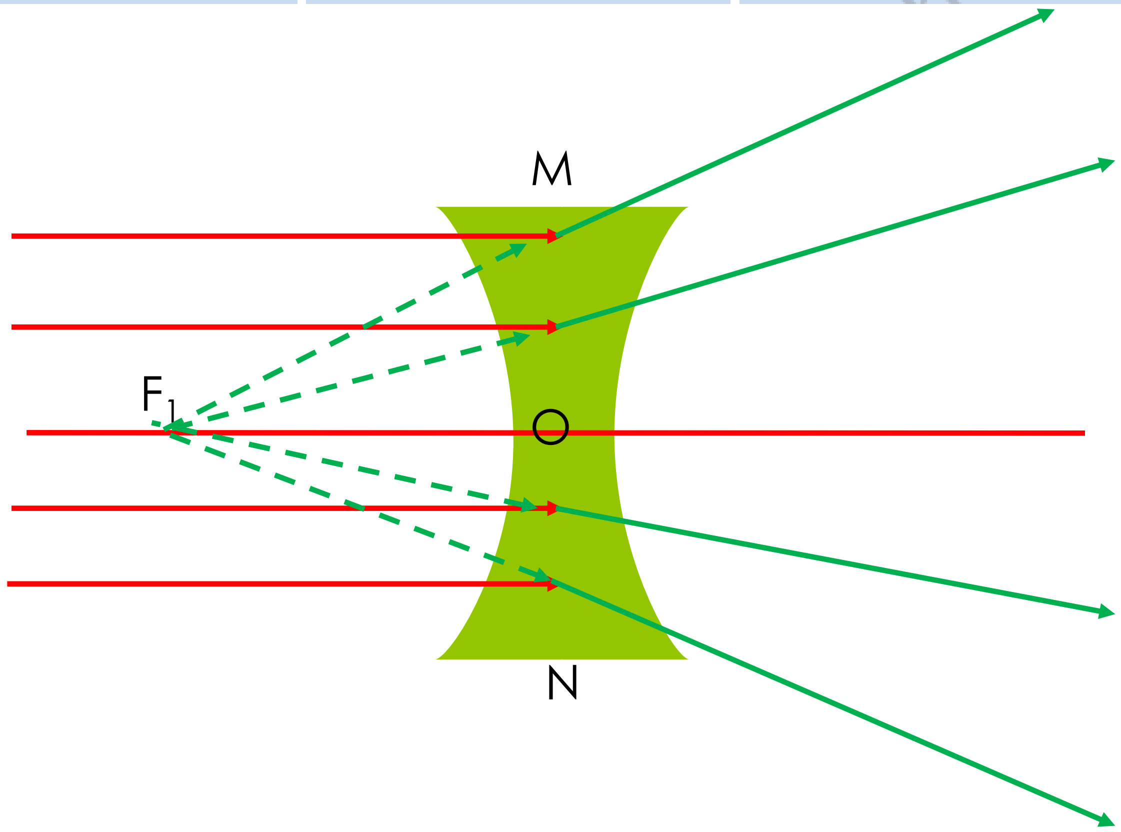


# Uses of Convex Lens

- **Magnifier – Reading Lens, Eye Lens (farsightedness), microscopes, cameras etc…**


# Image formation by Concave Lens(i)

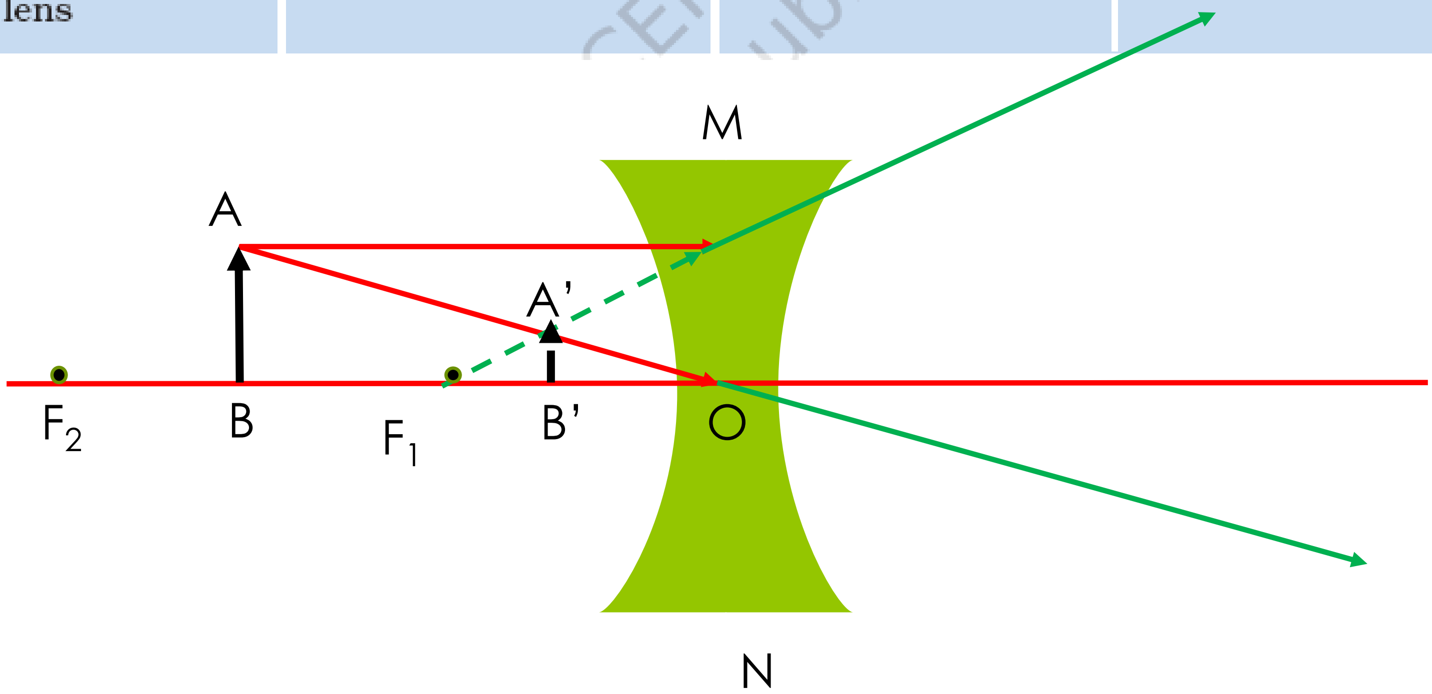
| Position of the object | Position of the image | Relative size of the image | Nature of the image |
|---|---|---|---|
| At infinity | At focus $F_1$ | Highly diminished, point-sized | Virtual and erect |




X: Light-Refraction

# Image formation by Concave Lens(i)

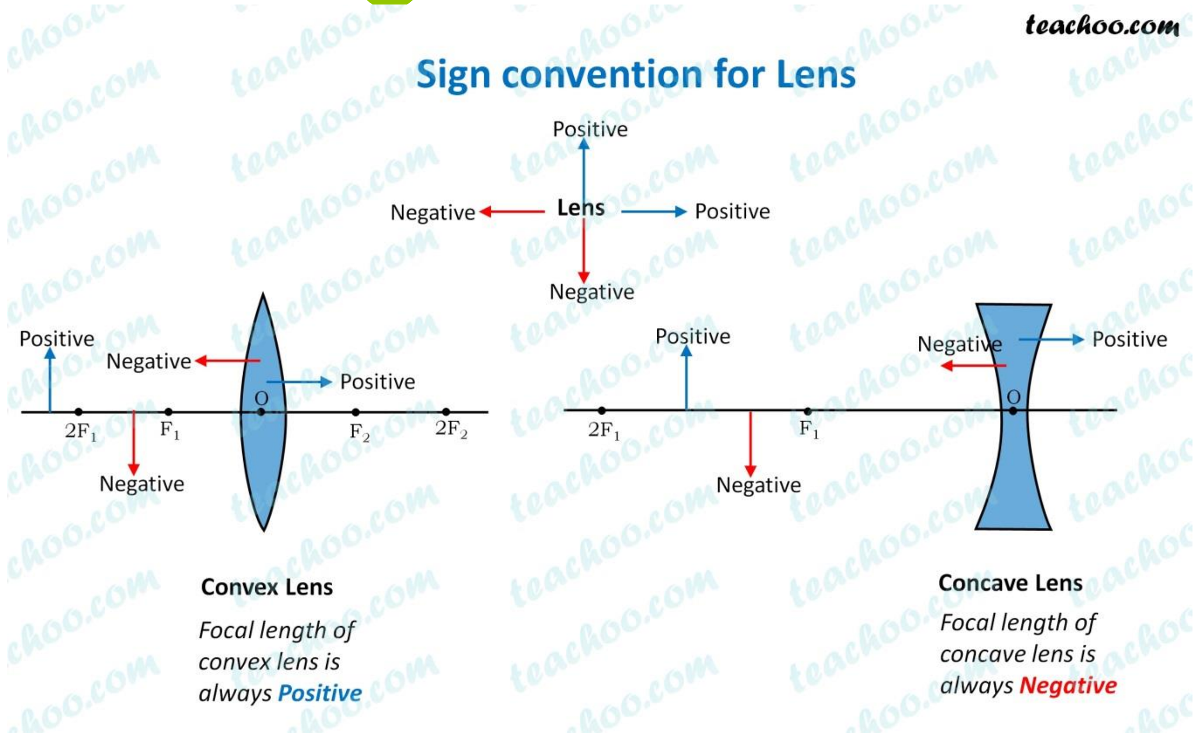
| Position of the object | Position of the image | Relative size of the image | Nature of the image |
|---|---|---|---|
| Between infinity and optical centre O of the lens | Between focus $F_1$ and optical centre O | Diminished | Virtual and erect |



# Uses of Concave Lens

- Telescope and binoculars, eyeglass ( myopia /nearsightedness), peepholes, flashlights, cameras etc…

# Cartesian sign convention




For lenses, we follow sign convention, similar to the one used for spherical mirrors. We apply the rules for signs of distances, except that all measurements are taken from the optical centre of the lens. According to the convention, the focal length of a convex lens is positive and that of a concave lens is negative.

# Lens formula for magnification

- This formula gives the relationship between object distance (*u*), image-distance (*v*) and the focal length (*f* ).
- $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$
- Magnification is represented by the letter *m*. If *h* is the height of the object and *h* is the height of the image given by a lens,
- $m = \frac{height\ of\ the\ object}{height\ of\ the\ image} = \frac{h\prime}{h} = \frac{v}{u}$
- For enlarged image, m will be +ve, for diminished one, m will be –ve.

# Power of a Lens

- The ability of a lens to converge or diverge light rays depends on its focal length.
- For example, a convex lens of short focal length bends the light rays through large angles, by focussing them closer to the optical centre.
- Similarly, concave lens of very short focal length causes higher divergence than the one with longer focal length.
- The degree of convergence or divergence of light rays achieved by a lens is expressed in terms of its power.
- The power of a lens is defined as the reciprocal of its focal length. It is represented by the letter *P*

# Power of a Lens

- Power, $P = \frac{1}{f},$ where f is the focal length
- S.I. Unit of power is diopter (D) when focal length I expressed in metre.
- The ***power of a convex lens is positive and that of a concave lens is negative.***
- Many optical instruments consist of a number of lenses. They are combined to increase the magnification and sharpness of the image.
- The net power (*P* ) of the lenses placed in contact is given by the algebraic sum of the individual powers *P1*, *P2*, *P3*, … as ***P = P1 + P2 + P3 + …***

# Refraction at a spherical surface

- Thank You.
- Ref: NCERT Text Book, Class X,XII Physics