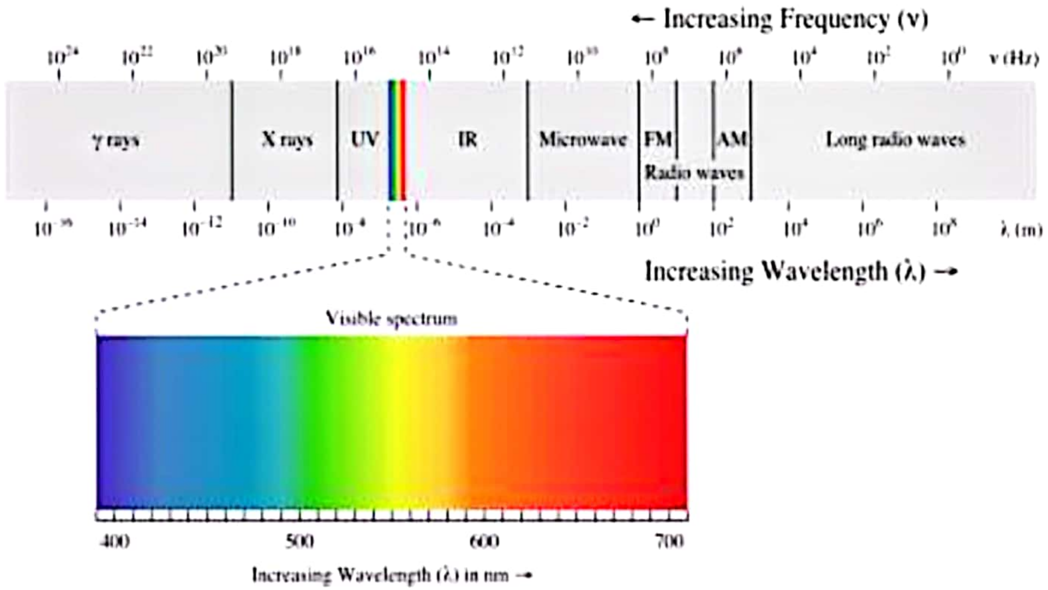
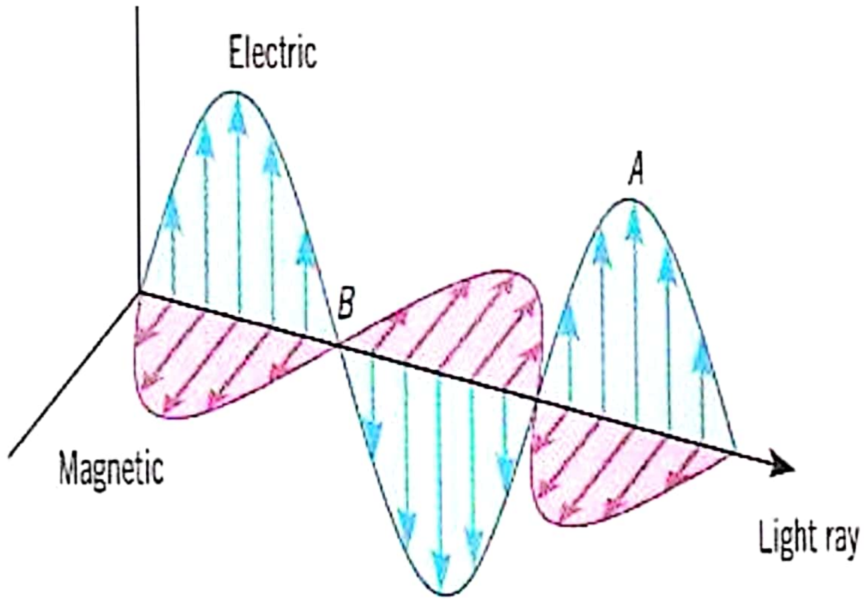
Light

- **Light is the electromagnetic radiation in the wavelength region between about 400 and 700 nm (1 nm $=10^{-9}$ m). Although light is only a tiny part of the electromagnetic spectrum, it has been the subject of much research in both physics and biology. The importance of light is due to its fundamental role in living systems. Most of the electromagnetic radiation from the sun that reaches the Earth's surface is in this region of the spectrum.**

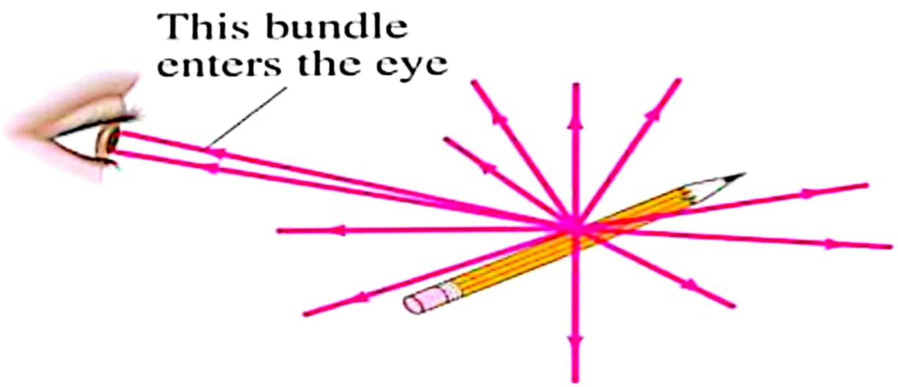




Optics

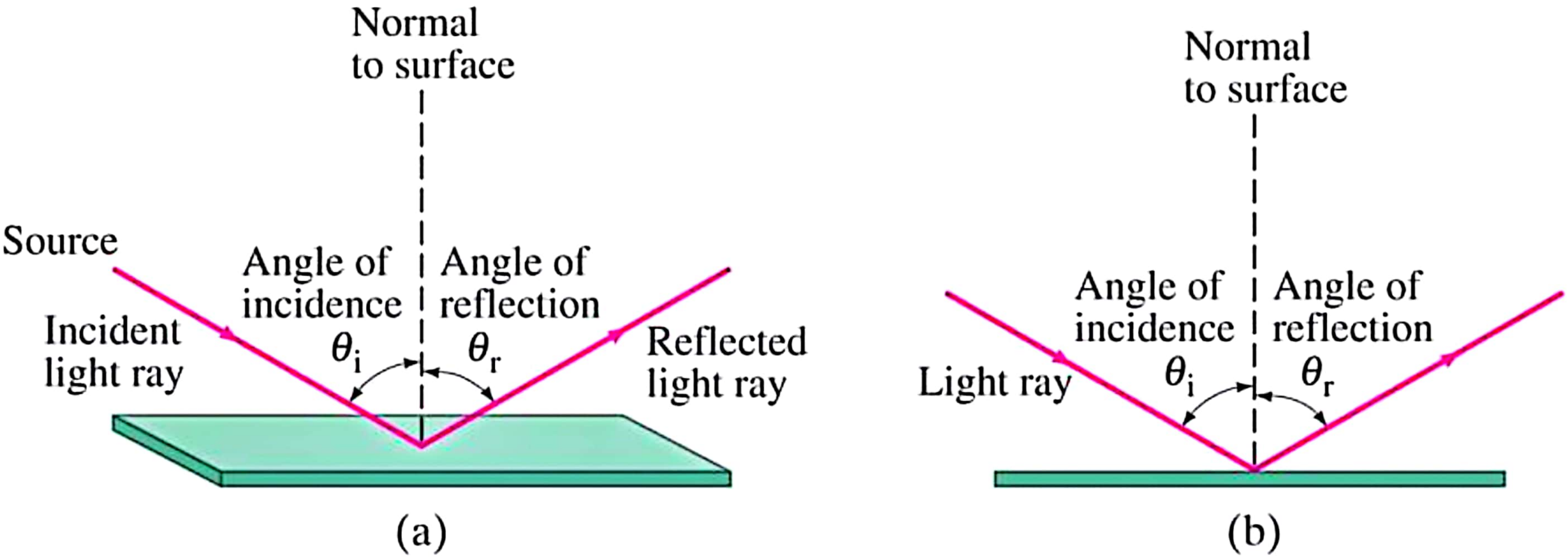
Optics, which is the study of light. It includes topics such as microscopes, telescopes, vision, color, pigments, illumination, spectroscopy, and lasers, all of which have applications in the life sciences.

- **Vision is our most important source of information about the external world.**
- **It has been estimated that about 70% of a person's sensory input is obtained through the eye.**
- **The three components of vision are the stimulus, which is light;**
- **the optical components of the eye, which image the light;**
- **and the nervous system, which processes and interprets the visual images.**



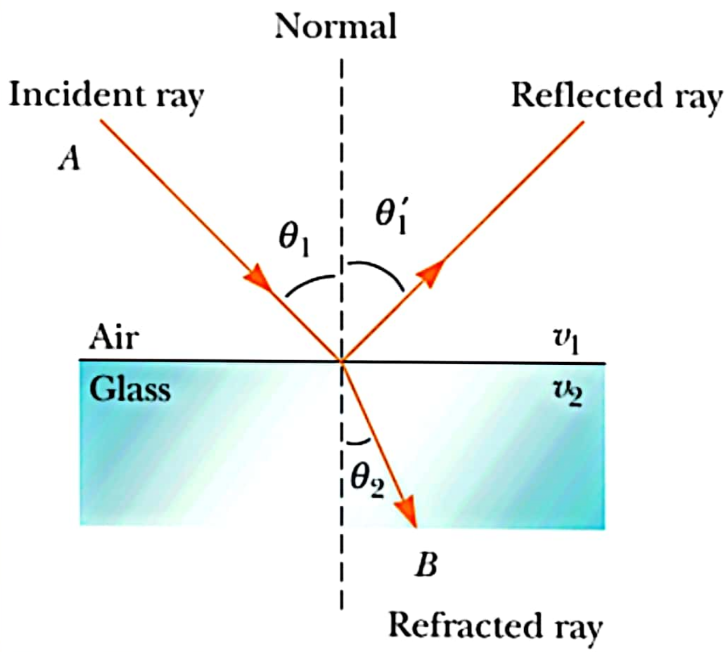
Reflection

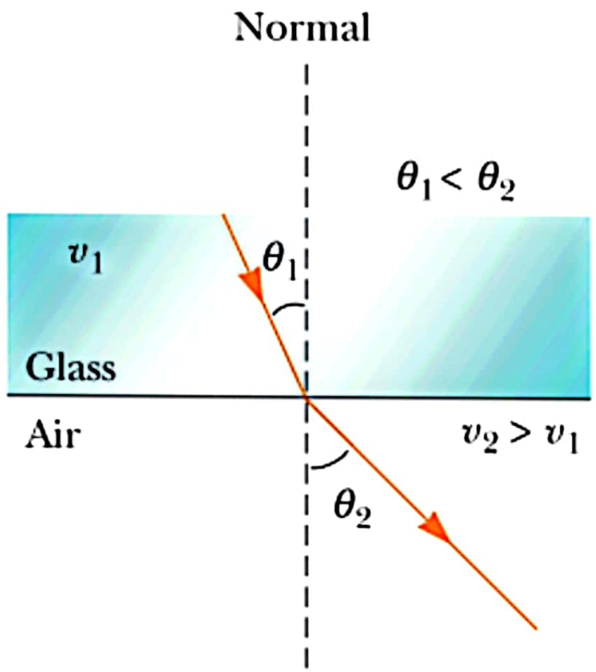
Law of reflection: the angle of reflection (that the ray makes with the normal to a surface) equals the angle of incidence.



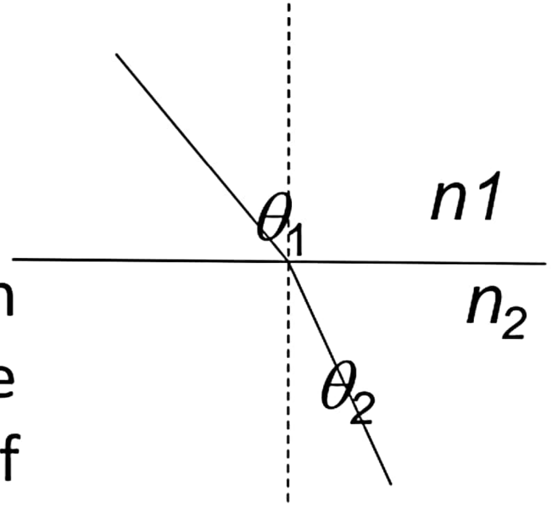
Law of refraction

- When light goes from a medium with smaller index of refraction to a medium with larger index of refraction, it bends toward the normal.
- When light goes from a medium with larger index of refraction to a medium with smaller index of refraction, it bends away from normal.





Snell's Law



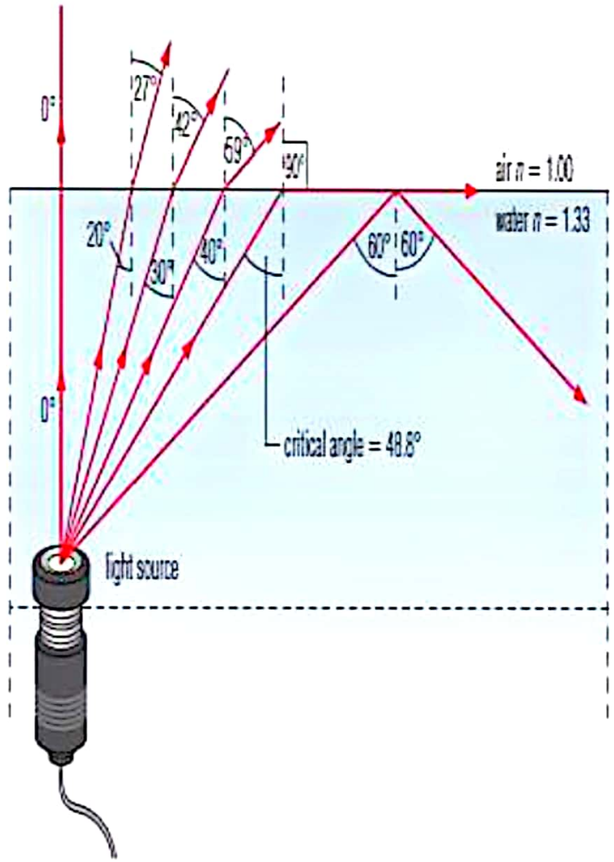
Snell's law states that a ray of light bends in such a way that the ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant. Mathematically,

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Here n_1 is the index of refraction in the original medium and n_2 is the index in the medium the light enters. θ_1 and θ_2 are the angles of incidence and refraction, respectively.

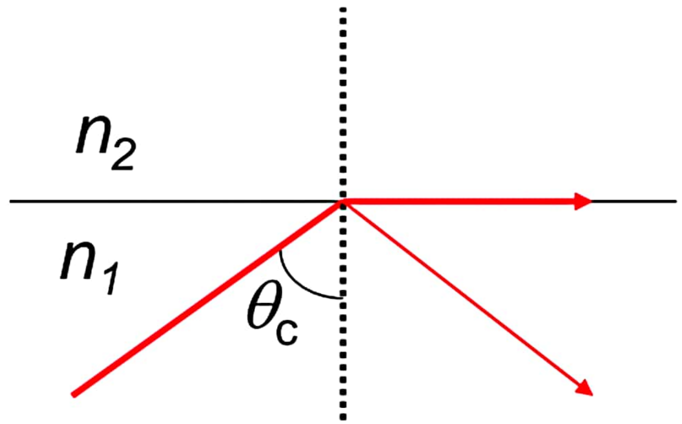
If $n_1 > n_2$, then $\theta_1 < \theta_2$

If $n_1 < n_2$, then $\theta_1 > \theta_2$



Critical Angle

The incident angle that causes the refracted ray to skim right along the boundary of a substance is known as the critical angle, θ_c. The critical angle is the angle of incidence that produces an angle of refraction of 90º. If the angle of incidence exceeds the critical angle, the ray is completely reflected and does not enter the new medium. A critical angle only exists when light is attempting to penetrate a medium of higher optical density than it is currently traveling in.



From Snell,

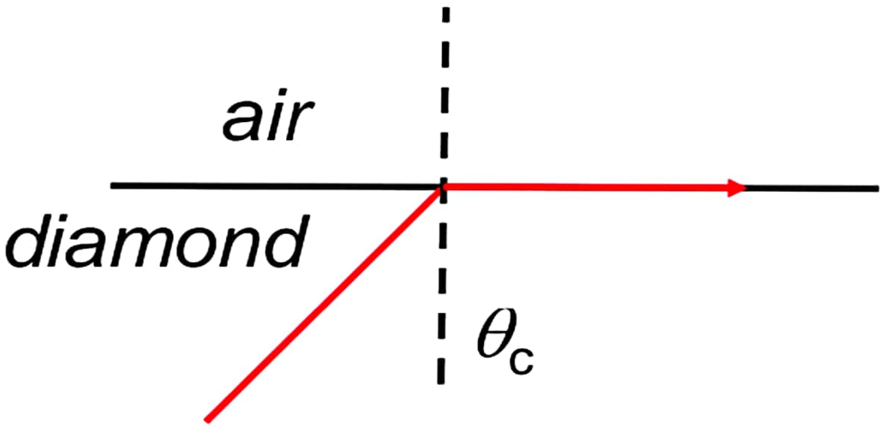
$$n_1 \sin\theta_c = n_2 \sin 90°$$

Since $\sin 90° = 1$, we have $n_1 \sin\theta_c = n_2$ and the critical angle is

$$\theta_c = \sin^{-1}\frac{n_2}{n_1}$$

Critical Angle Sample Problem

Calculate the critical angle for the diamond-air boundary. Refer to the Index of Refraction chart for the information.



$\theta_c = \sin^{-1} (n_r / n_i$

$= \sin^{-1} (1 / 2.42)$

$= 24.4°$

Any light shone on this boundary beyond this angle will be reflected back into the diamond.

total internal reflection: **This phenomenon is absorbed only in the passage of light from a more dense to a less dense medium ,the angle of incident in the dense medium must be greater than critical between the two media . For glass, *n*2 is typically 1.5, and the critical angle at the glass-air interface is sin ϑc = 1/1.5 or ϑc = 42°.**

Suppose $n_2 < n_1$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

- largest possible value of $\sin(\theta_2)$ is 1 (when $\theta_2 = 90$)
- therefore, largest possible value of $\sin(\theta_1)$ is

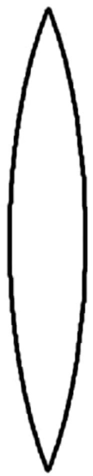
$$\sin(\theta_{1,max}) = \sin(\theta_c) = \frac{n_2}{n_1}.$$

For θ_1 larger than θ_c , Snell's Law cannot be satisfied!

- for $\theta_1 > \theta_C$: no refracted ray, light is **totally reflected**
- θ_C is called the critical angle of total internal reflection
- **Critical angles the angle at which the refracted ray is at 90°**

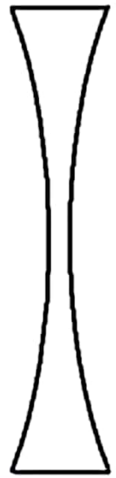
Lenses and Refraction

Convex lens

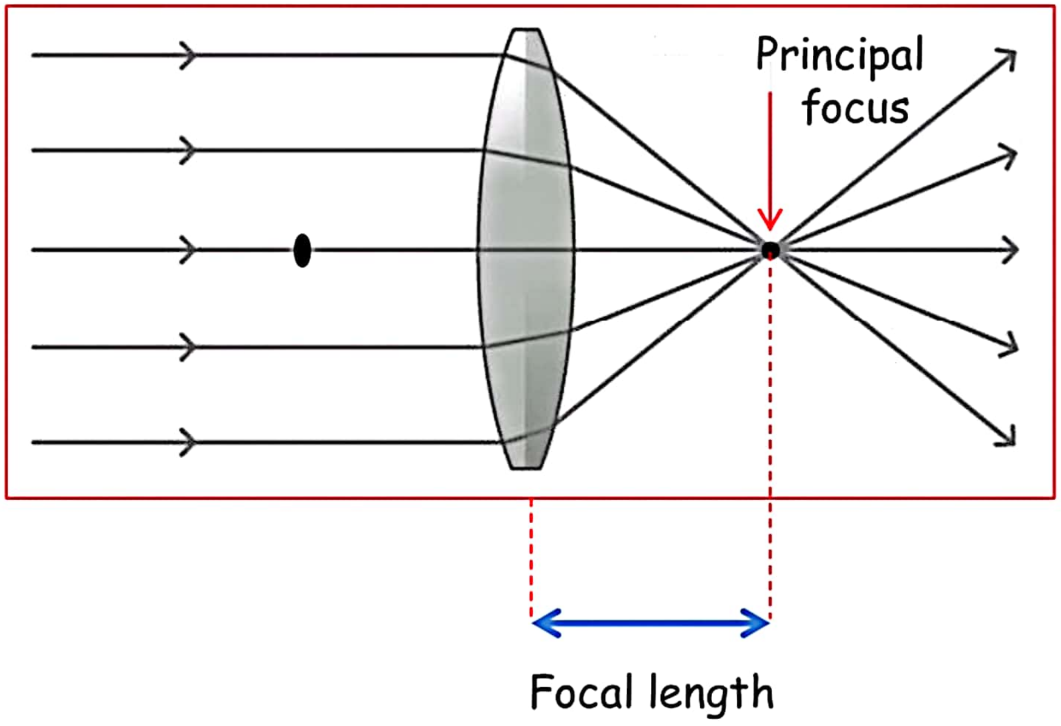


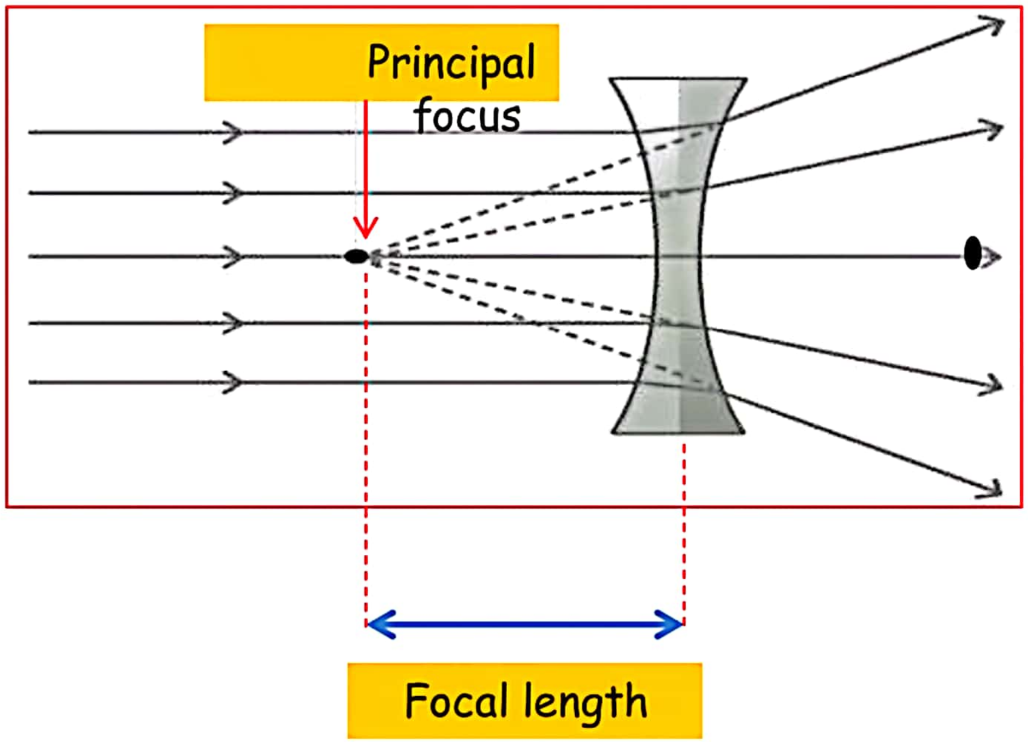
Converging lens

Concave lens



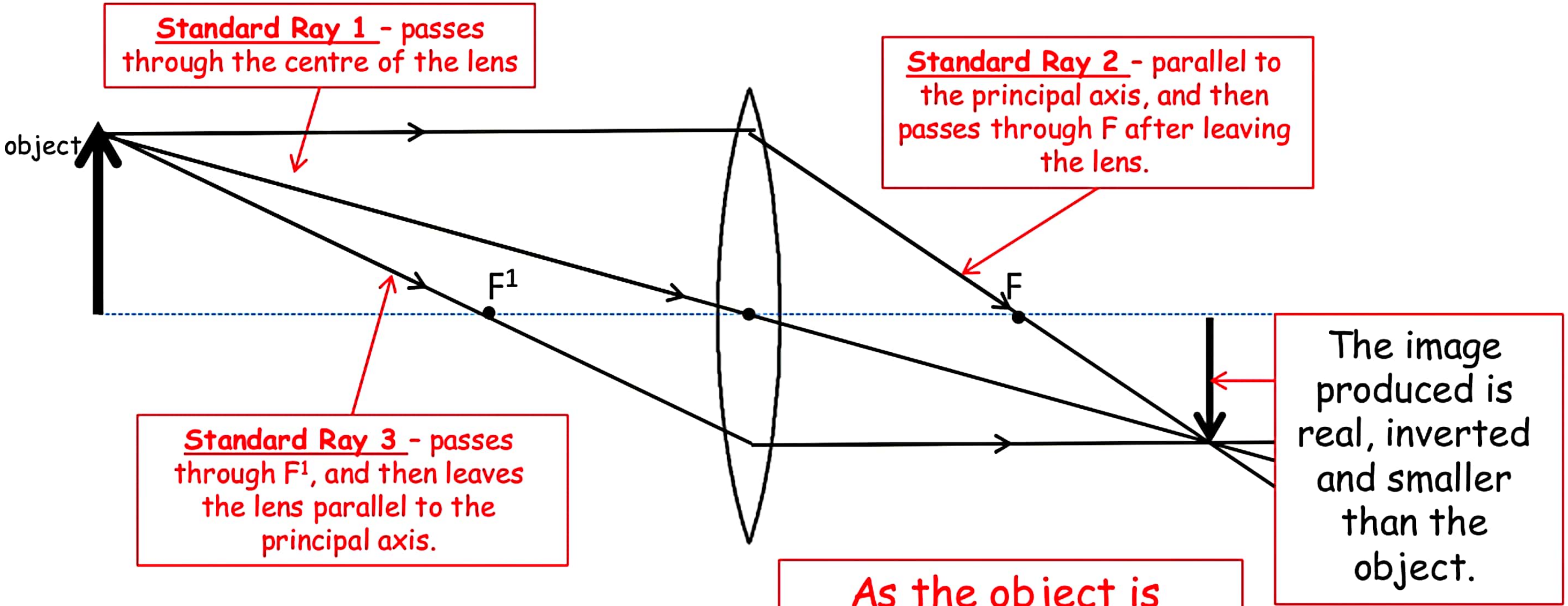
Diverging lens





Lenses and Ray Diagrams

- Predicting where a convex lens will form an image.

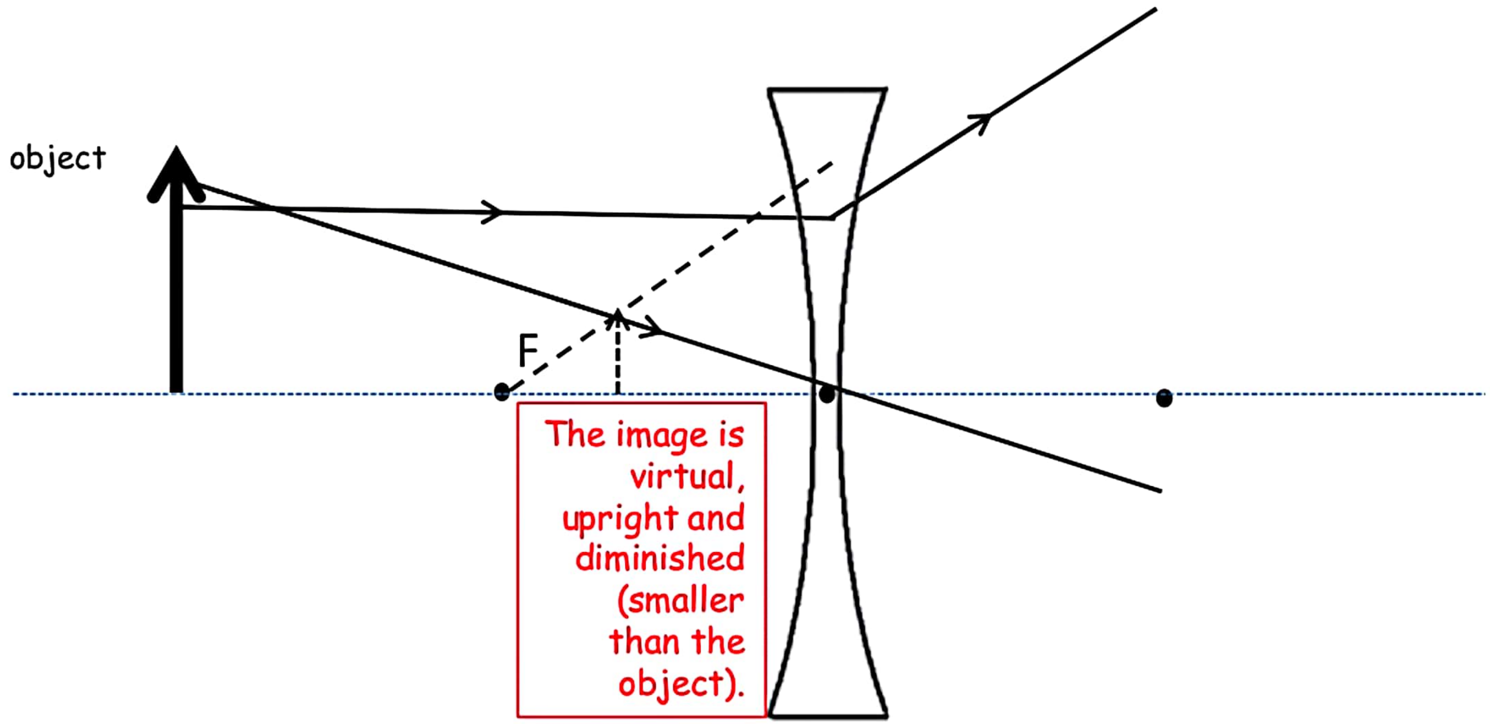


Only two of the standard rays are required to work out where they go.

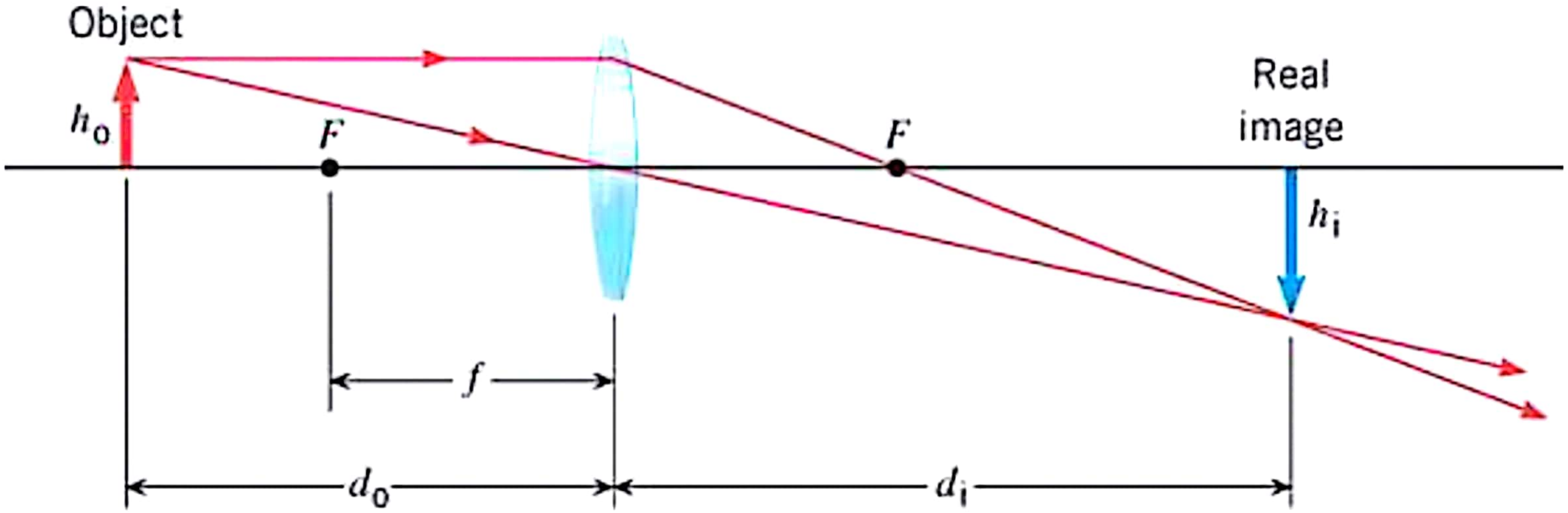
As the object is moved closer towards the lens, the image becomes bigger and further away.

Ray Diagram for a Concave Lens

- Predicting where a concave lens will form an image.



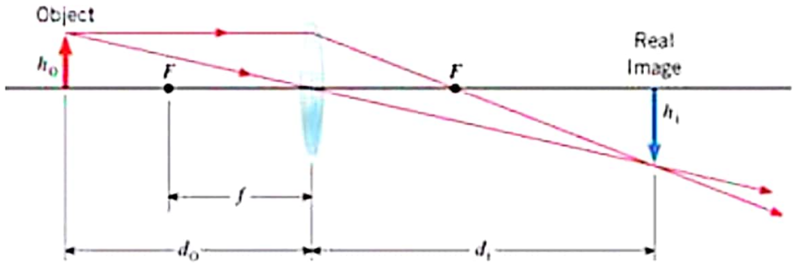
The Thin-Lens Equation and the Magnification Equation



$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

Summary of Sign Conventions for Lenses



f is + for a converging lens.

f is – for a diverging lens.

d_o is + if the object is to the left of the lens.

d_o is – if the object is to the right of the lens.

d_i is + for an image (real) formed to the right of the lens.

d_i is – for an image (virtual) formed to the left of the lens.

m is + for an image that is upright with respect to the object.

m is – for an image that is inverted with respect to the object.

Example : The Real Image Formed by a Camera Lens

A 1.70-m tall person is standing 2.50 m in front of a camera. The camera uses a converging lens whose focal length is 0.0500 m. Find the image distance and determine whether the image is (a) real or virtual. (b) Find the magnification and height of the image on the film.

(a)

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{0.0500\,\text{m}} - \frac{1}{2.50\,\text{m}} = 19.6\,\text{m}^{-1}$$

$$d_i = 0.0510\,\text{m}$$

real image

(b)

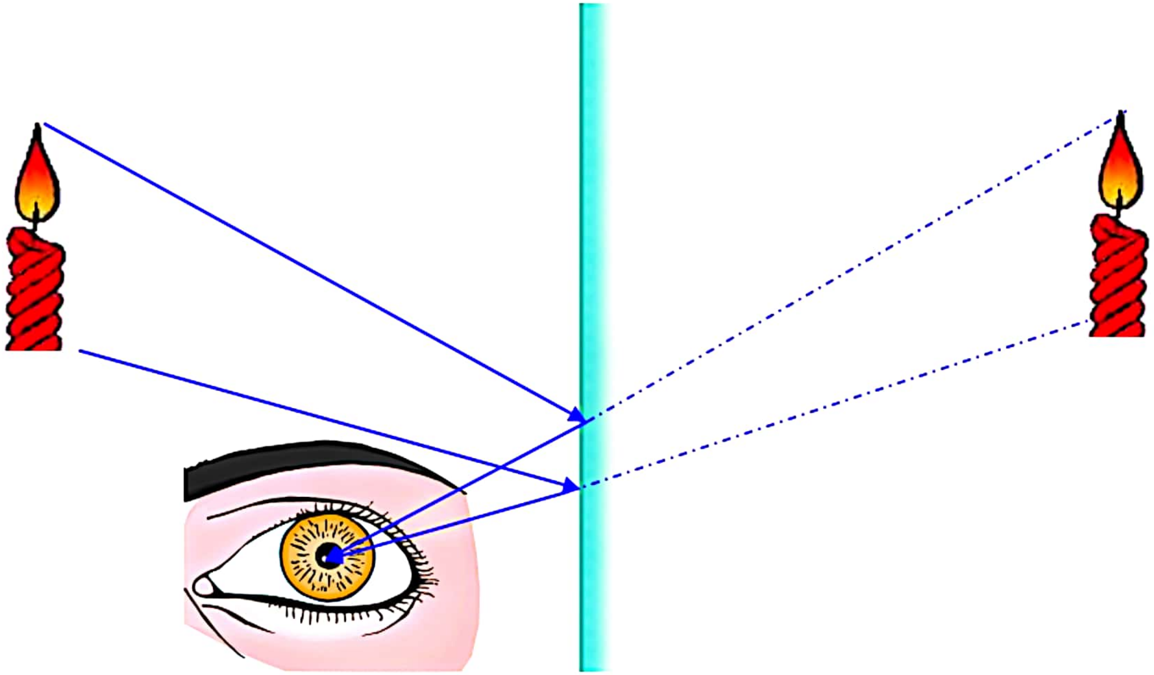
$$m = -\frac{d_i}{d_o} = -\frac{0.0510\,\text{m}}{2.50\,\text{m}} = -0.0204$$

$$h_i = m h_o = (-0.0204)(2.50\,\text{m}) = -0.0347\,\text{m}$$

Plane Mirrors

How do we see images in mirrors?

Light reflected off the mirror converges to form an image in the eye.

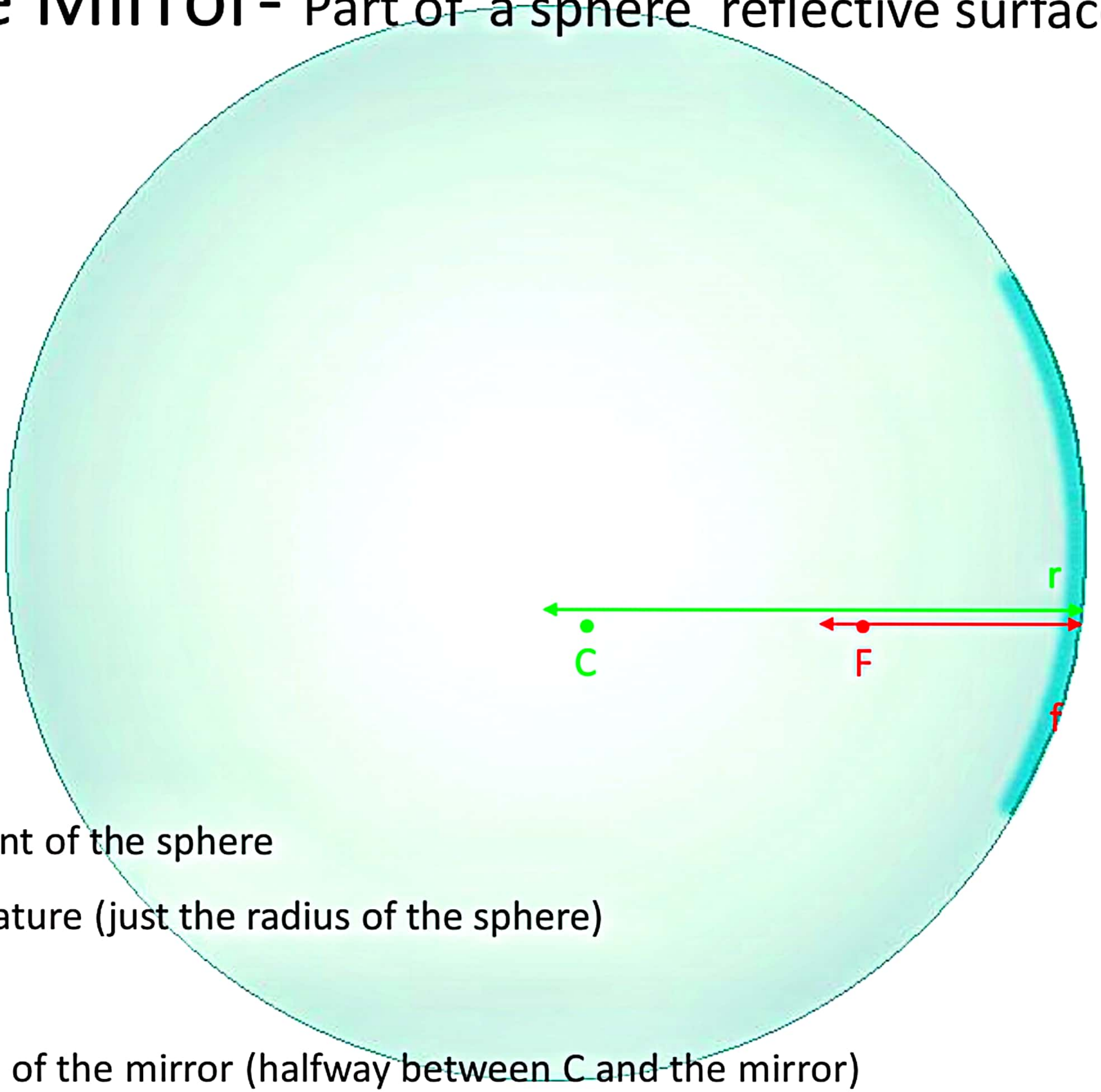


The eye perceives light rays as if they came from the mirror.

The image is virtual since it is formed by the *apparent* intersection of light rays.

(apparent rays are indicated on the diagram as broken lines and actually don't exist)

Concave Mirror- Part of a sphere reflective surface on inside



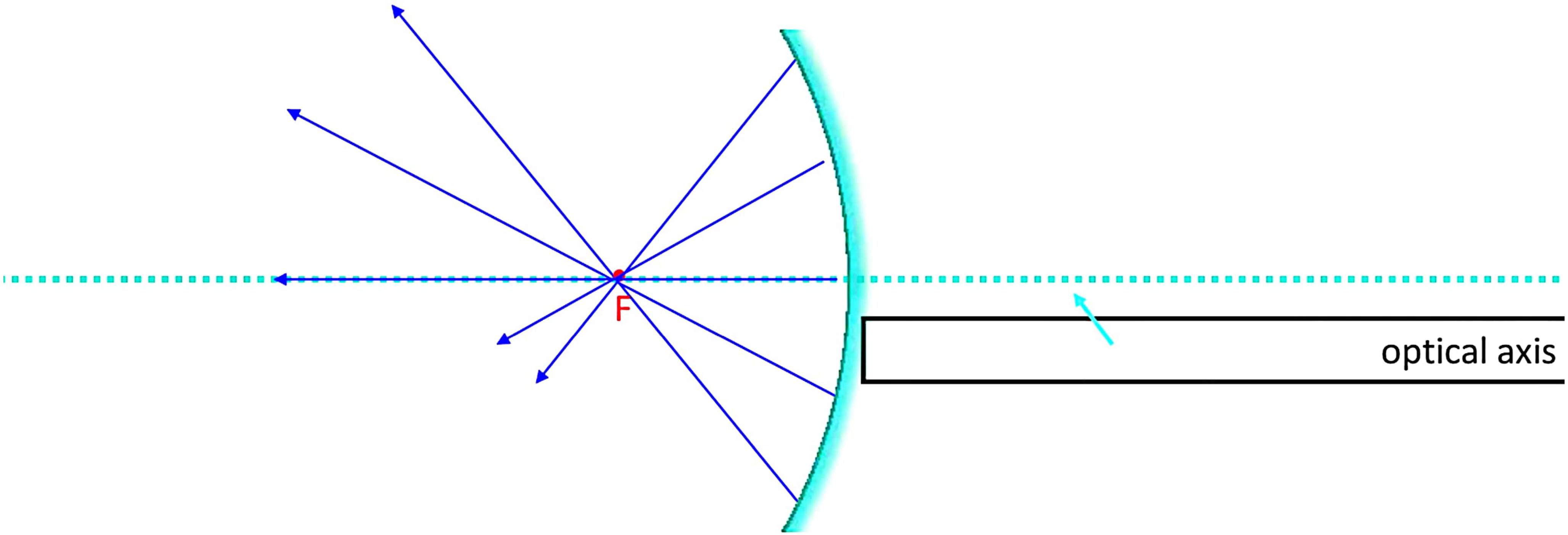
C: the center point of the sphere

r: radius of curvature (just the radius of the sphere)

F: the focal point of the mirror (halfway between C and the mirror)

f: the focal distance. $f = r/2$

Concave Mirrors
(caved in)



- Light rays that come in parallel to the optical axis reflect through the focal point
- Light rays that come in along the optical axis strike the mirror at 90 so reflect back along optical axis through the focal point.

Concave Mirror

Image formed in a concave mirror object placed outside centre of curvature

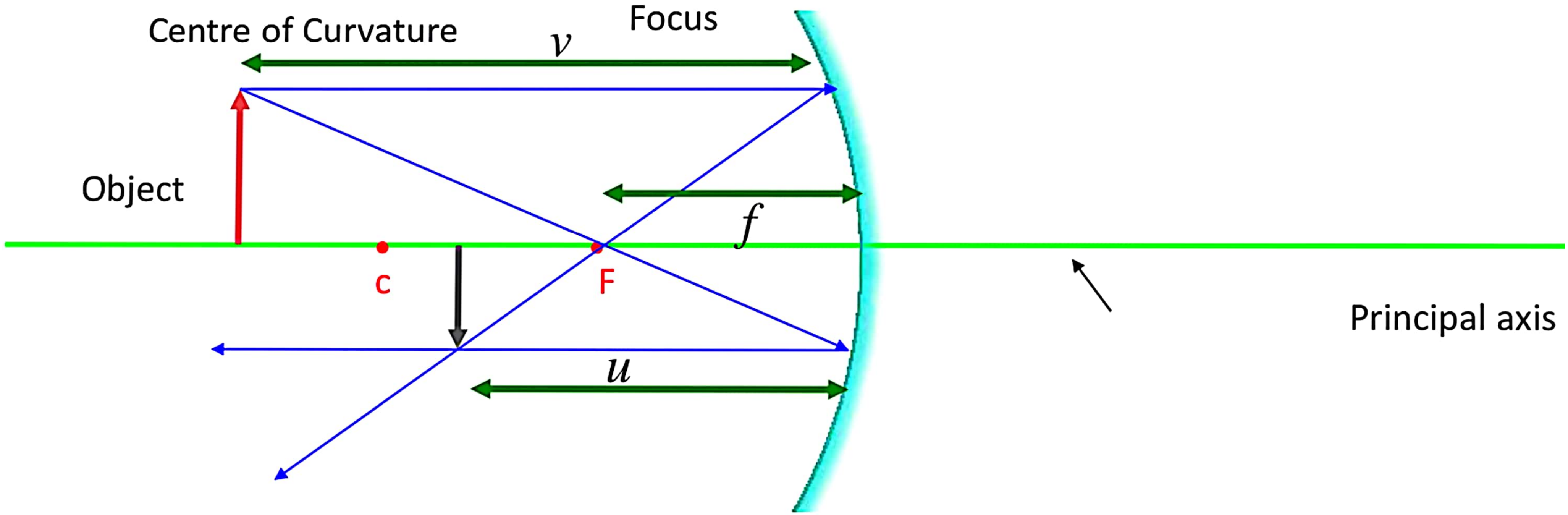


Image:- Real, Inverted & diminished

Concave Mirror

Image formed in a concave mirror when object placed at centre of curvature

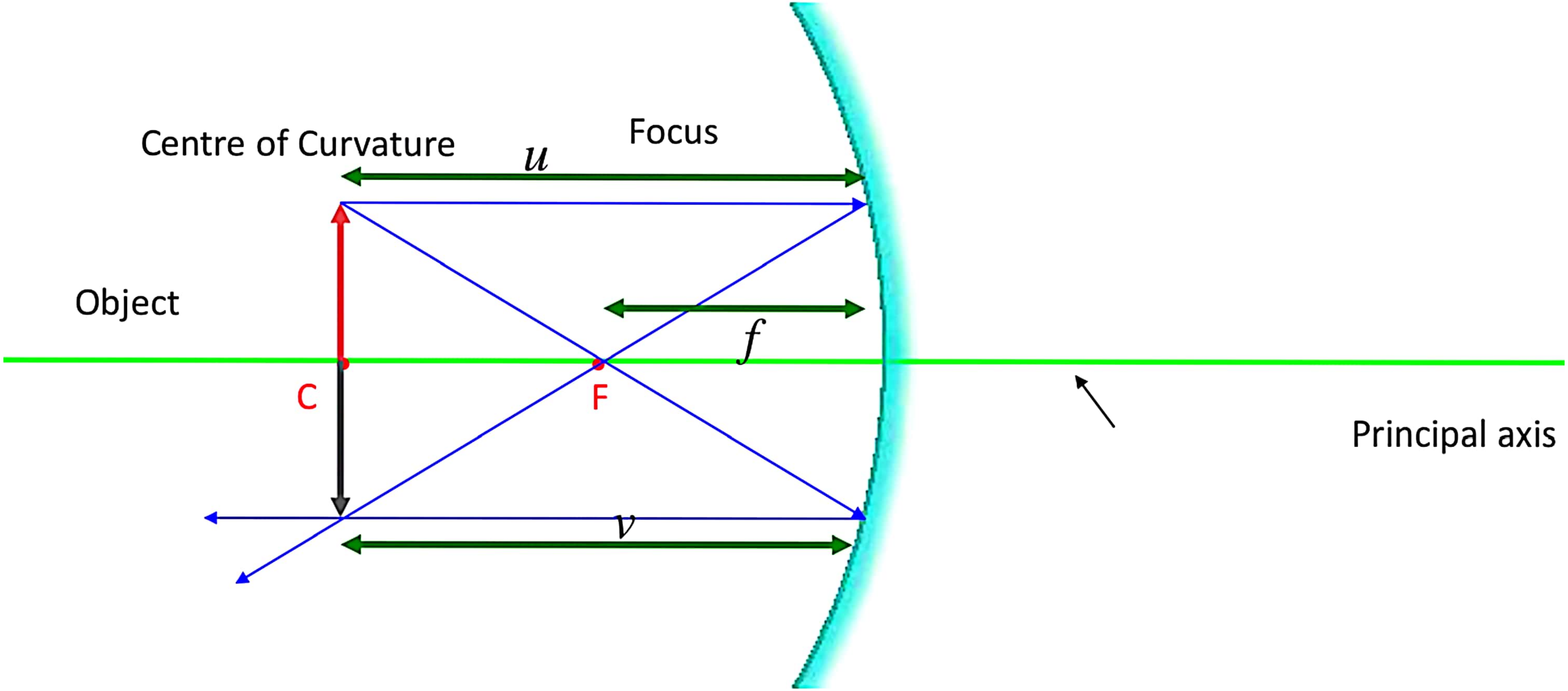


Image:- Real, Inverted & diminished

Concave Mirror

Image formed in a concave mirror when object placed between centre of curvature & focus

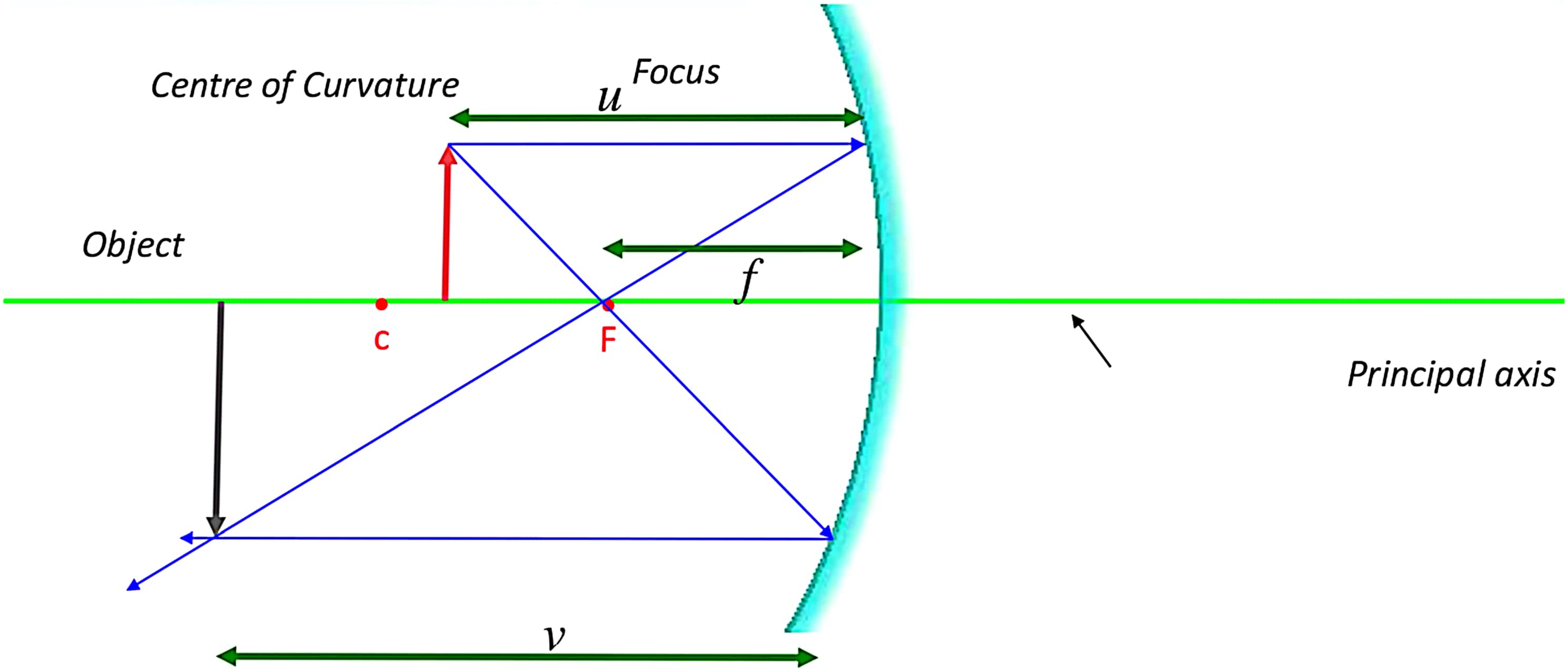


Image:- Real, Inverted & Enlarged

Concave Mirror

Image formed in a concave mirror when object placed at focus

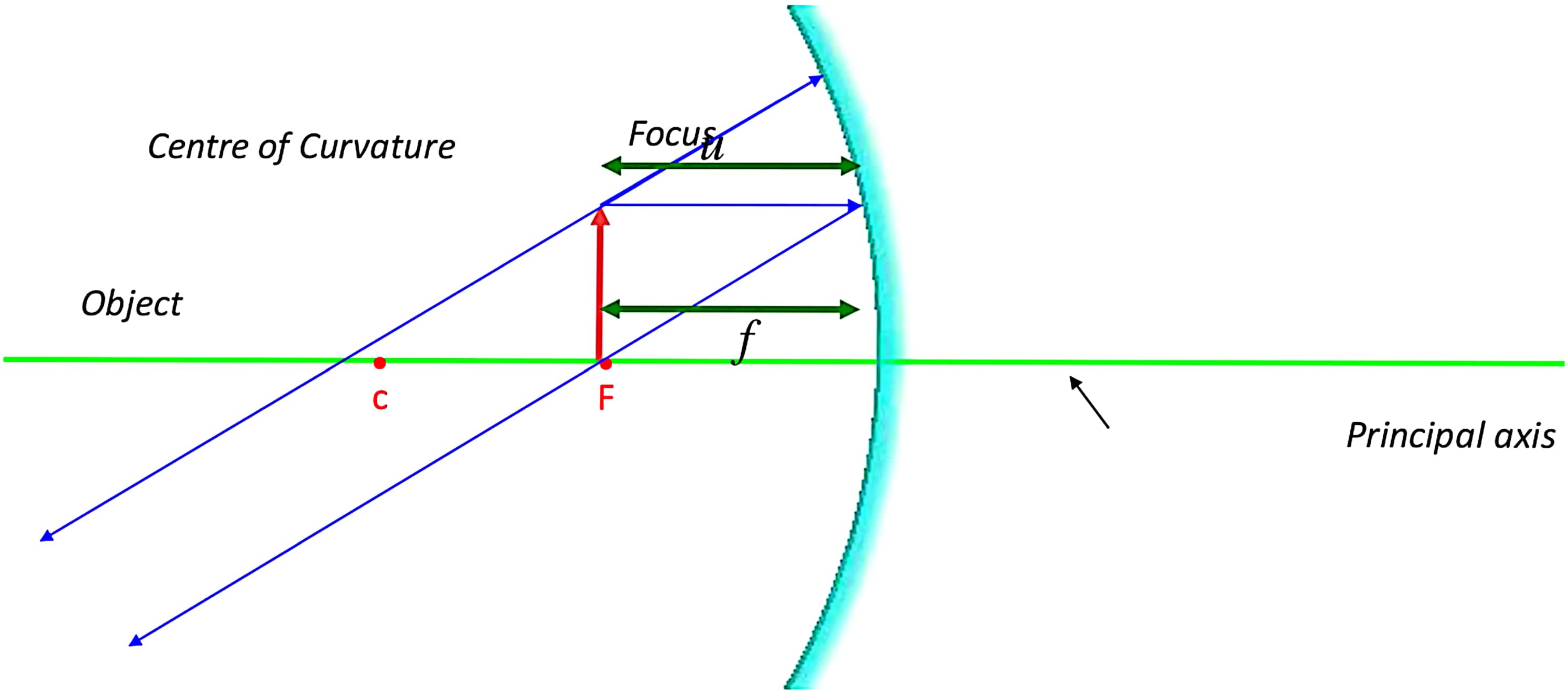


Image:- At Infinity

Concave Mirror

Image formed in a concave mirror when object placed inside focus

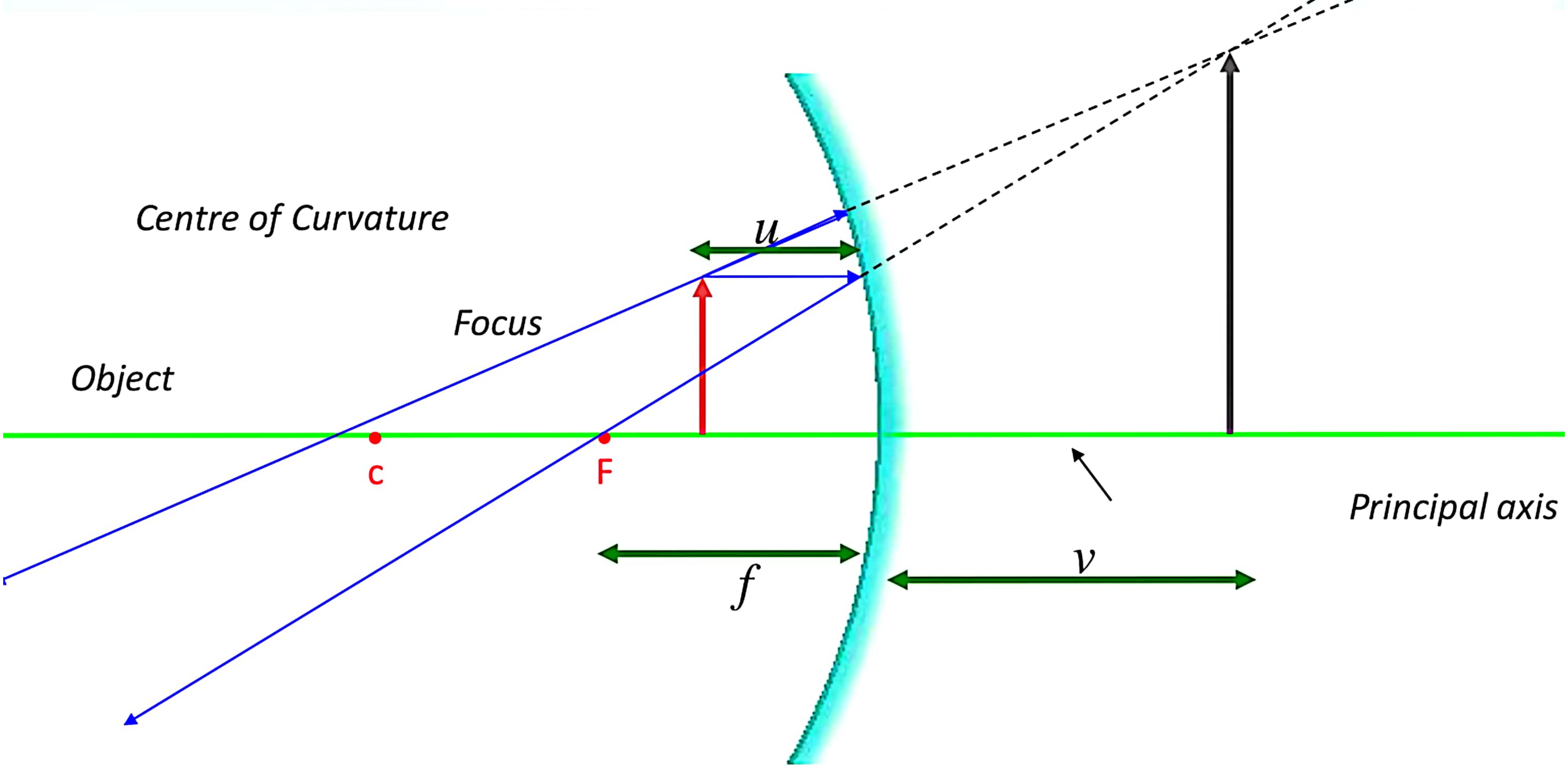
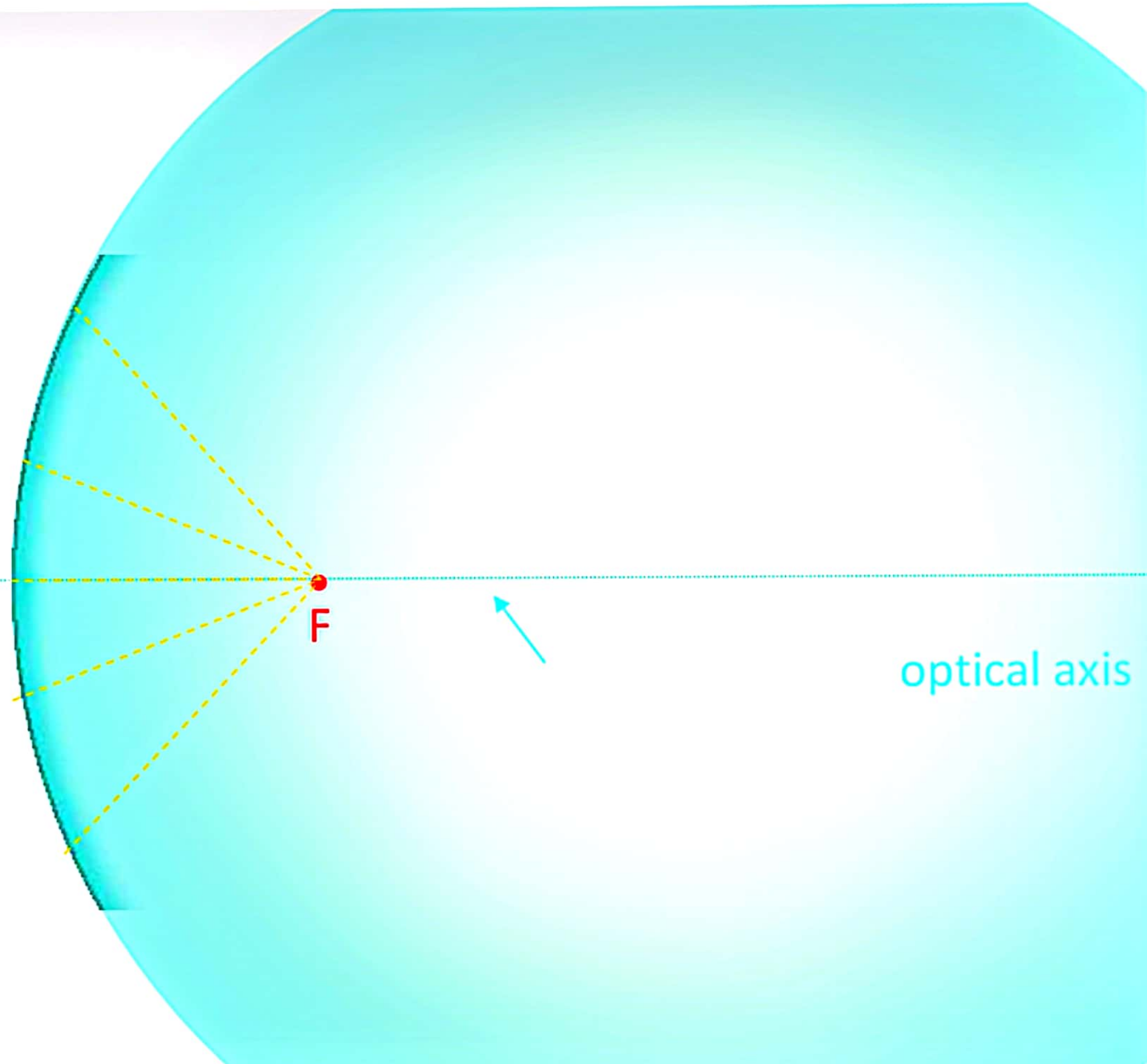


Image:- Virtual, Erect & Enlarged



Light rays that come in parallel to the optical axis reflect from the focal point.

The focal point is considered virtual since sight lines, not light rays, go through it.

Convex Mirrors

Focus

Centre of Curvature

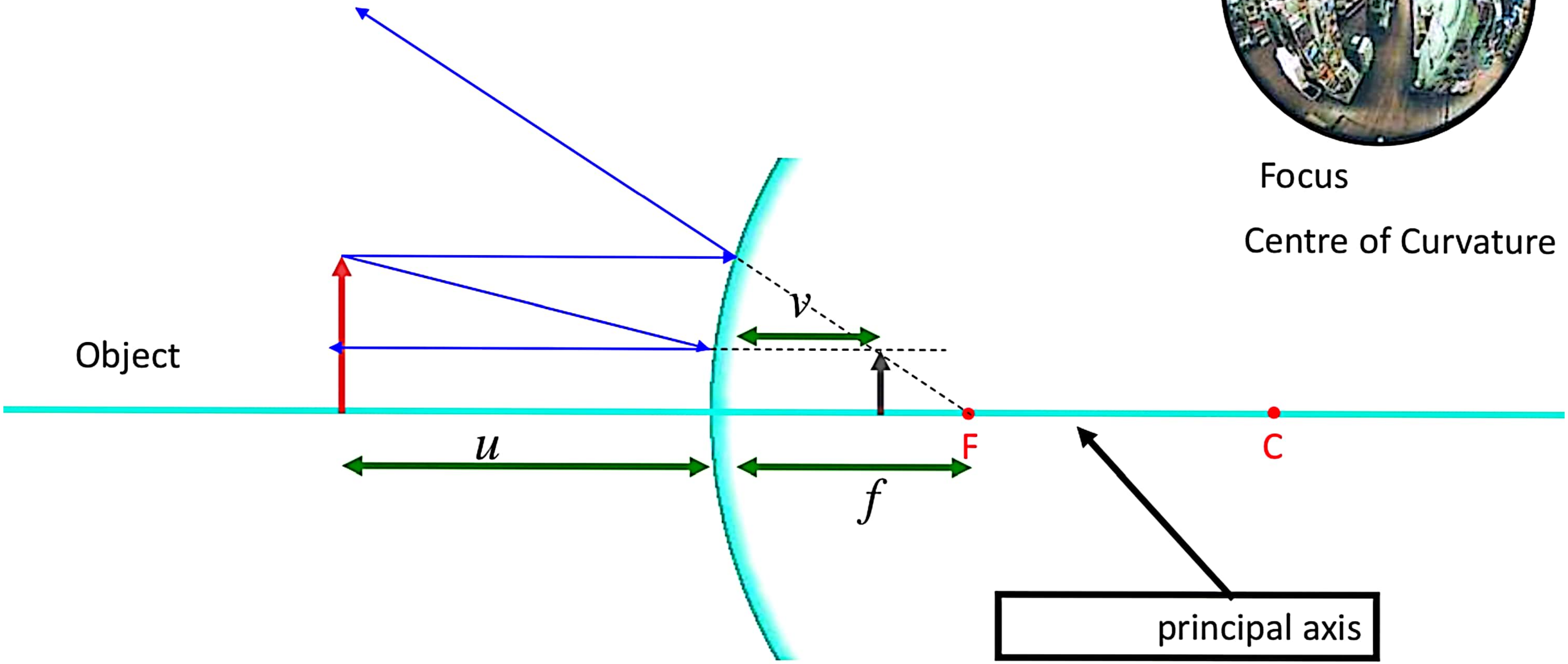


Image:- Virtual, Erect & Diminished