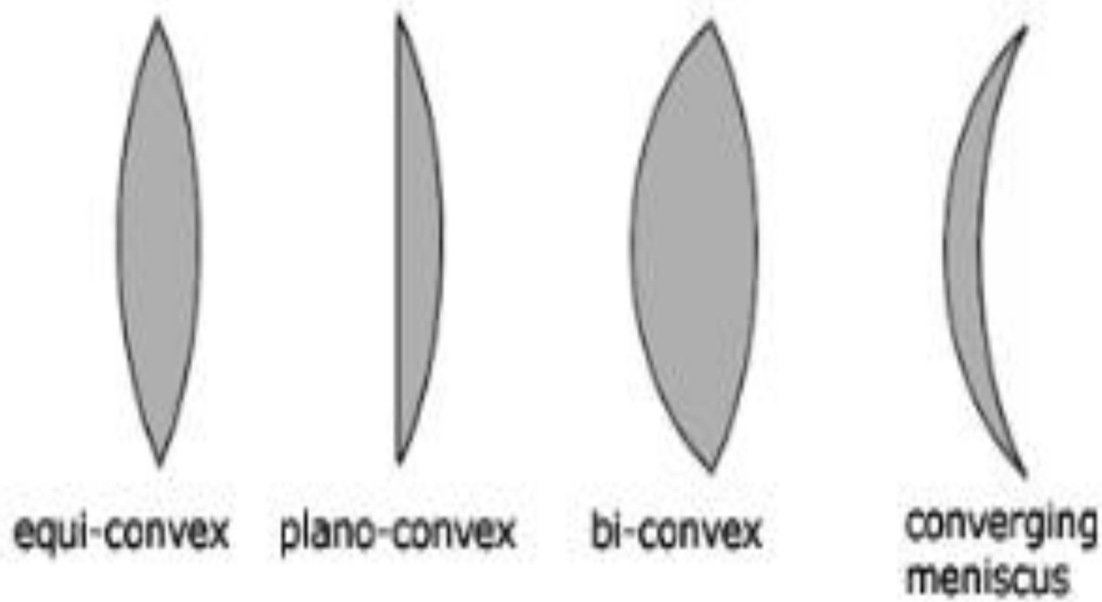
Refraction of Lenses

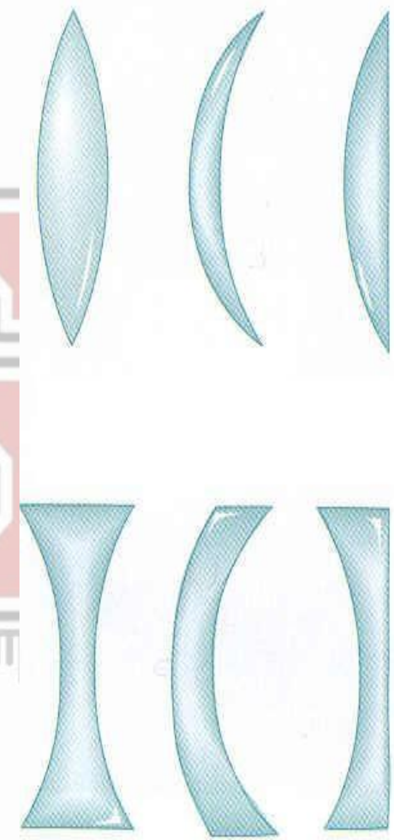
Convex Lenses

Types of lens

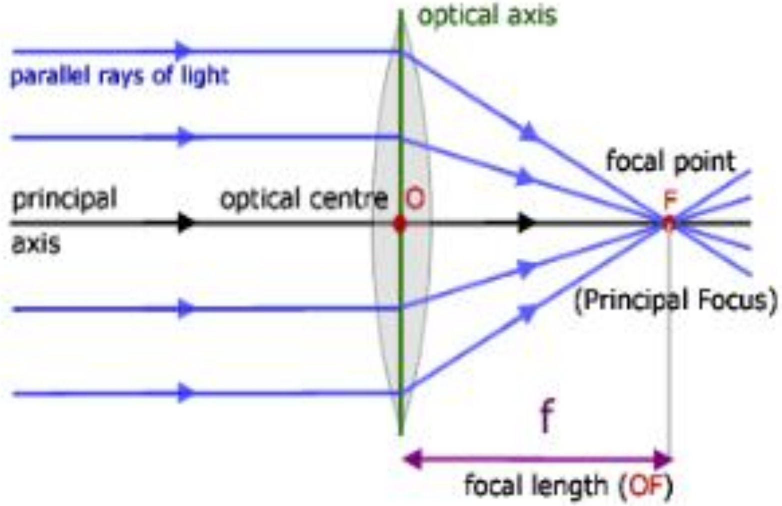


All four types of convex lens are converging lenses. That is, they bring parallel rays of light to a focus, producing a real image.

A typical thin **lens** consists of a piece of glass or plastic, ground so that each of its two refracting surfaces is a segment of either a sphere or a plane. Lenses are commonly used to form images by refraction in optical instruments, such as cameras, microscopes, and telescopes. The equation that relates object and images distances for a lens
is virtually identical to the mirror equation.
Lenses can be placed in two groups. The lenses that are thicker at the center than at the tim are called **converging lenses**, and those that are thinner at the center than at the rim are **diverging lenses**.



Basic ray diagram



The basic ray diagram for a convex lens introduces a number of important terms:

principal axis - the line passing through the centres of curvature of the lens

principal focus - a point on the principal axis where rays of light parallel to the principal axis converge

focal length - the horizontal distance between the principal focus and the optical centre of the lens

optical centre - an imaginary point inside a lens through which a light ray is able to travel without being deviated

centre of curvature - the centre of the sphere of which the lens surface is part

Power of a lens

$$P = \frac{1}{f}$$

The power ***P*** of a lens is the inverse of its focal length ***f***. Since ***f*** is measured in metres 'm' the units of lens power are m^{-1}. **What we call- Diopters/ D**

The power also depends on the type of lens. **Convex** lenses have **positive** powers, while **concave** lenses all have **negative** powers.

For example, a 10 cm focal length convex lens has a power of $+10\ m^{-1}$; while a 20 cm focal length concave lens has a power of $-5\ m^{-1}$.

Ray diagrams

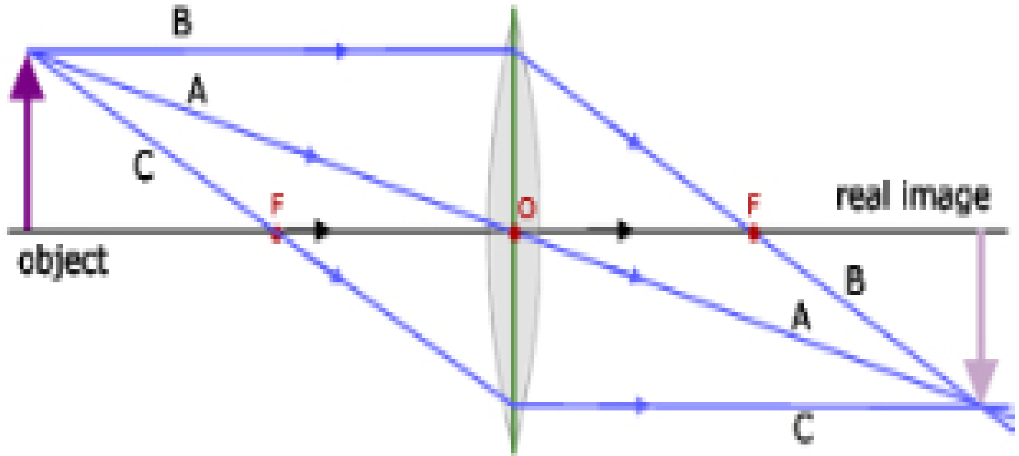
To understand ray diagrams it is important to know something about images. Images come in two categories :

real images - are produced from actual rays of light coming to a focus (eg a film projected onto a screen)

virtual images - are produced from where rays of light appear to be coming from (eg a magnifying glass image)

Ray diagrams are constructed by taking the path of three distinct rays from a point on the object:

note - the lens is considered to be so thin as to be represented by the axis of the lens(green)

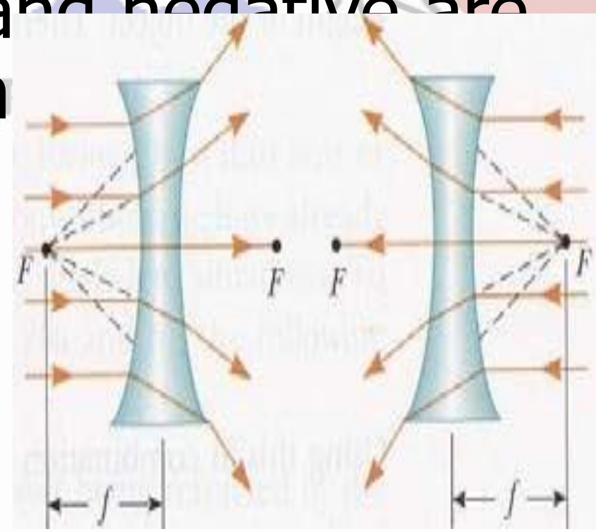


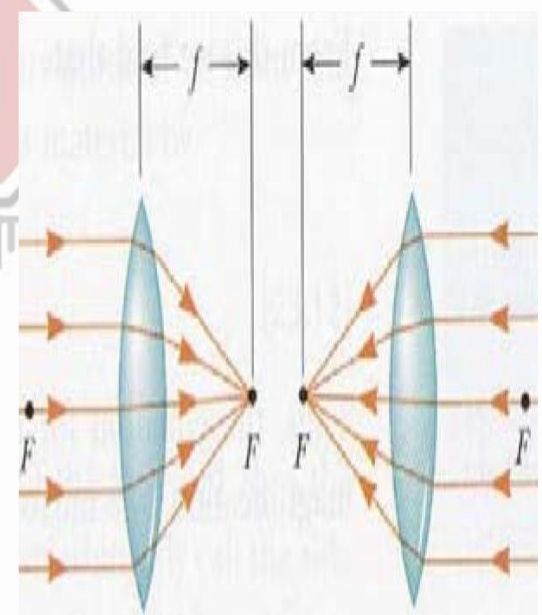
A) a ray passing through the optical centre of the lens

B) a ray parallel to the principal axis, which refracts through the lens, passing through the principal focus

C) a ray passing through the principal focus(on the same side as the object) and being refracted through the lens, emerging parallel to the principal axis

- The **focal length, f,** is defined as the image distance that corresponds to an infinite object distance. Note that a converging lens has a positive focal length, and a diverging has a negative focal length. Hence the names positive and negative are often given to th

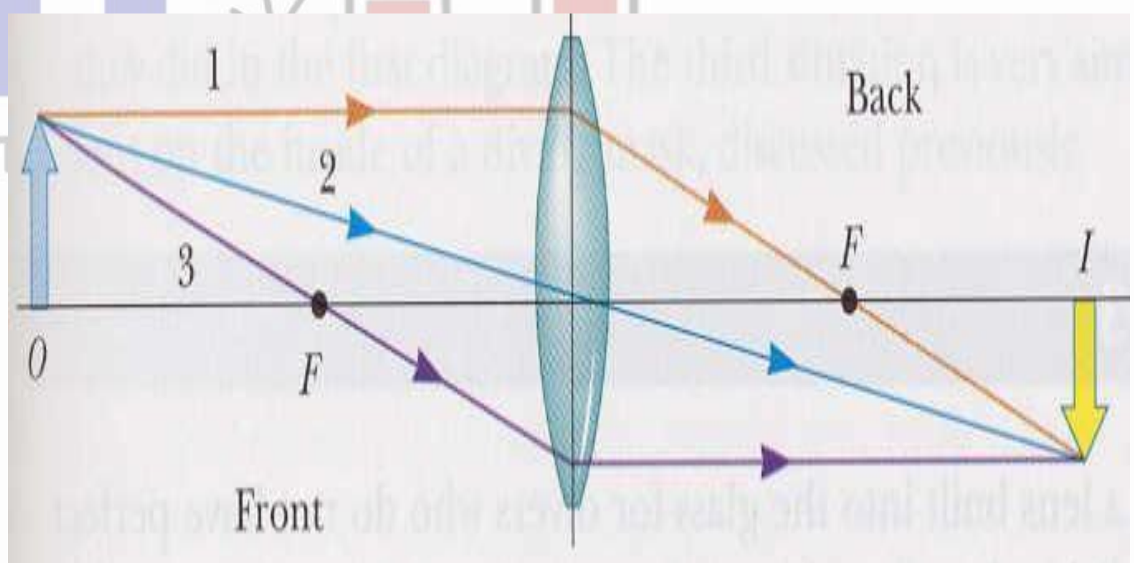


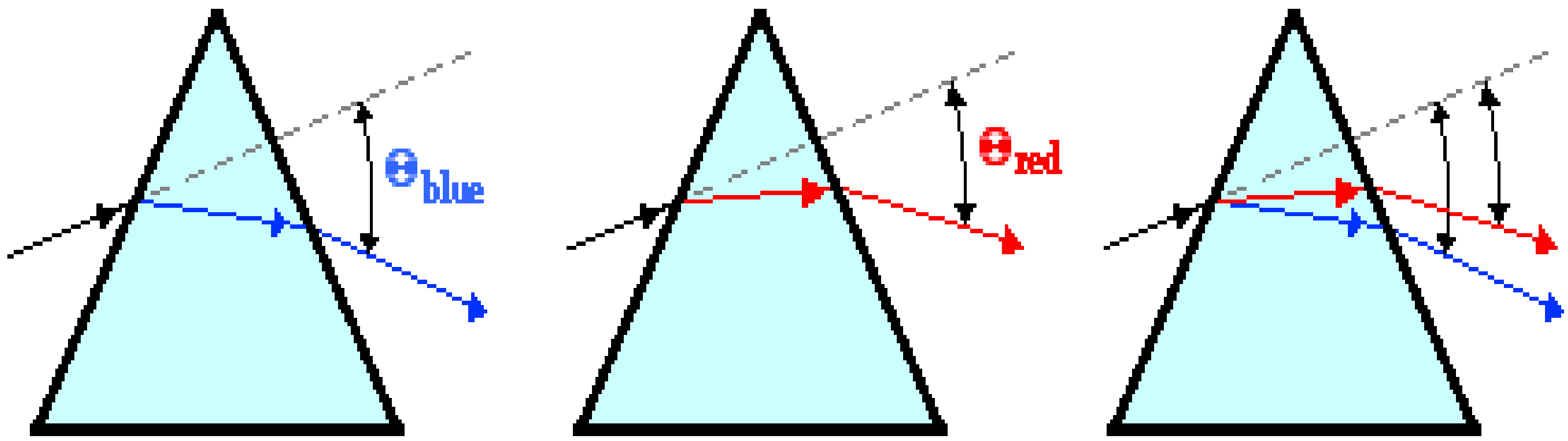


- A converging lens of focal length 10 cm forms images of object placed 30 cm from the lens. Find the image distance and describe the image.

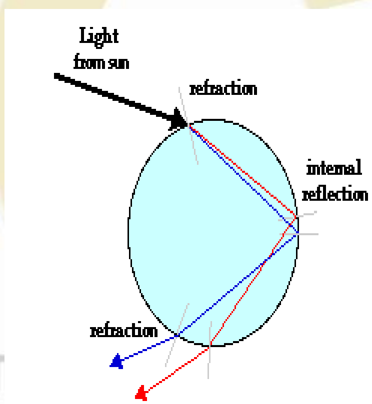
$$\begin{aligned}\frac{1}{p}+\frac{1}{q} &= \frac{1}{f}\\ \frac{1}{30\text{ cm}}+\frac{1}{q} &= \frac{1}{10\text{ cm}}\\ q &= 15\text{ cm}\\ M &= -\frac{q}{p} = -\frac{15\text{ cm}}{30\text{ cm}} = -0.5\end{aligned}$$

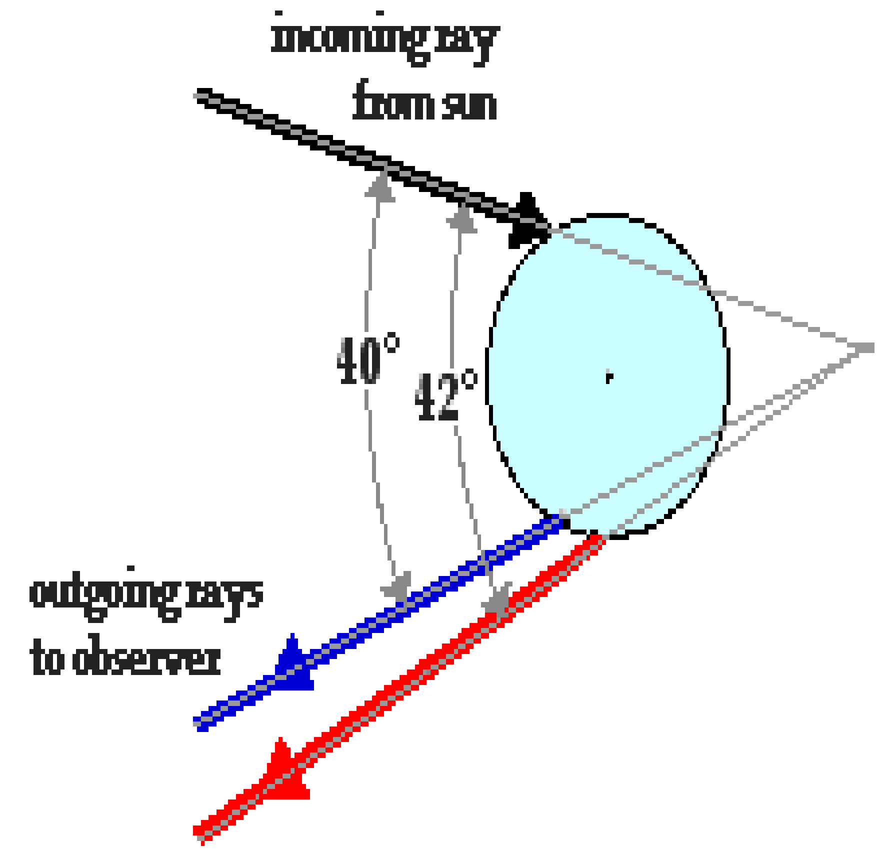
The image is reduced in height by one half, and the negative sign for M tells us that the image is inverted.

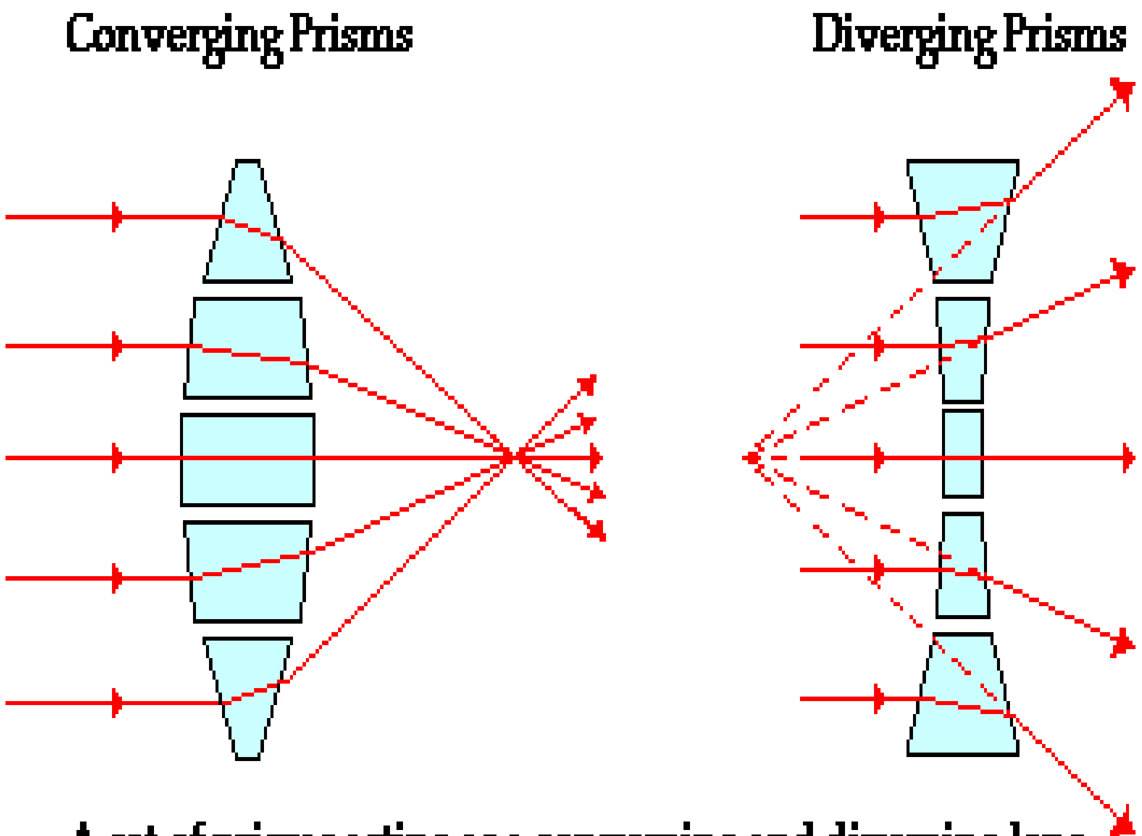




Blue light refracts more than red light due to the difference in wavelength. This causes blue light to deviate from its original path by a greater angle than the red light.


Light
from sun
refraction
internal
reflection
refraction


incoming ray
from sun
40°
42°
outgoing rays
to observer



A set of prisms acting as a converging and diverging lens.

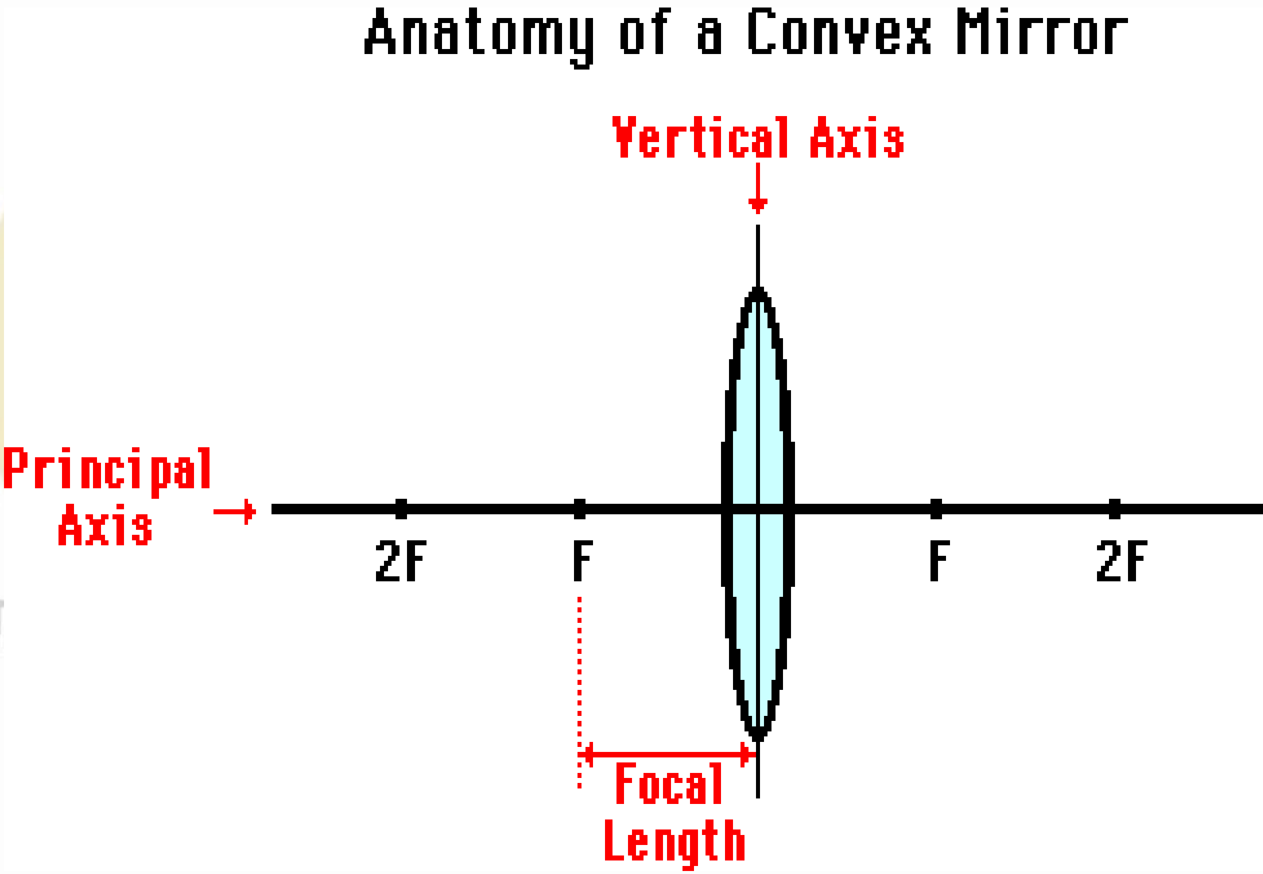
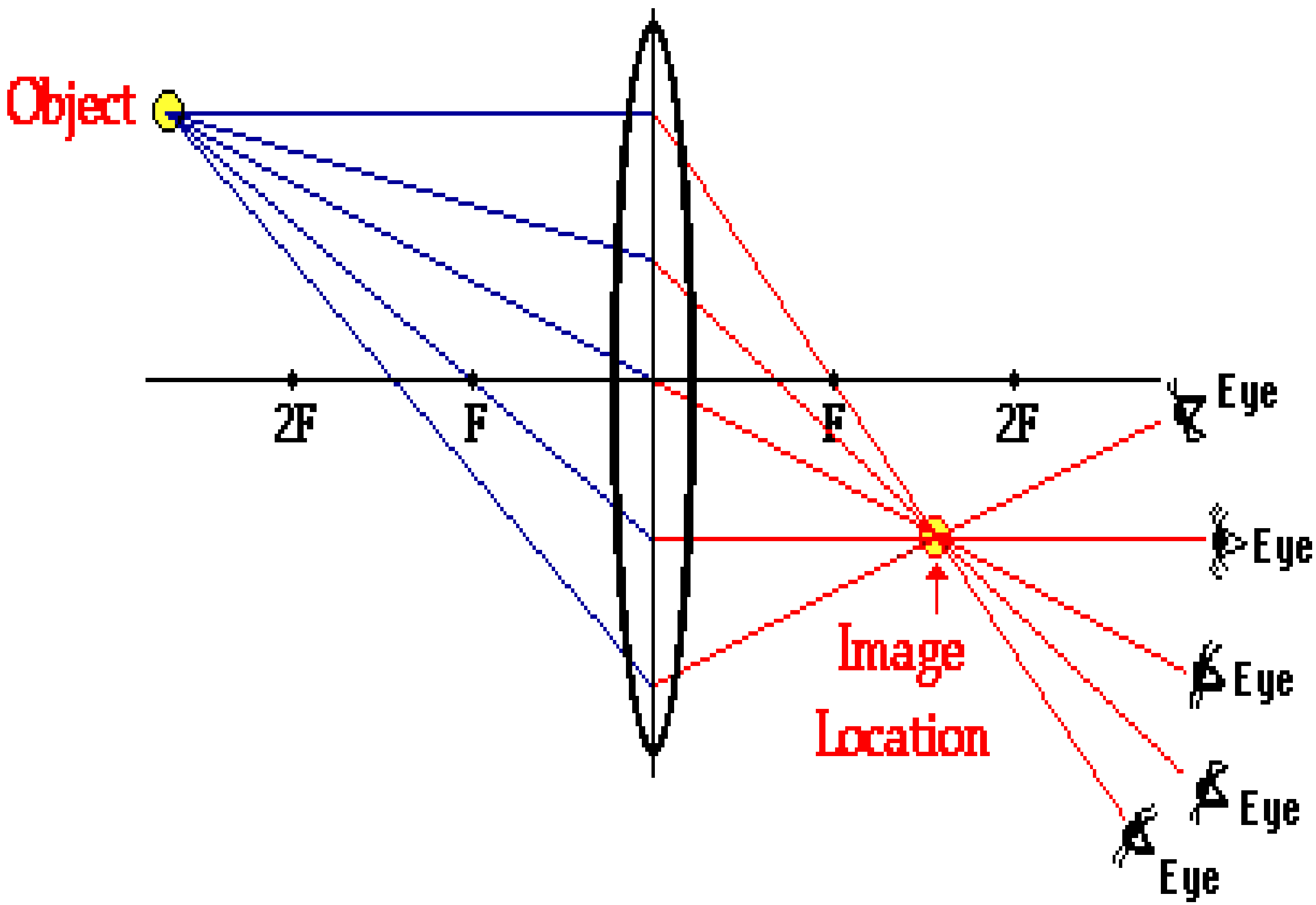

Anatomy of a Convex Mirror
Vertical Axis
Principal Axis
2F
F
F
2F
Focal Length

Image Formation by a Converging Lens



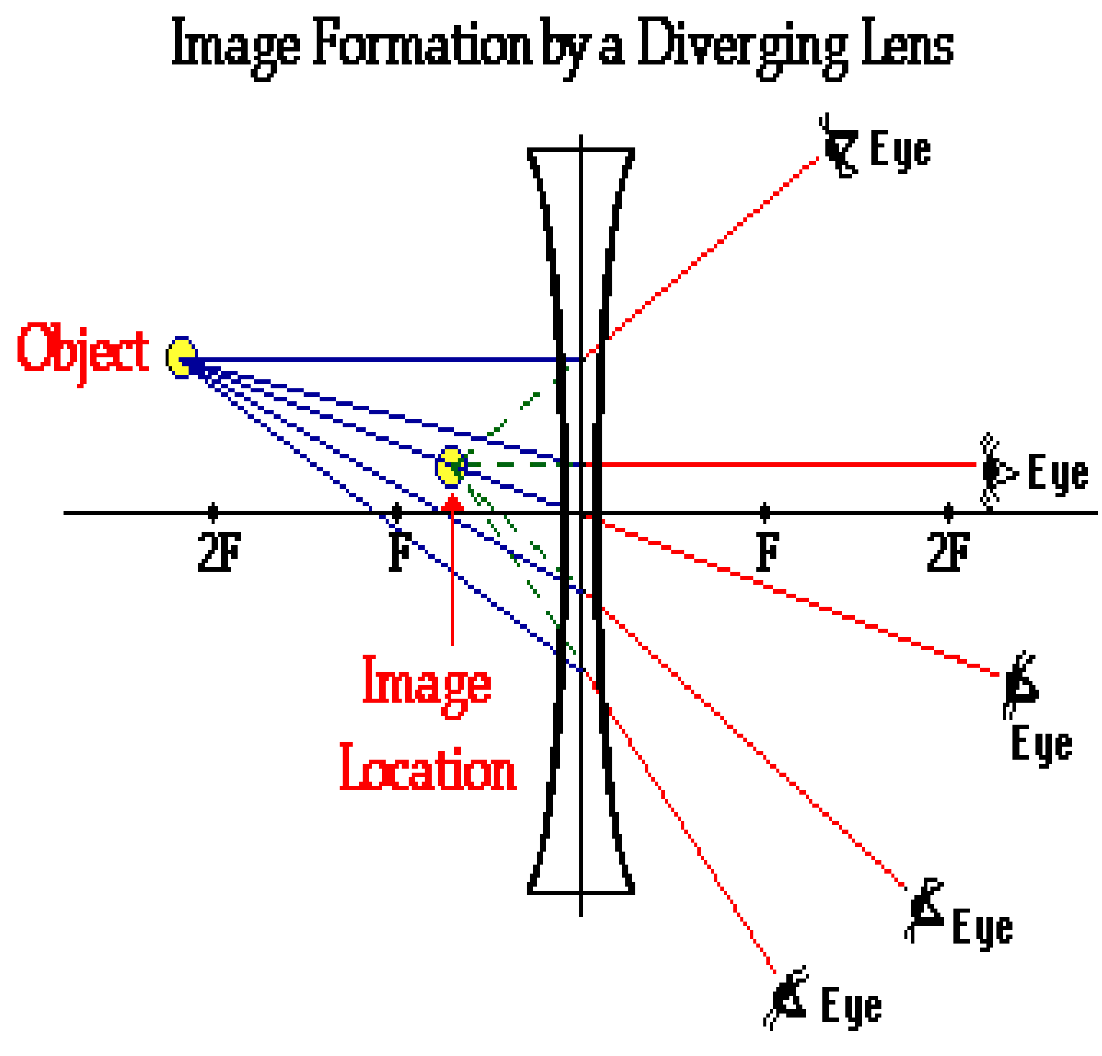
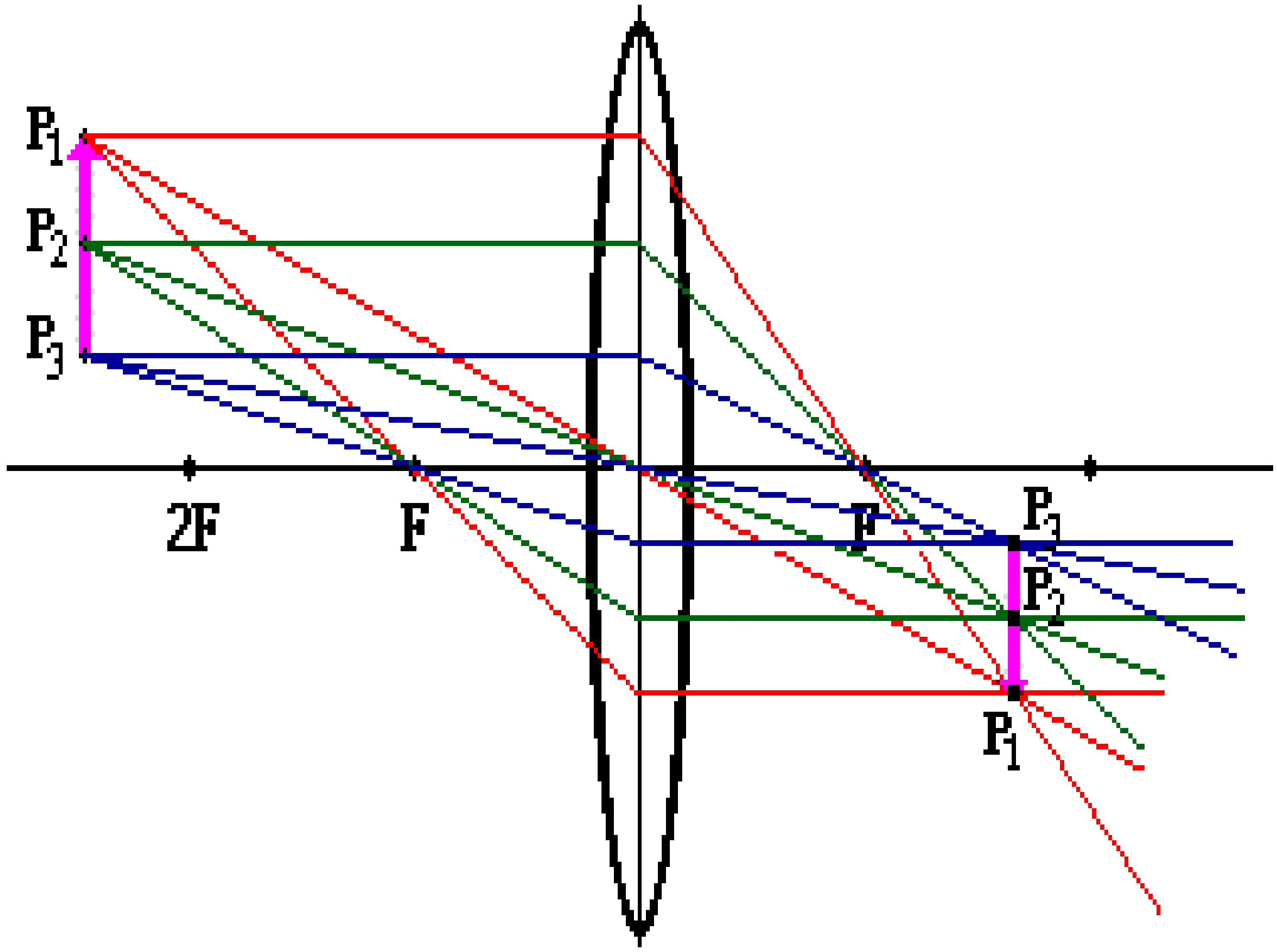
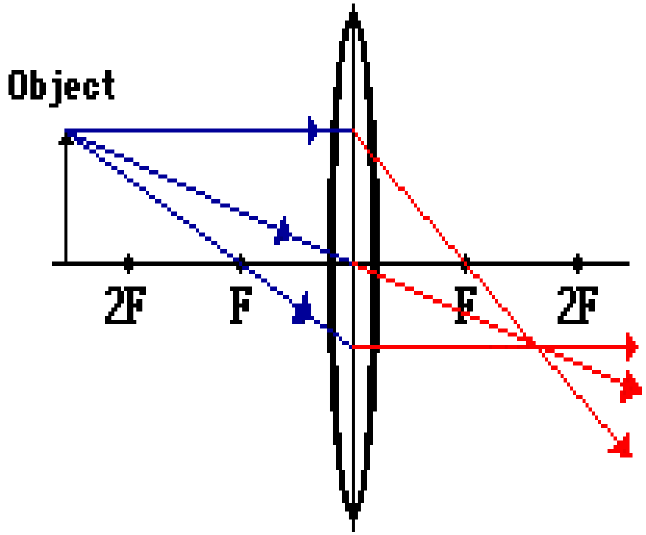
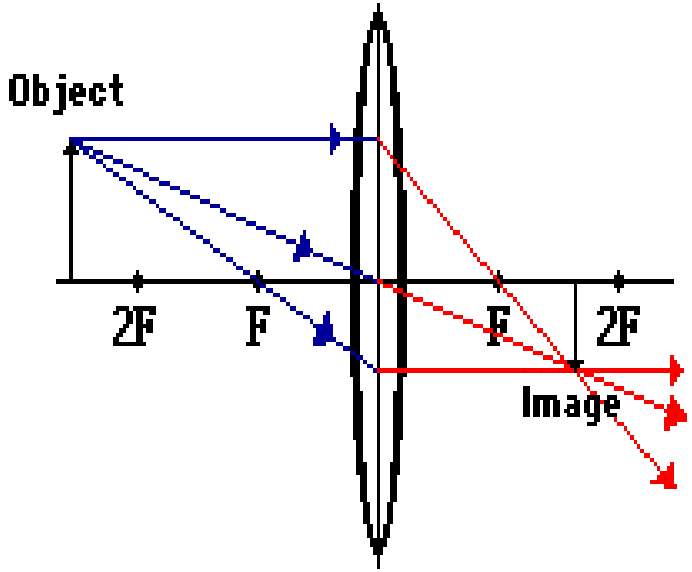


Image Formation by a Diverging Lens
Object
Eye
Eye
2F
F
F
2F
Eye
Image
Location
Eye
Eye

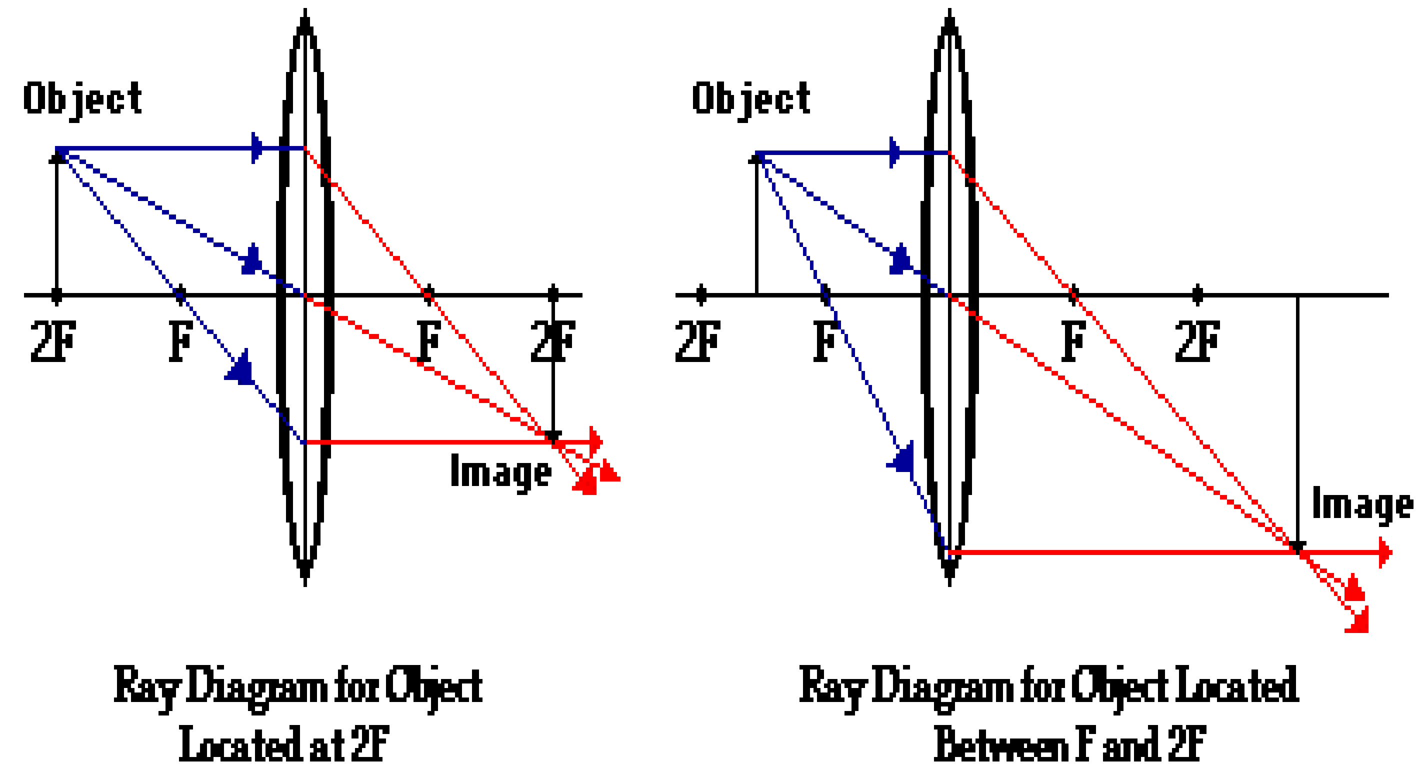


All the rays of light emanating from each individual point on the object will refract and intersect at a single point in space. An image is created - the image is merely a replica or reproduction of the object.



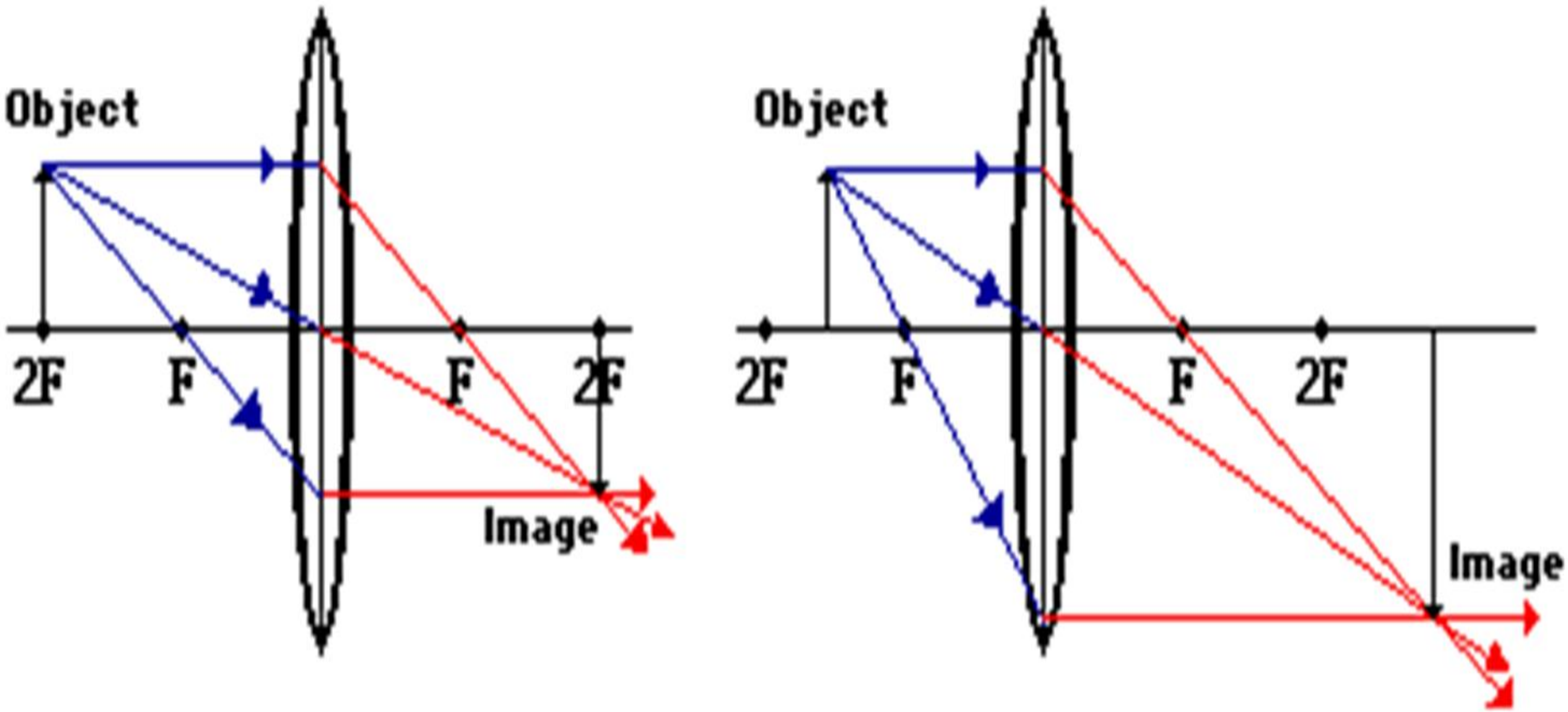


When U>2F, the Image formed is Real, Inverted & Diminished.



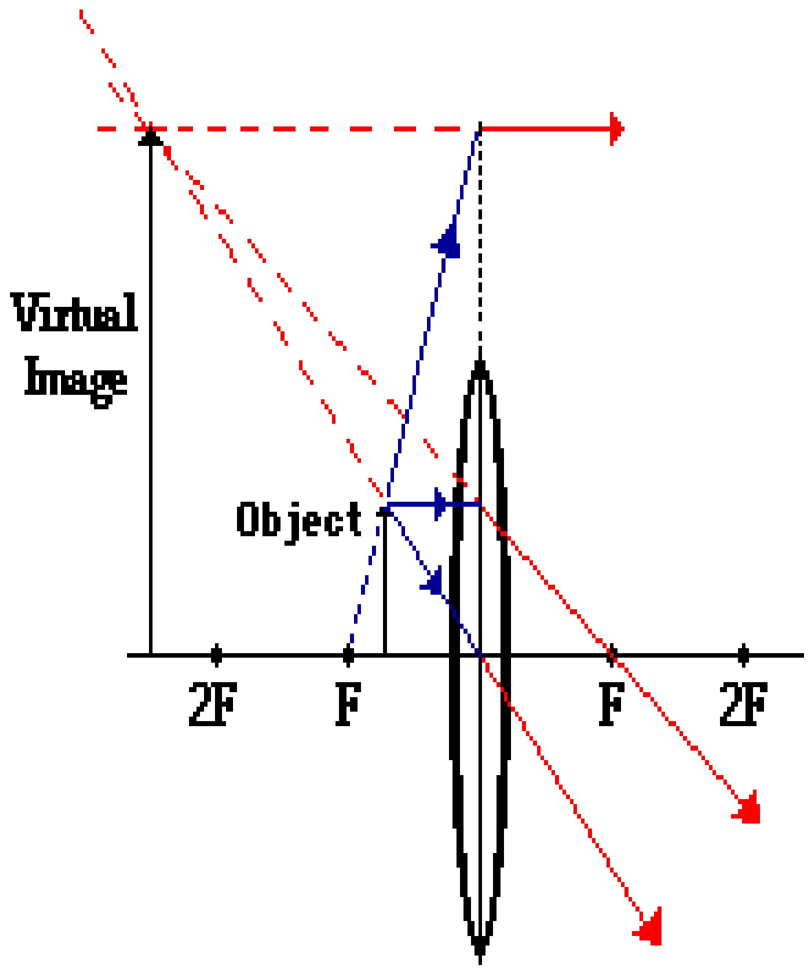
When U=2F, the Image formed is Real, Inverted & Same size.

When 2F >U>F, the Image formed is Real, Inverted & Magnified.



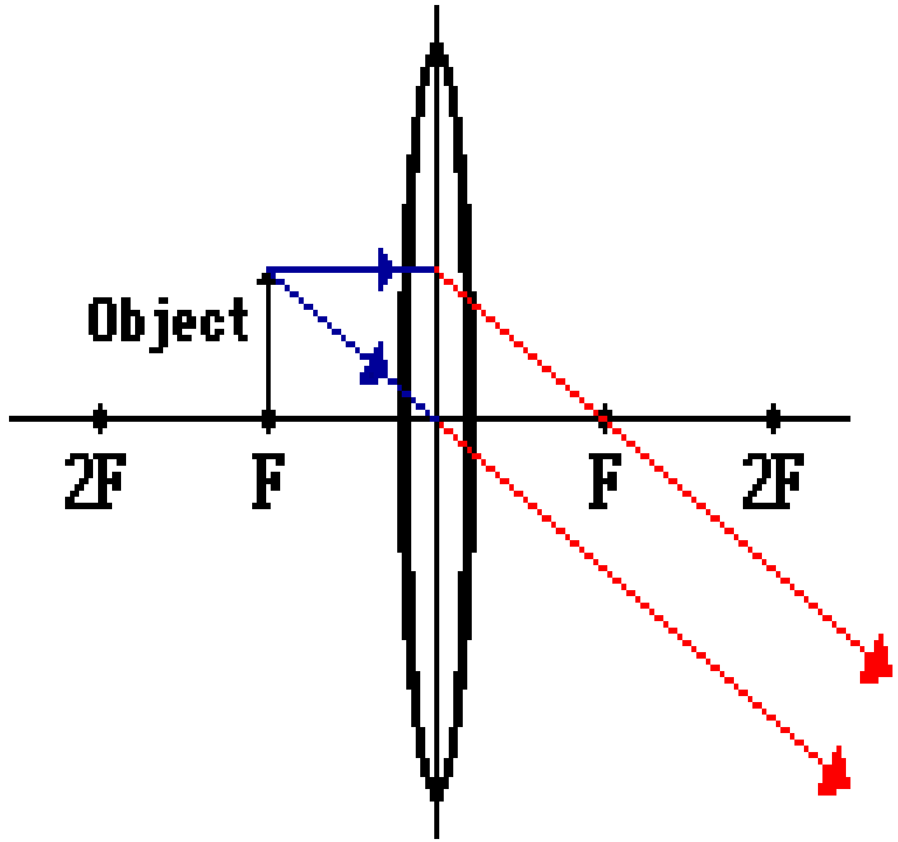
Ray Diagram for Object Located at 2F

Ray Diagram for Object Located Between F and 2F



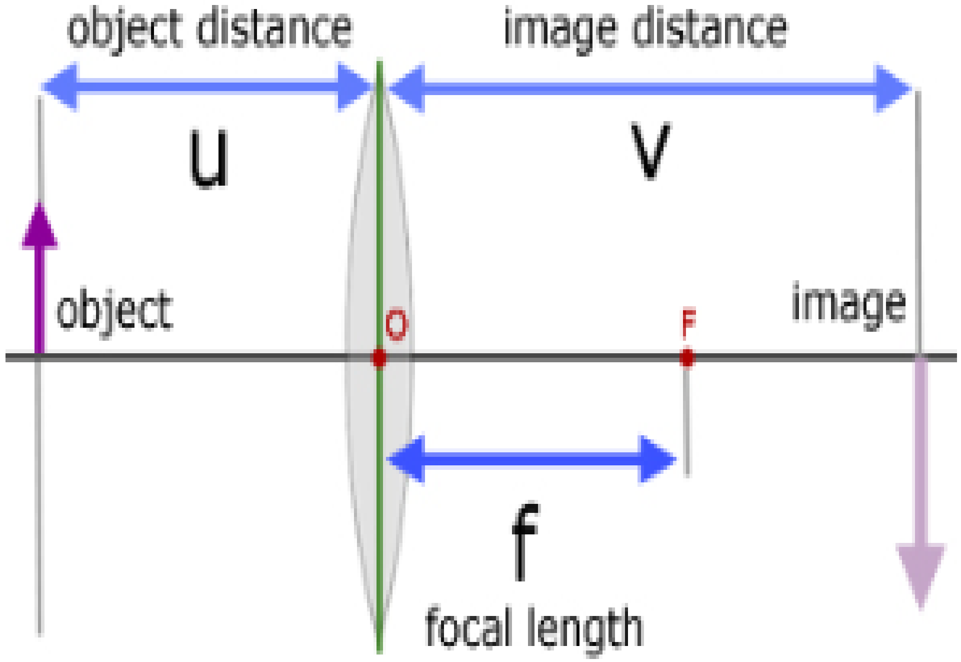
Ray Diagram for Object Located in Front of F

When U=F, the Image formed is Real, Inverted & Highly Magnified.



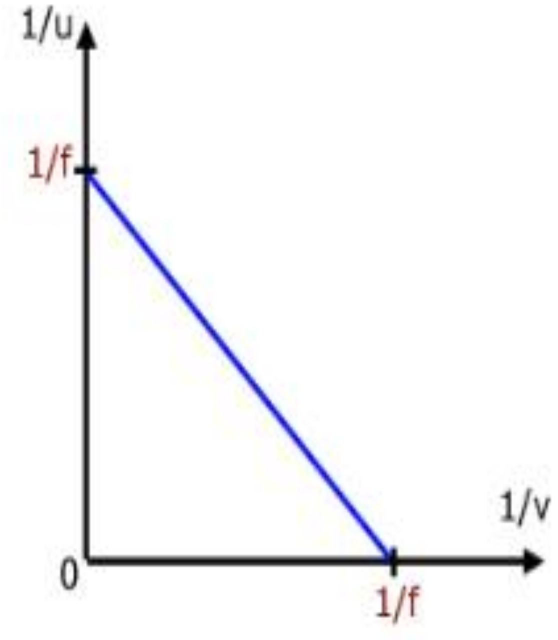
Ray Diagram for Object Located at F
(an image is not formed)

The Lens Formula



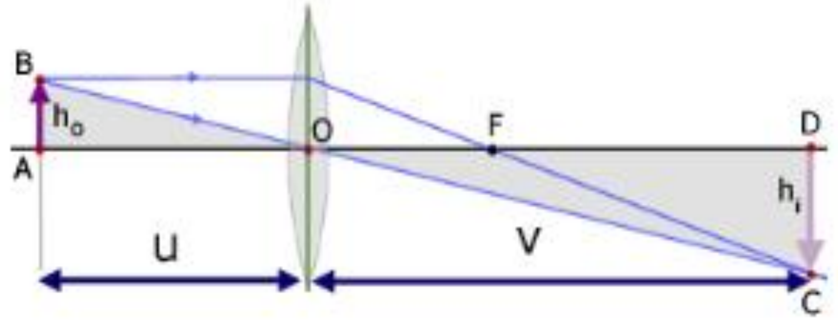
$$1/v - 1/u = 1/f$$

The focal length *f* of a lens can be found quite accurately by moving an illuminated object infront of a lens so that an image is cast on a screen. By taking readings of image and object distances for different positions, a graph can be drawn.



Plotting 1/u against 1/v gives a straight line with a negative gradient. The focal length can be found from the intercept, which is 1/f on both the x and y axes.

Magnification



Magnification (***m***) is simply the image height divided by the object height.

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

To obtain a relation involving object distance (***u***) and image distance (***v***), consider the image formed by two rays from a point on the object.

Triangles **AOB** and **COD** are similar.

Therefore,

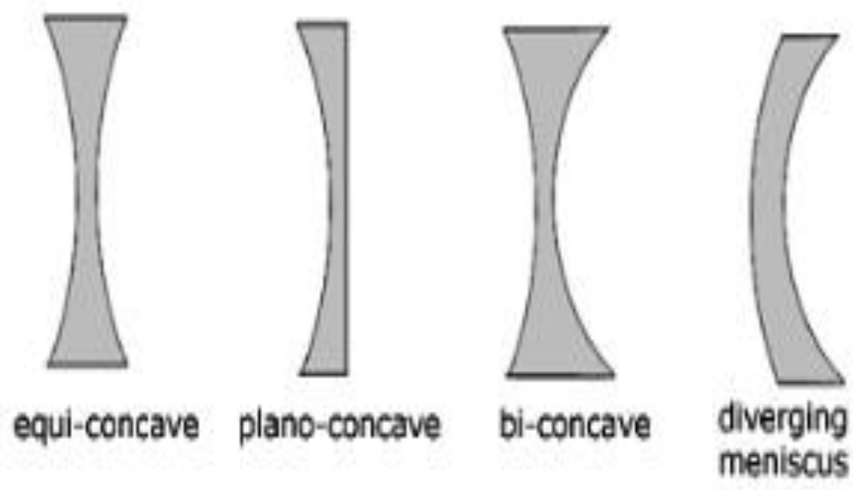
$$\frac{CD}{AB} = \frac{DO}{AO}$$

$$\frac{h_i}{h_o} = \frac{v}{u}$$

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

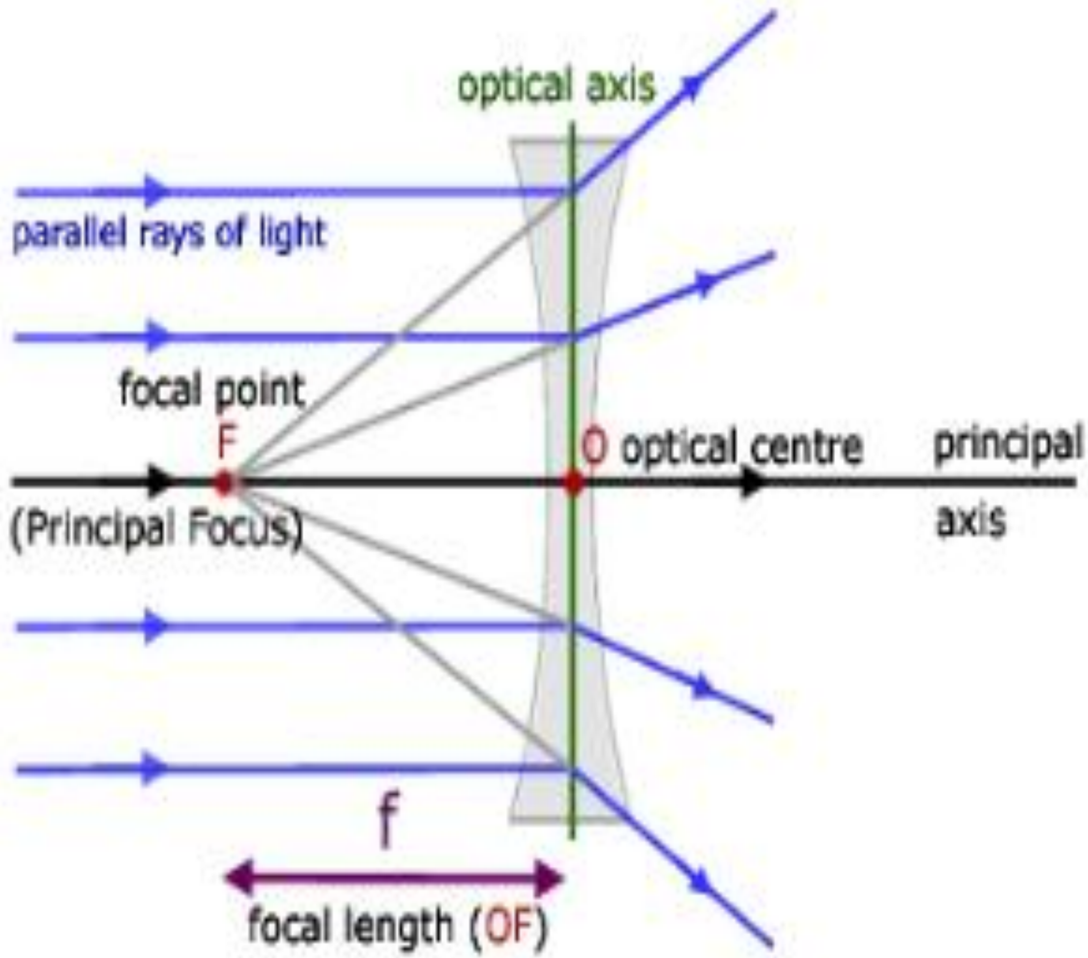
Concave Lenses

Types of lens

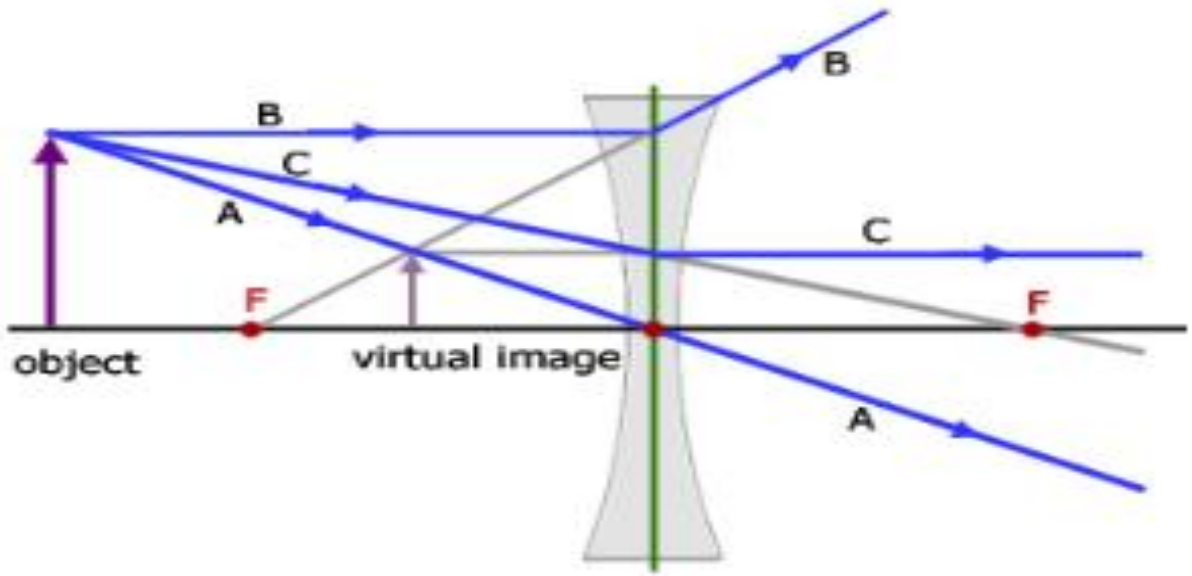


All four types of concave lens are diverging lenses. That is, they diverge parallel rays of light from a focus, producing a virtual image.

Basic ray diagram



RAY DIAGRAMS



A) a ray passing through the optical centre of the lens

B) a ray parallel to the principal axis, which refracts through the lens and appears to have come from the principal focus

C) a ray heading towards the principal focus(on the opposite side of the lens) and being refracted through the lens, emerging parallel to the principal axis

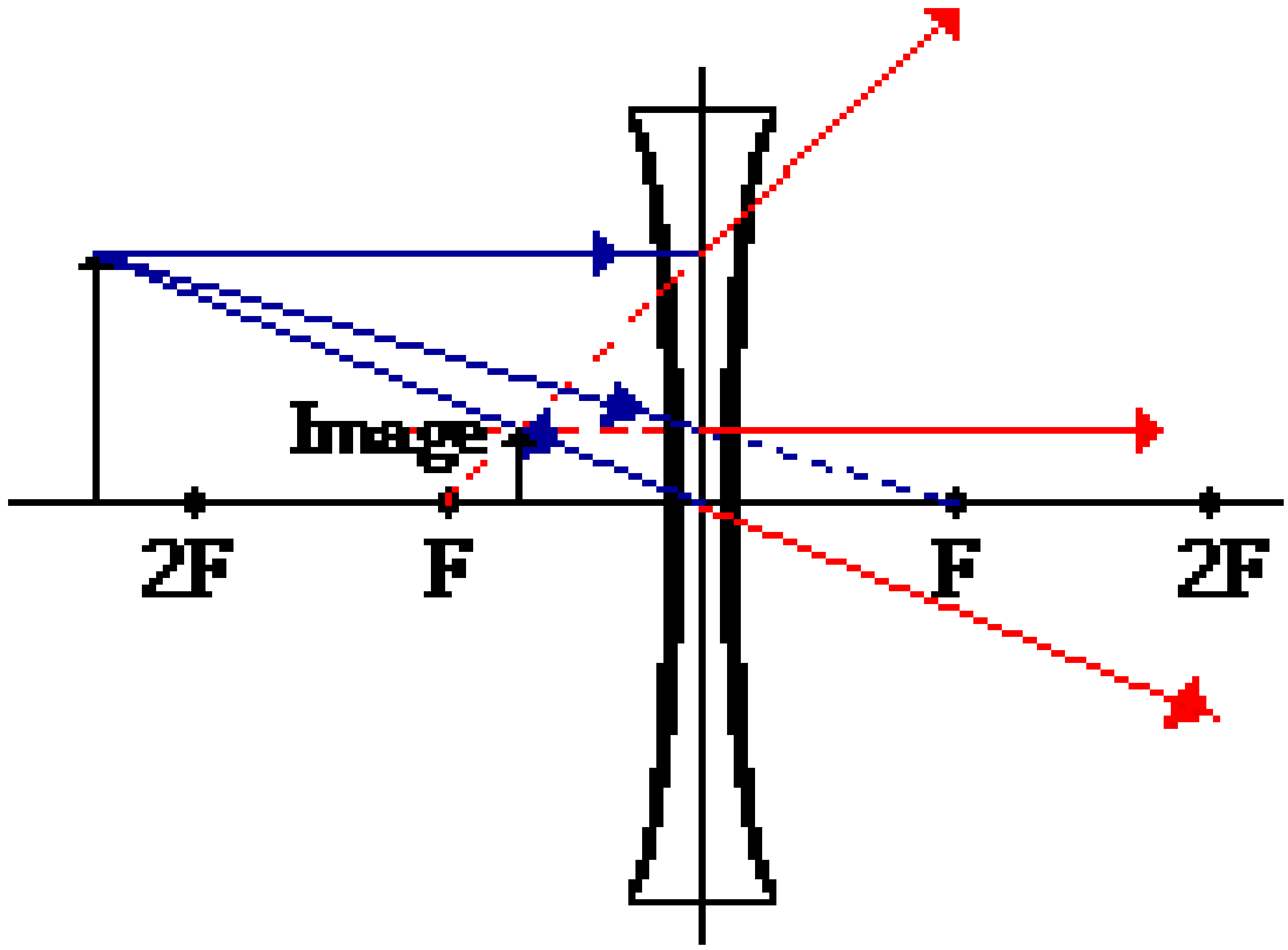
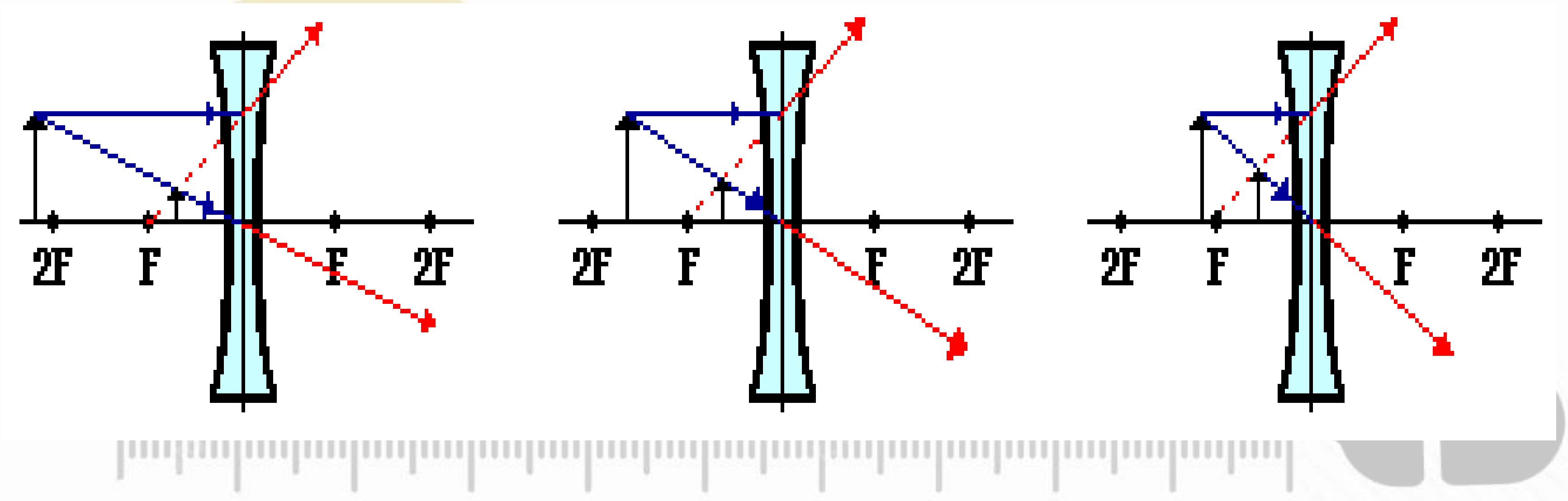


Image
2F
F
F
2F


2F
F
F
2F
2F
F
F
2F
2F
F
F
2F