Chapter #2

Light

We will discuss :-

- Light .
- Reflection.
- Flat mirror.
- Curved mirror .
- Mirror and magnification equation.
- Index of refraction.
- Snell's law.
- Critical angle.
- Refraction.
- total internal refraction.
- Fiber optics .
- Medical application.
- Lenses.
- Lens equation.
- Microscope.
- Eye defects.

Light

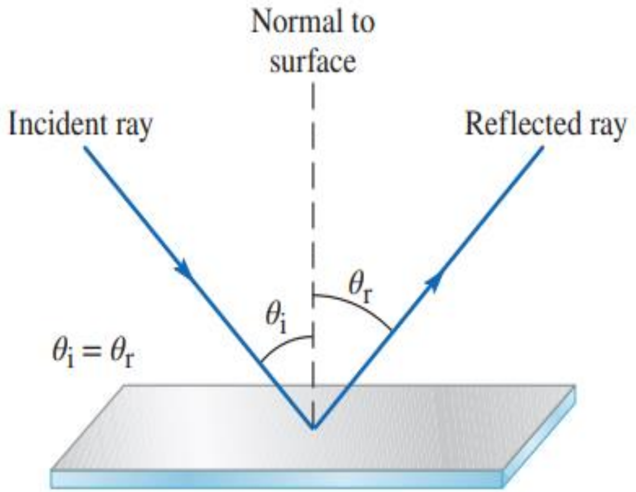
- Light: electromagnetic radiation that can be detected by human eye
- Light incident on an object

Light absorption, reflection, and refraction

Reflection

- The angle of incidence θ_i: is the angle between an incident ray and the normal .
- The angle of reflectionθ_r: is the angle between an reflected ray and the normal .

$$\theta_i = \theta_r$$



Flat mirror

- A plane or flat mirror forms a virtual image of a point source .
- The image appears :-

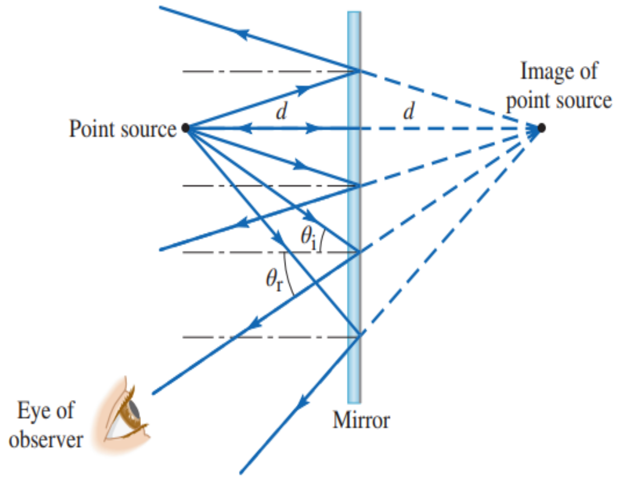
-Upright

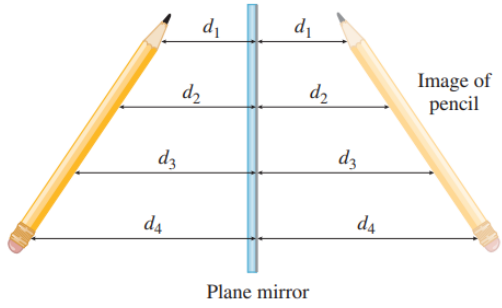
-same size

-Located same distance from , but behind ,mirror .

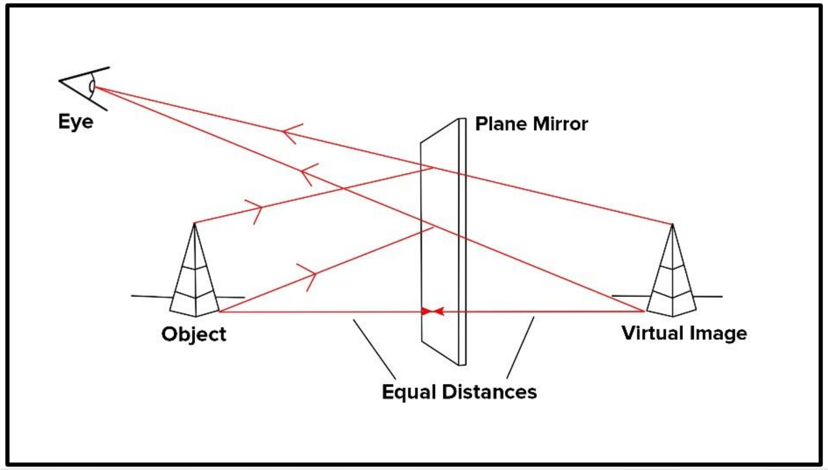
-facing opposite direction :left/right inverted

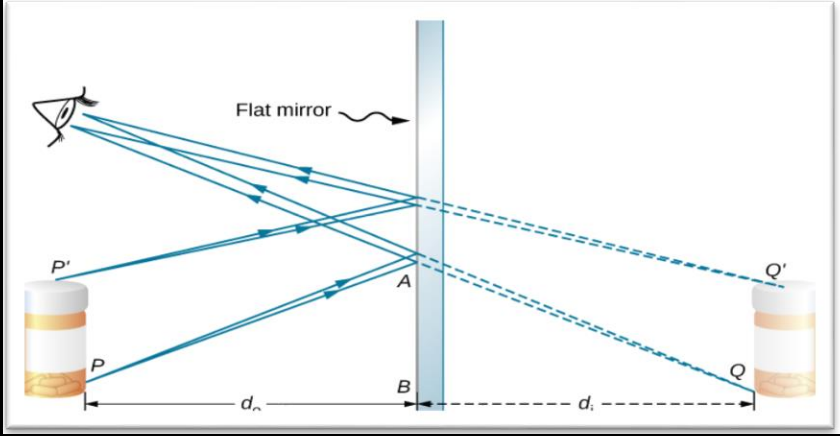
-virtual image :light rays don’t actually intersect at image location

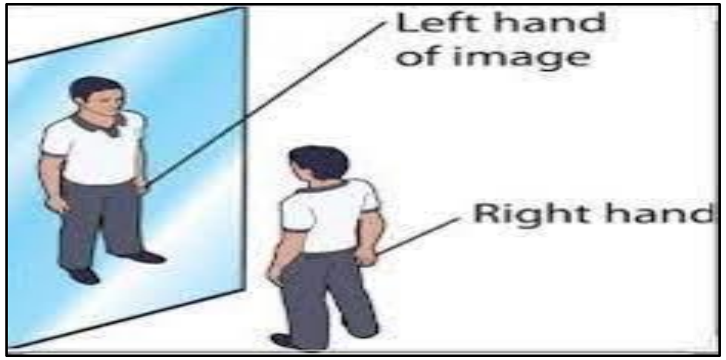


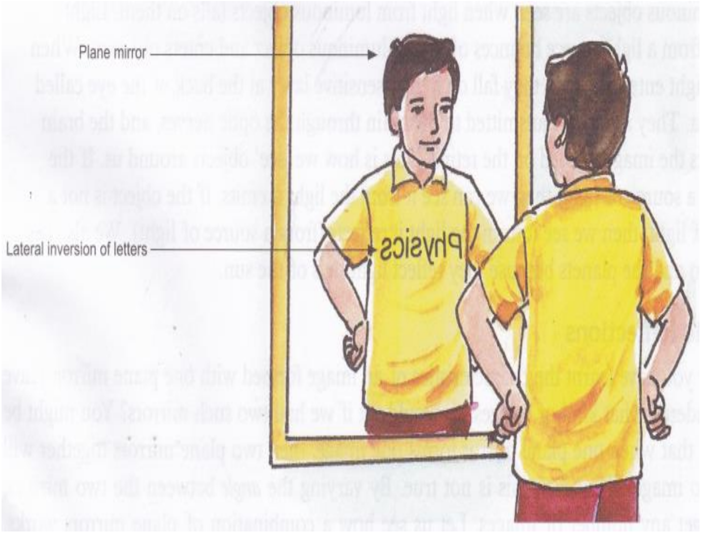


Flat mirror

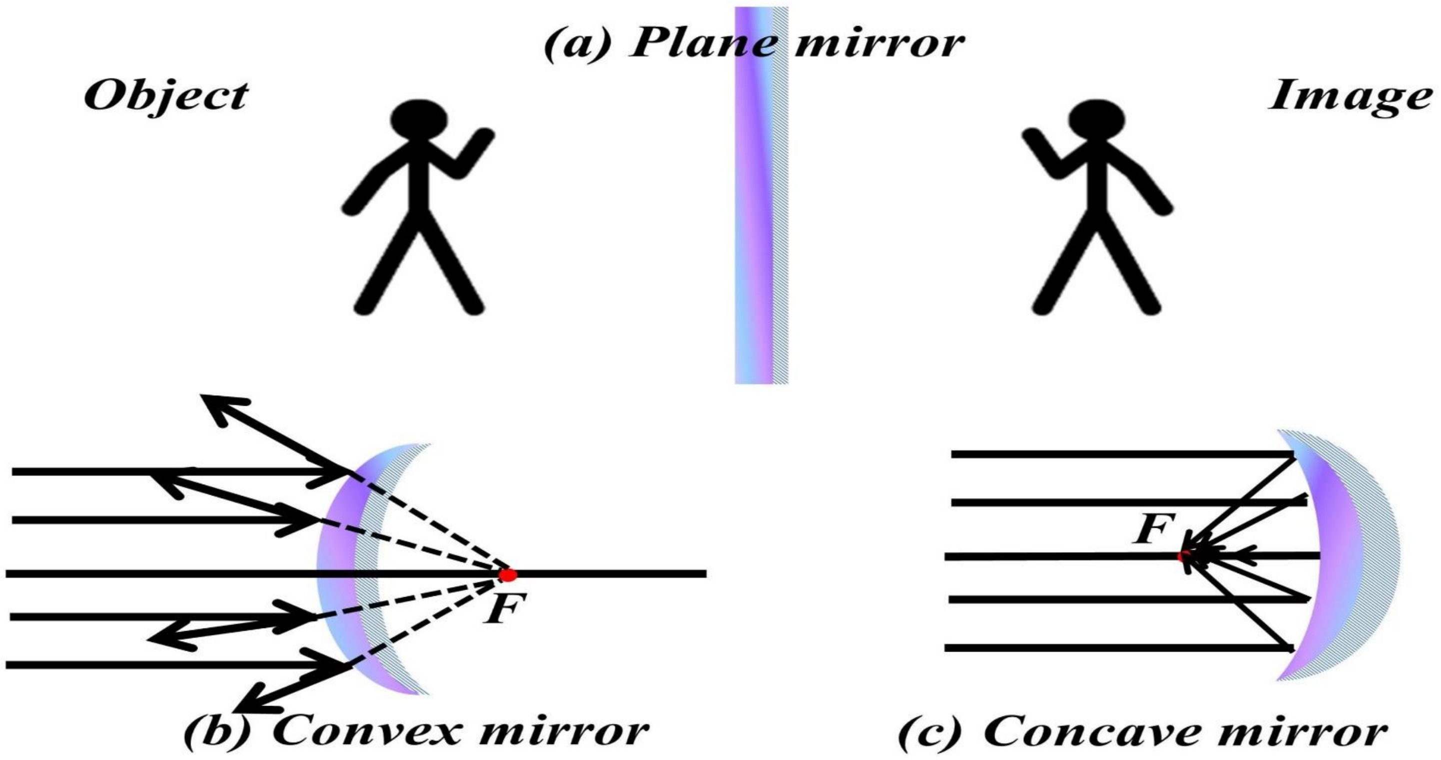

Eye
Plane Mirror
Object
Virtual Image
Equal Distances


Flat mirror
P'
Q'
A
P
B
Q
d_o
d_i


Left hand
of image
Right hand


Plane mirror
Lateral inversion of letters

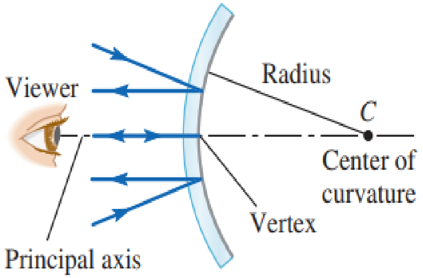
Curved mirror



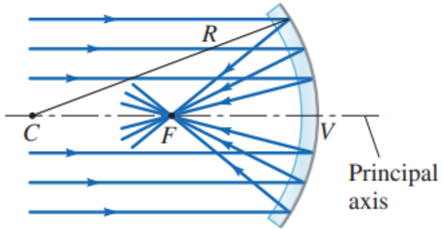
Curved or spherical mirror

Curved mirror

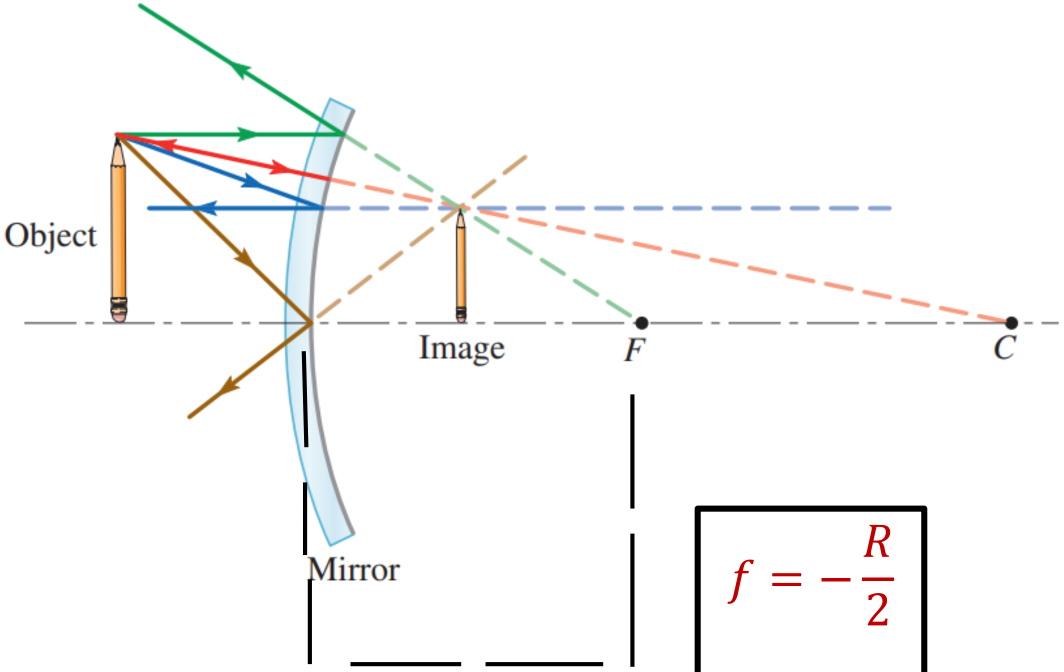
Convex mirror /curves from the viewer ; its center of curvature is behind the mirror.



Concave mirror/ curves toward the viewer ; it center of curvature is in front of the mirror .



Convex mirror



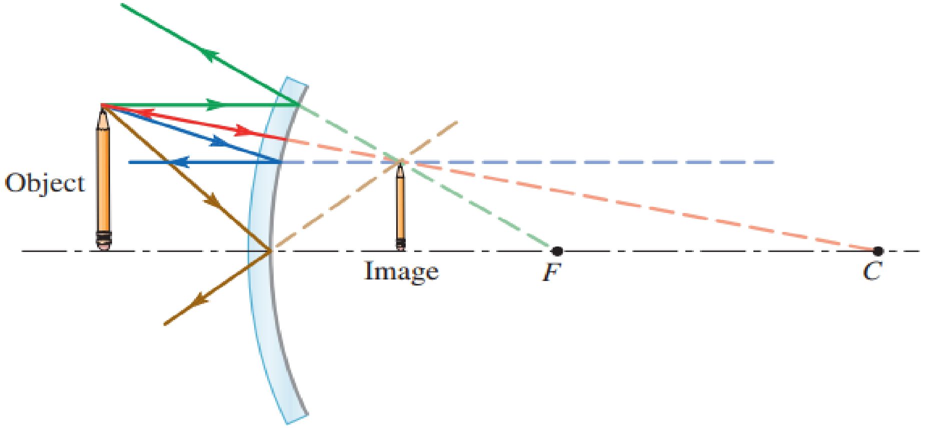
$$f = -\frac{R}{2}$$

Principal rays for convex mirrors

1. A ray parallel to the principal axis is reflected as if it came from a focal point.
2. A ray along a radius is reflected back on itself.
3. A ray directed toward the focal point is reflected parallel to the principal axis.
4. A ray incident on the vertex of the mirror reflects at an equal angle to the axis.

The distance from F to the center of the mirror is called the "Focal length" F

Convex mirror



1-Parallel to principle axis reflects through f .

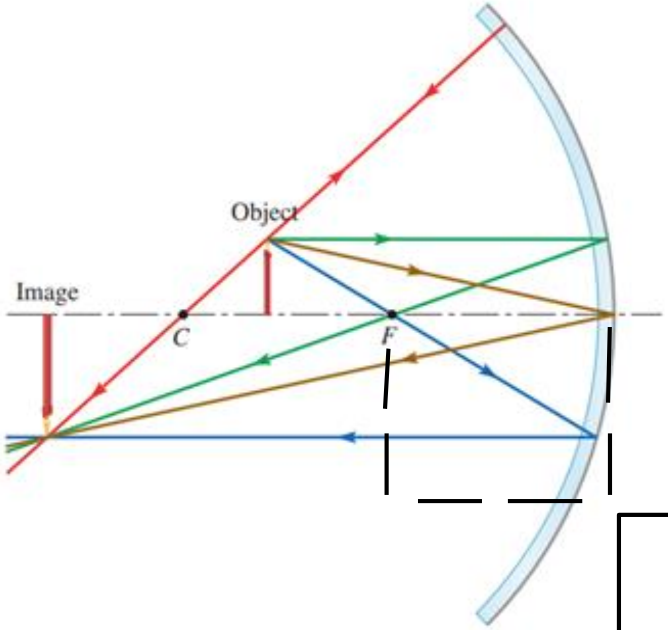
2- Through f reflects parallel to principle axis.

3- Through center is reflected back on itself.

Image is :

Virtual (light rays don't really cross)
Upright (same direction as object)
Reduced(smaller than object)

Concave mirror

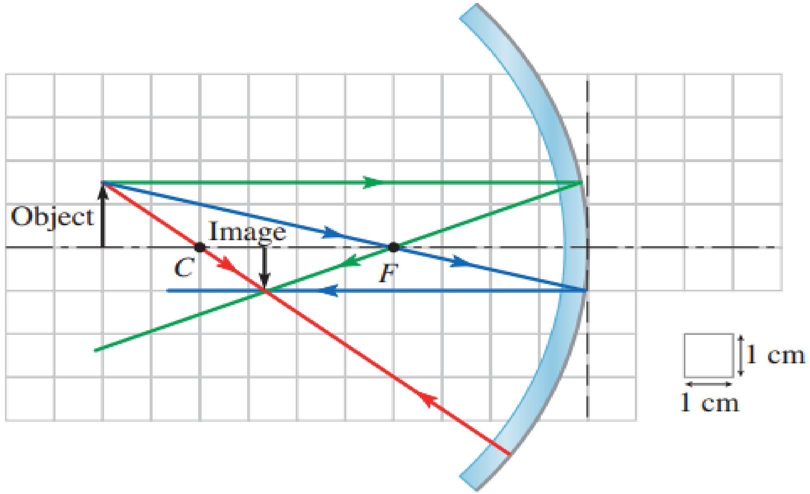


Principal rays for concave mirrors

1. A ray parallel to the principal axis is reflected through the focal point.
2. A ray along a radius is reflected back on itself.
3. A ray along the direction from the focal point to the mirror is reflected parallel to the principal axis.
4. A ray incident on the vertex of the mirror reflects at an equal angle to the axis.

$$f = \frac{R}{2}$$

Concave mirror



1-Parallel to principle axis reflects through f .

2- Through f reflects parallel to principle axis.

3- Through center is reflected back on itself.

The image (in this case):

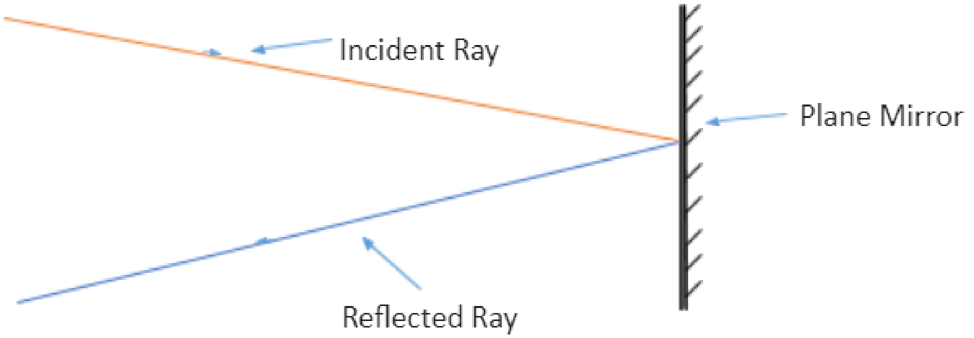
Real (light rays actually cross)
Inverted(Arrow points opposite direction)
Reduced (smaller than object)

Mirror focal lengths

- A concave mirror has a positive focal length f>0 .

- A convex mirror has a negative focal length f<0 .
- What is the focal length of a flat mirror ?

1) $f=0$ 2) $f=\infty$



Starting a fire without lighter or (matches)

- what kind of spherical mirror can be used to start a fire ?

1) Concave
2) Convex

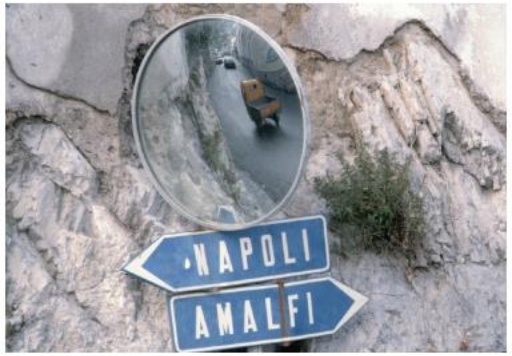
- How far from the paper to be ignited should the mirror be held ?

1) Farther than the focal length
2) Closer than the focal length
3) At focal length

Uses of mirror

*Convex mirror provides a larger

Field of view than a plane mirror would



Uses of mirror

mirrors designed for shaving or for applying cosmetics are often concave in order to Form a magnified image . Dentists use concave mirrors for same reason .

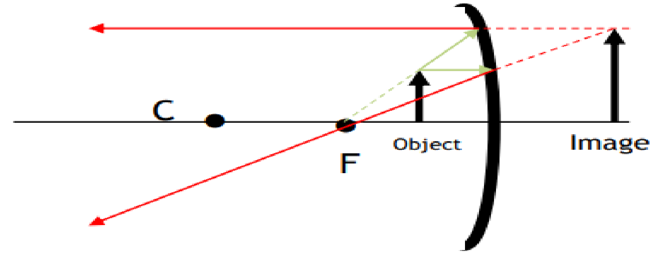
Why is ambulance written in reverse ?

Lateral Inversion

The word **AMBULANCE** written in reverse order

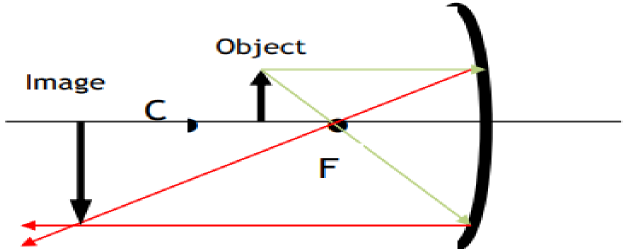
The word AMBULANCE viewed in the correct order in the rearview mirror

3 cases for concave mirror



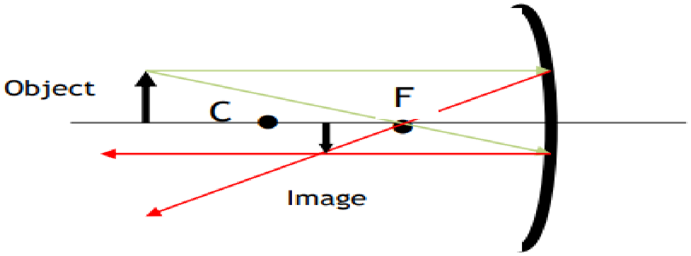
Inside F

Upright
Enlarged
Virtual



Between C&F

Inverted
Enlarged
Real



Past C

Inverted
Reduced
Real

Mirror equation

<u>P=distance object is from mirror:</u>

Positive: object in front of mirror .

Negative: object behind mirror .

<u>q= distance image is from mirror:</u>

Positive : real image (in front of mirror)

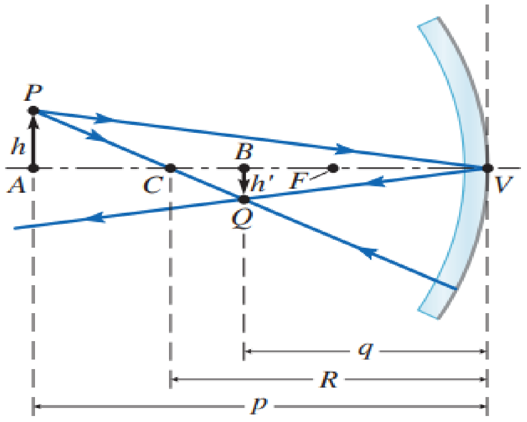
Negative: *virtual* image (behind mirror)

<u>f= focal length mirror</u>

Positive : concave mirror.

Negative: convex mirror

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



Magnification equation

- $$m = \frac{h_i}{h_0} = -\frac{q}{p}$$

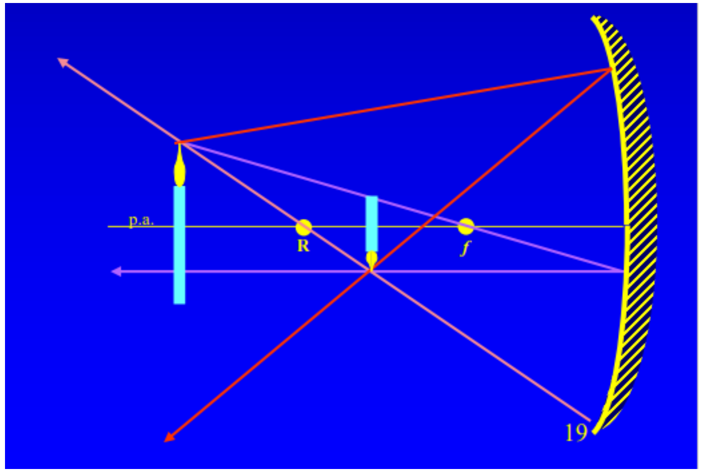
h_0= height of object
Positive : always
h_i= height of image
Positive :image is upright
Negative : image is inverted
m =magnification
Positive / negative same as h_i
< 1 image is reduced
> 1 image is enlarged

Example

- A candle is placed 6m in front of a concave mirror with focal length f

F=2 cm .

Determine the image location .



Compared to the candle the image will be :

-larger

-smaller

-same size

Magnification

- A 4 inch arrow pointing down is placed in front of a mirror that creates an image with a magnification of -2 .

*what is the size of the image ?

1) 2 inches
2) 4 inches
3) 8 inches

- What direction will the image arrow point ?

1) UP 2)Down

M=$\frac{h_i}{h_0}$

Magnitude gives us size
(-) sign tells us it's inverted from object

Example

- A candle is placed 6 cm in front of convex mirror with focal length

F=-3 cm. Determine the image location.

*magnification of the candle ?

*if the candle is 9 cm tall, how tall does the image candle appear to be?

Example

- Where should you place an object in front of a convex mirror to produce a real image?

1) Object close to the mirror
2) Object far from the mirror
3) Either close or far
4) You can't

Convex mirror : $f<0$
Object in front of mirror : $P>0$
Real image means $q>0$

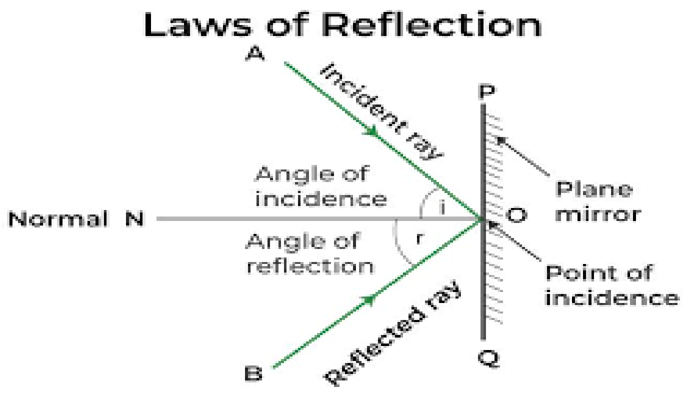
Table 23.2 Sign Conventions for Mirrors

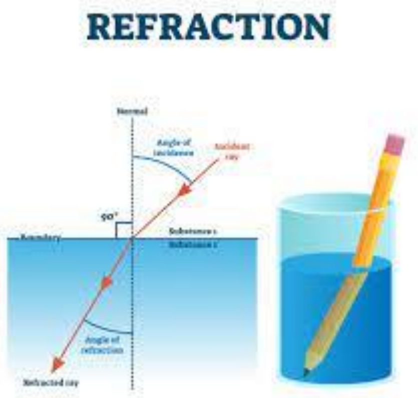
Quantity	When Positive (+)	When Negative (−)
Object distance p	Real object*	Virtual object*
Image distance q	Real image	Virtual image
Focal length f	Converging mirror (concave): $f = \frac{1}{2}R$	Diverging mirror (convex): $f = -\frac{1}{2}R$
Magnification m and image height h'	Upright image	Inverted image

Light doesn't just bounce it also refracts !

- Reflected : Bounces (Mirrors)

- Refracted : Bends (Lenses)





Index of Refraction

- <u>Speed of light in vacuum =3$\times 10^{8}$ m/s</u>

**Example

The index of refraction of diamond is 2.4. what is the speed of light
In diamond if its speed in vacuum is 3$\times 10^{8}$ m/s ?

index of refraction
velocity of light in vacuum

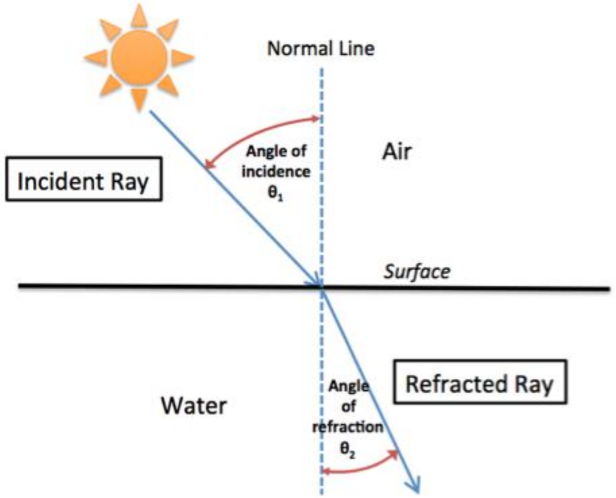
$$n = \frac{c}{v}$$

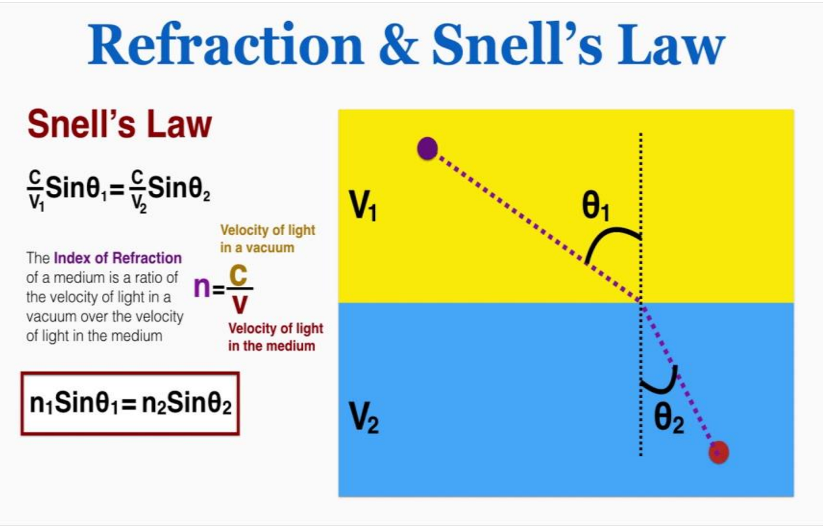
velocity of light in the medium

Snell's law

- When light travels from one medium to another the speed changes v=c/n, but the frequency is constant so the light bends:

$$n_1 \text{Sin}\,(\theta_1) = n_2 \text{Sin}\,(\theta_2)$$

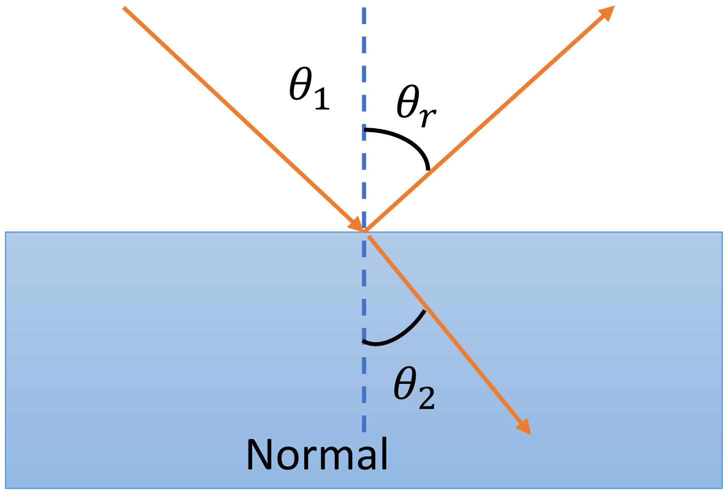




Snell's law practice

- Usually, there is both reflection and refraction

** A ray of light traveling through the air(n=1) is incident on water (n=1.33). Part of the beam is reflected at an angle θ_r=60. The other part of the beam is refracted . Find θ_2?



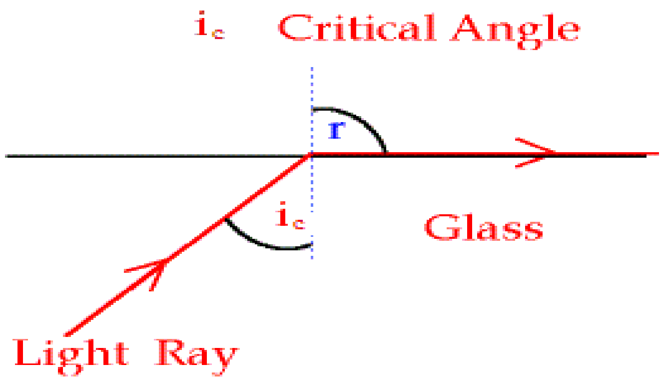
$\theta_1 = \theta_r$=60^0

Critical angle

- The angle of incidence for which the angle of refraction is 90^0 is called the critical angle θ_c.

Critical angle

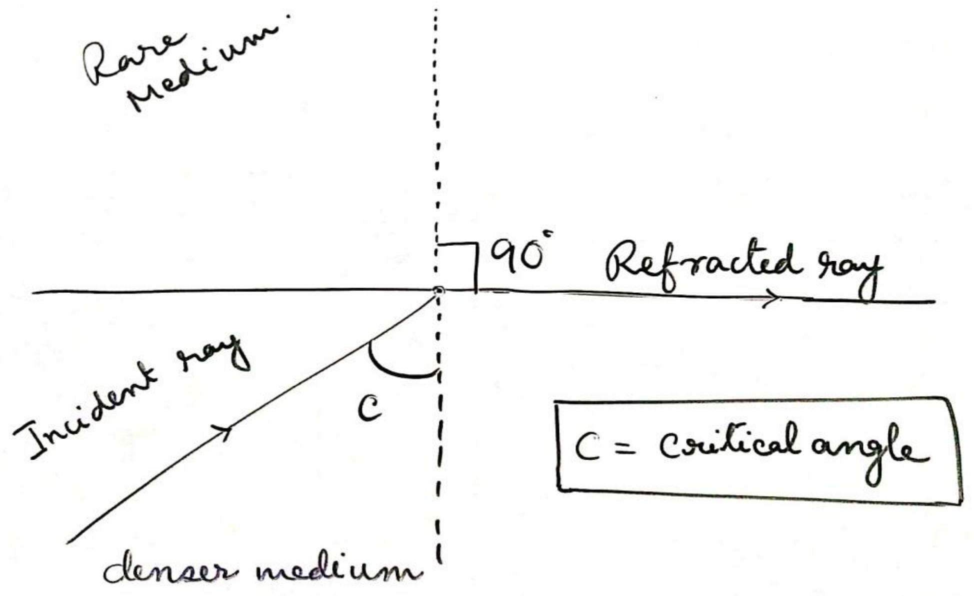
$$\theta_c = \sin^{-1}\frac{n_t}{n_i}$$



Critical angle

- Calculate the critical angle for glass block of refractive index 1.45

$n_{air} = 1$?

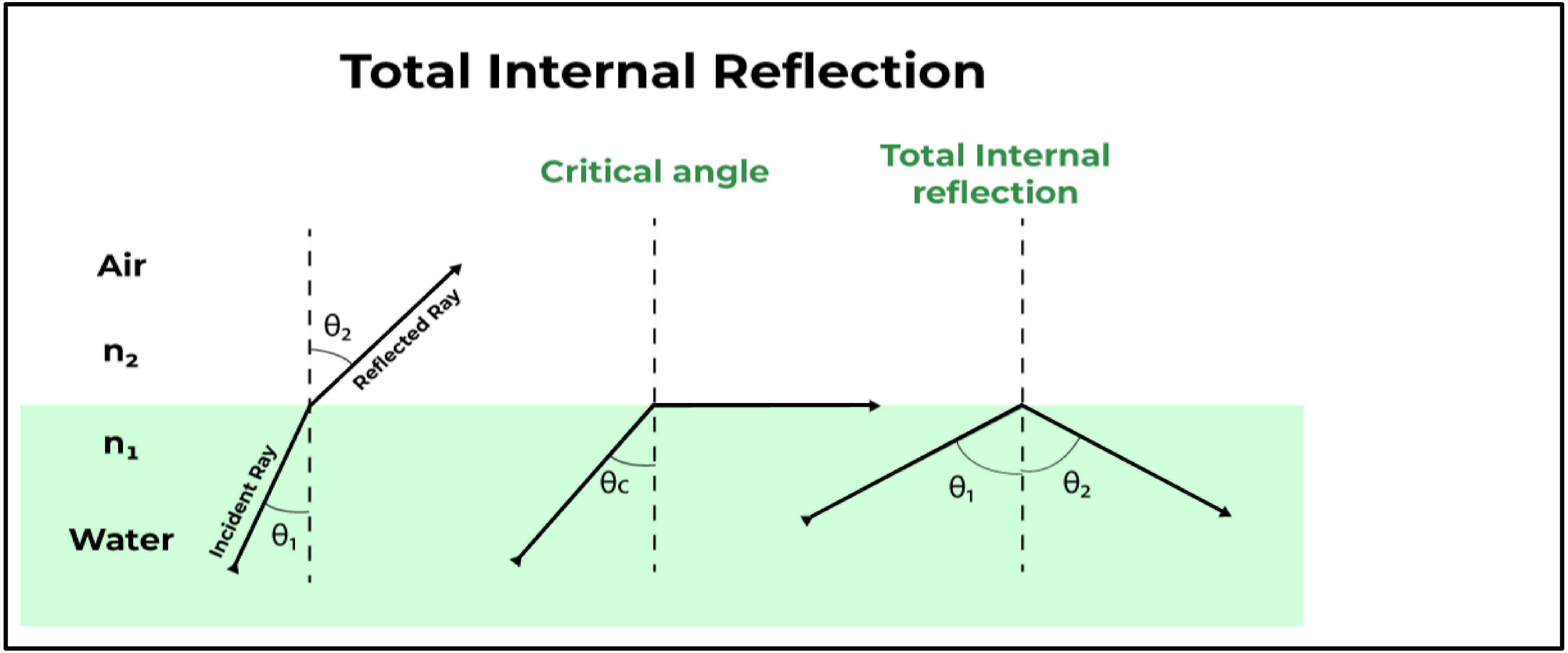


Refraction

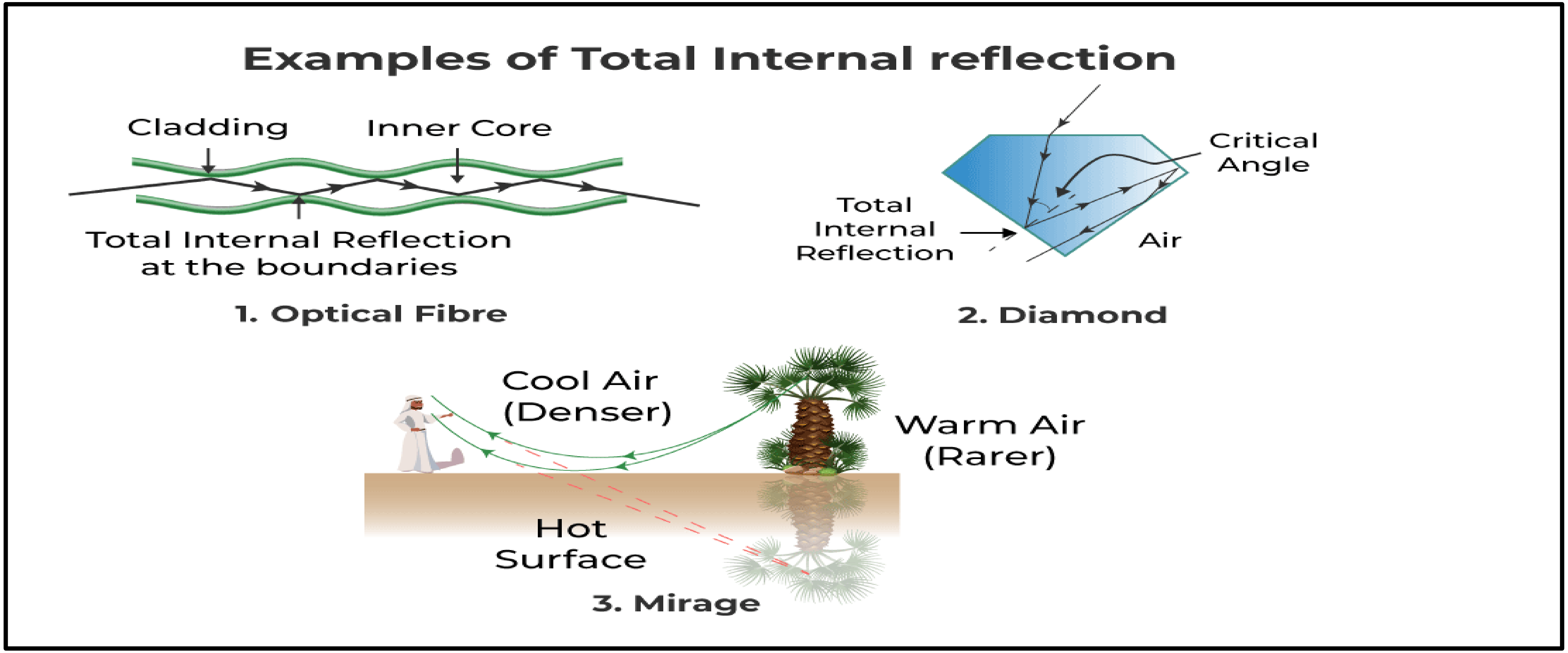
(a) (b) (c)

Figure 23.11 (a) The coin at the bottom of the empty mug is not visible. (b) After the mug is filled with water, the coin is visible. (c) Refraction at the water-air boundary bends light rays from the coin so they enter the eye.

Total internal refraction

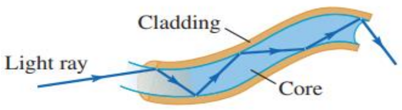


Total internal refraction

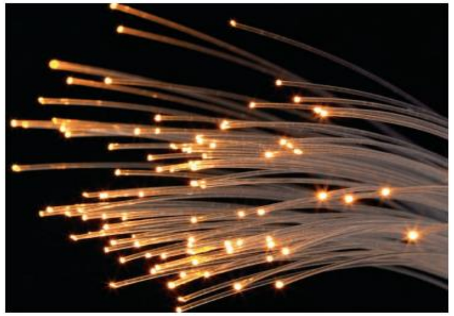


Fiber optics

- Total internal reflection is the principle behind fiber optics, a technology that has revolutionized both communications and medicine. As long as the angle of incidence is greater than the critical angle, the ray is totally reflected back-total internal reflection- into the core; no light leaks out into the cladding. A ray may typically reflect from the cladding thousands of times per meter of fiber, but since the ray is totally reflected each time, the signal can travel long distances—kilometers in some cases—before any appreciable signal loss occurs.



(a)

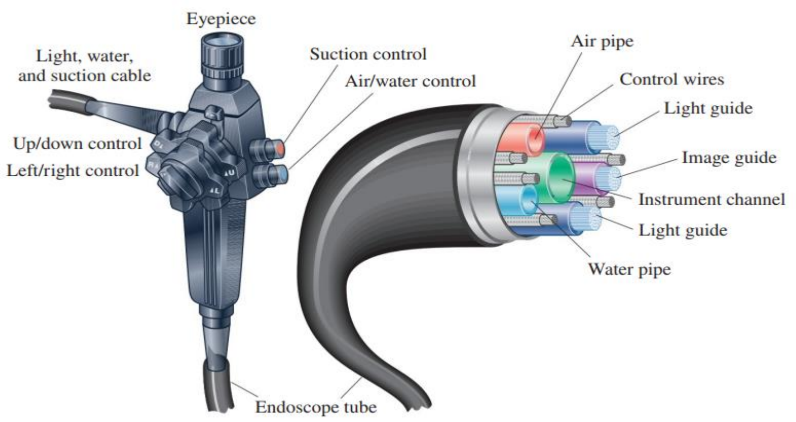


(b)

Figure 23.22 (a) An optical fiber. (b) A bundle of optical fibers.

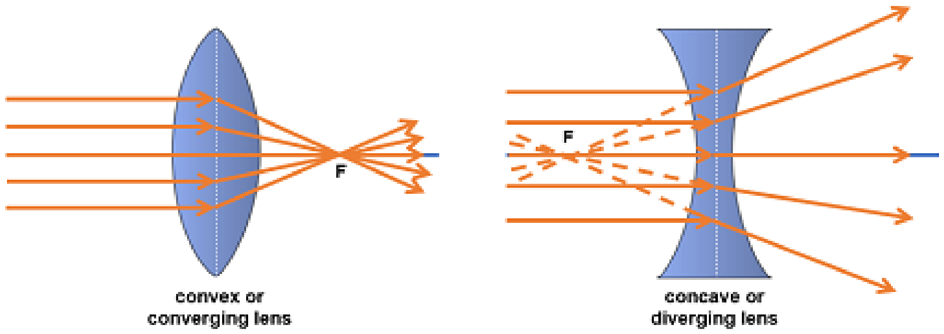
Medical application

- Endoscopy: In medicine, bundles of optical fibers are at the heart of the endoscope, which is fed through the nose , mouth or through a small incision into the body .
- One bundle of fibers carries light into body cavity or an organ and illuminates it ; another bundle transmits an image back to doctor for viewing.
- Is the endoscope is only for diagnosis ?

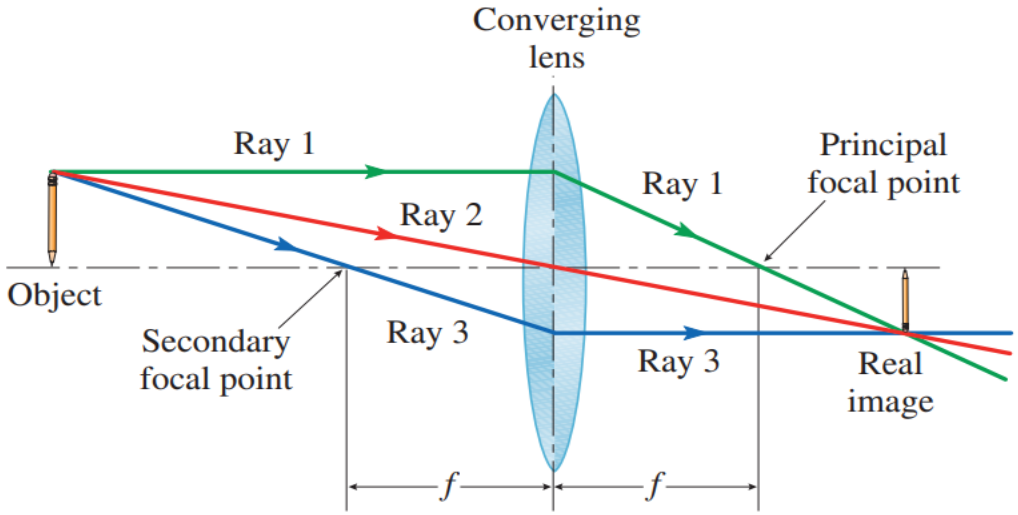


Lenses

- Whereas mirrors form images through reflection, lenses form images through refraction.
- Lenses are classified as diverging or converging, depending on what happens to the rays as they pass through the lens.
- A diverging lens bends light rays outward, away from the principal axis.
- A converging lens bends light rays inward, toward the principal axis.



Converging(Convex)lens

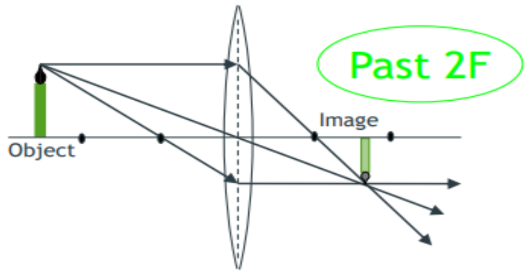


Principal rays for converging lenses

1. A ray parallel to the principal axis emerges from the lens headed toward the principal focal point.
2. A ray through the center of the lens passes through undeflected.
3. A ray coming from the secondary focal point emerges from the lens parallel to the principal axis.

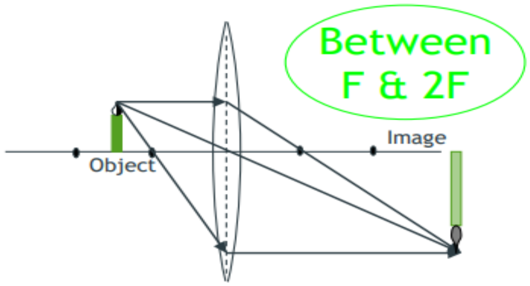
The image in this case(Real , inverted, Reduced)

3 cases for converging lenses



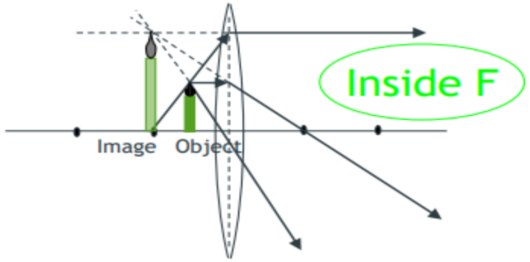
Inverted
Reduced
Real

This could be used in a **camera.** Big object on small film



Inverted
Enlarged
Real

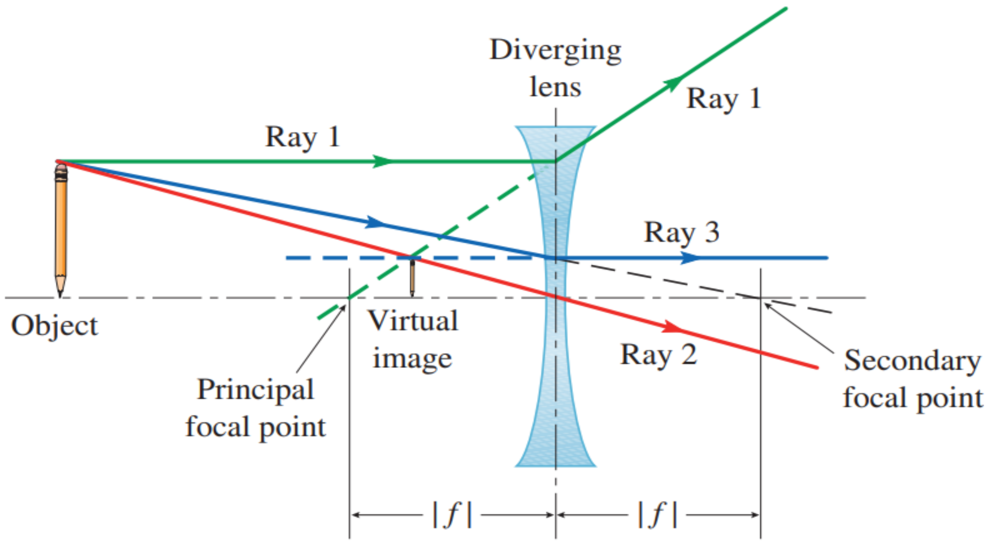
This could be used as a **projector.** Small slide on big screen



Upright
Enlarged
Virtual

This is a magnifying glass

Diverging (concave) lens



The image in the diverging lens is (virtual , upright and Reduced)

Principal rays for diverging lenses

1. A ray parallel to the principal axis emerges from the lens headed away from the principal focal point.
2. A ray through the center of the lens passes through undeflected.
3. A ray headed toward the secondary focal point emerges from the lens parallel to the principal axis.

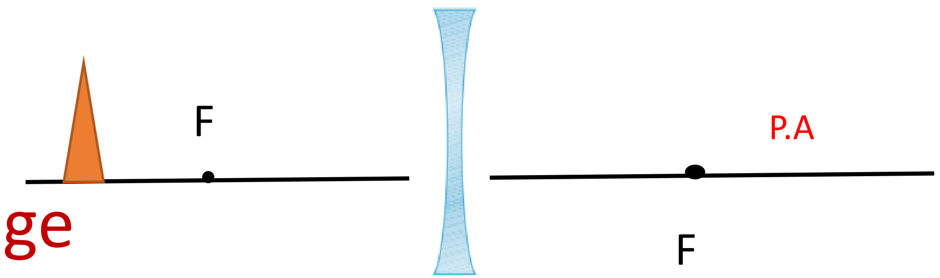
Diverging lens

- Which way should you move the object to have a real image ?

1)Closer to lens

2) Farther from lens

3) Diverging lens can't create a real image



Lens equation

P=distance object is from lens:

Positive: object in front of lens.

Negative: object behind lens.

q= distance image is from lens:

Positive : real image (behind lens)

Negative: *virtual* image (in front of lens)

f= focal length lens

Positive : Converging lens.

Negative: diverging lens.

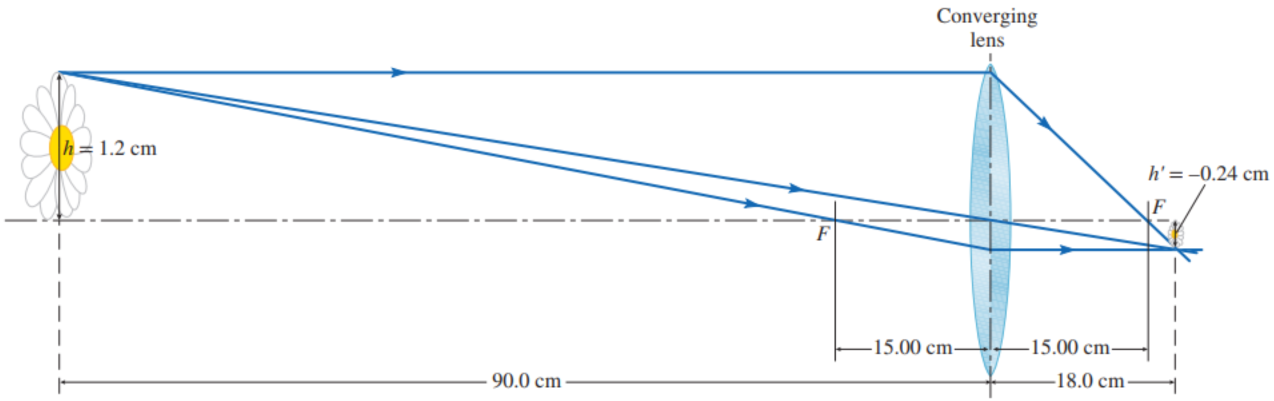
$$\frac{1}{f} = \frac{1}{P} + \frac{1}{q}$$

$$M = \frac{h_i}{h_0} = -\frac{q}{p}$$

Example

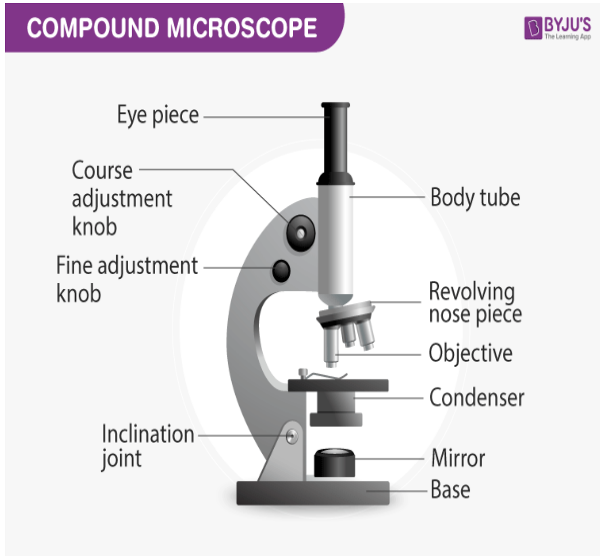
Zoom Lens

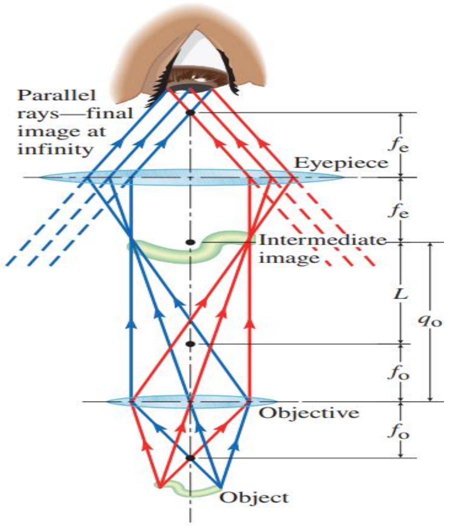
A wild daisy 1.2 cm in diameter is 90.0 cm from a camera's zoom lens. The focal length of the lens has magnitude 150.0 mm. (a) Find the distance between the lens and the image sensor. (b) How large is the image of the daisy?



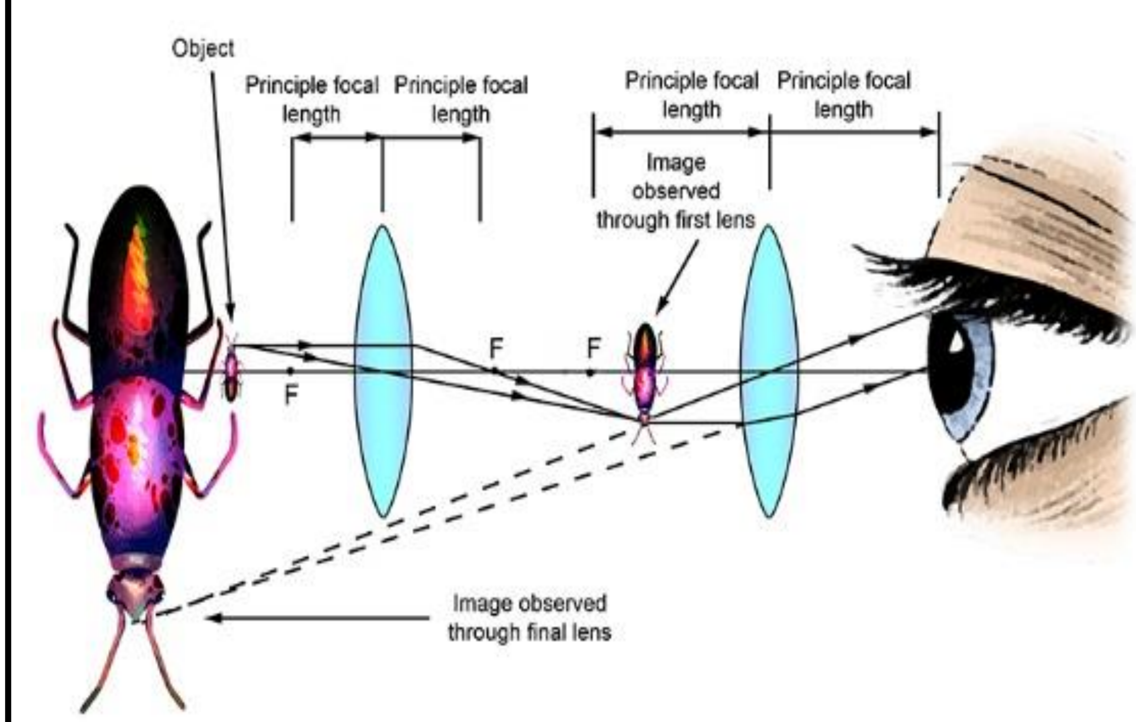
Microscope .

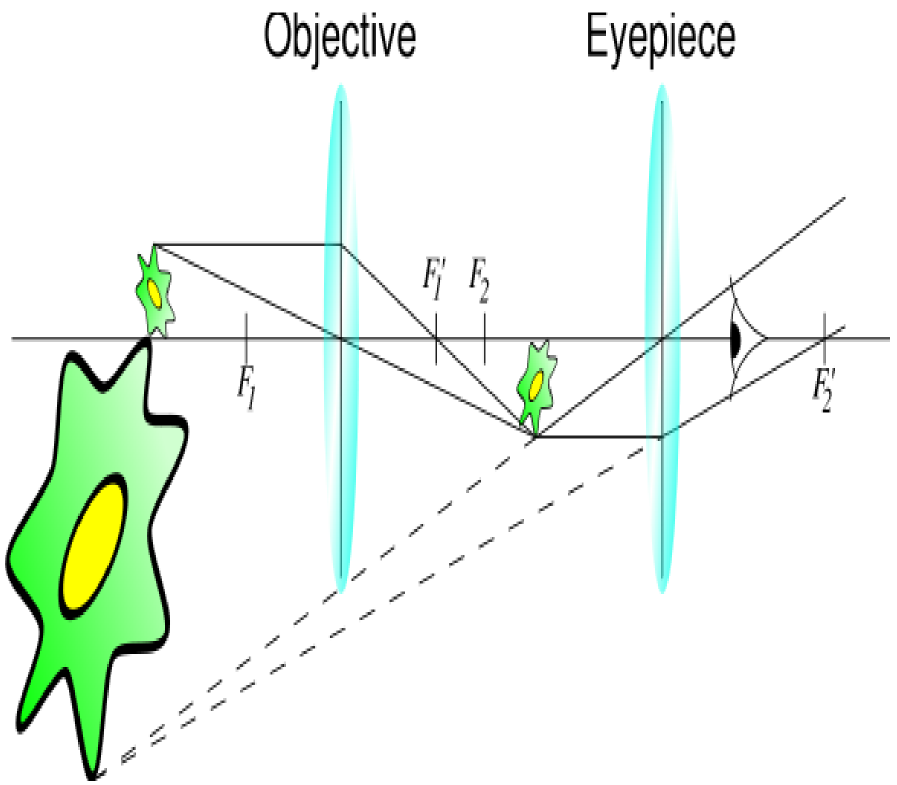
- The compound microscope, which uses two converging lenses, enables angular magnifications of 2000 or more.
- A small object to be viewed under the microscope is placed just beyond the focal point of a converging lens called the objective. The function of the objective is to form an enlarged real image. A second converging lens, called the ocular or eyepiece, is used to view the real image formed by the objective lens.
- Magnification of a microscope $M = m_1 m_2$



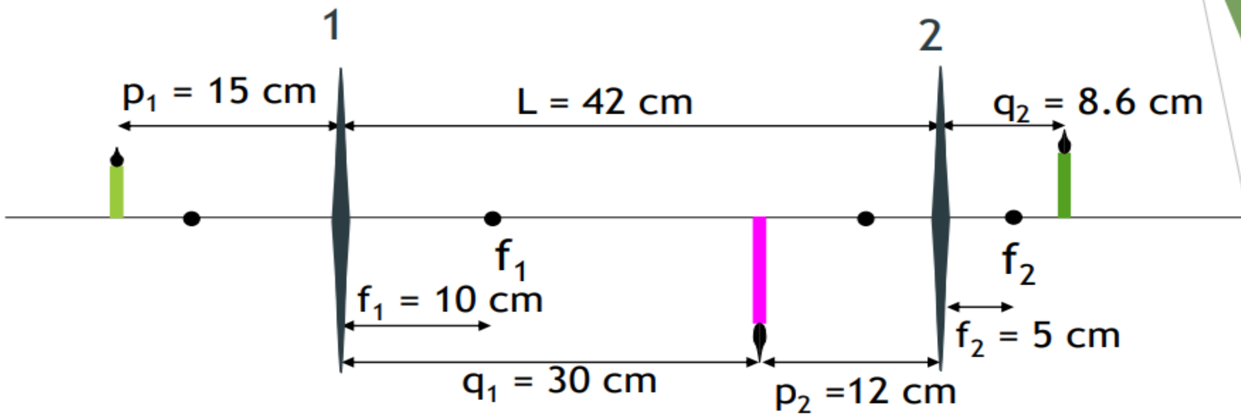


Microscope .


Object
Principle focal length
Principle focal length
Principle focal length
Principle focal length
Image observed through first lens
F
F
F
Image observed through final lens


Objective
Eyepiece

Microscope .



Net magnification: $m_{net} = m_1 m_2$

$$m_1 = -\frac{30}{15} = -2$$

$$m_2 = -\frac{8.6}{12} = -.72$$

$$m_{net} = m_1 m_2 = +1.43$$

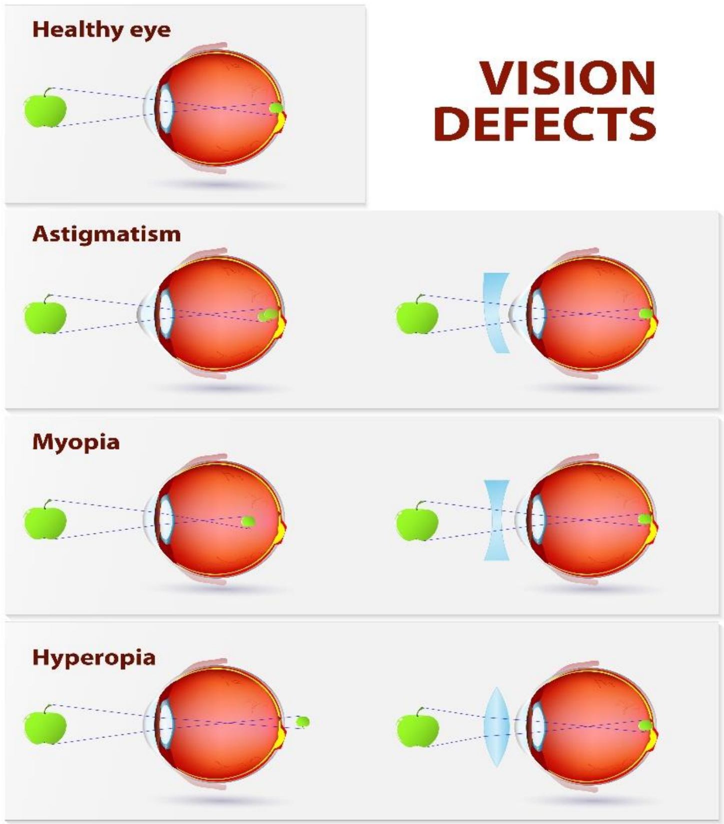
Eye defects

- There are three types of eye defects :-

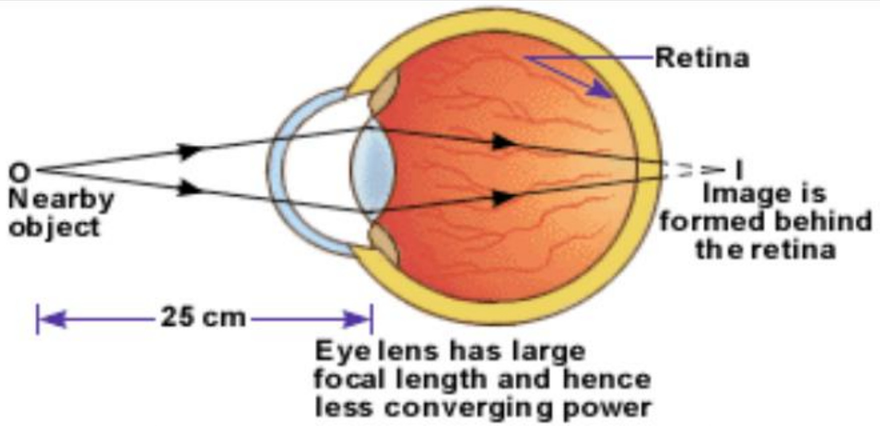
i. Long sightedness or hypermetropia .

ii. Short sightedness or myopia .

iii. Astigmatism.



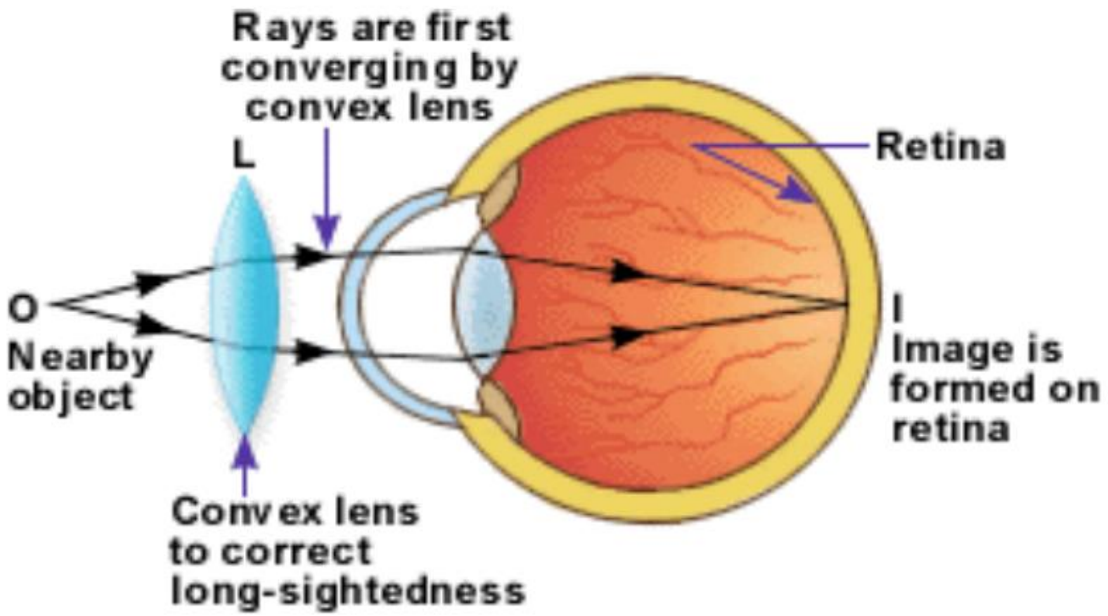
Long sightedness or hypermetropia



(a) An eye suffering from hypermetropia

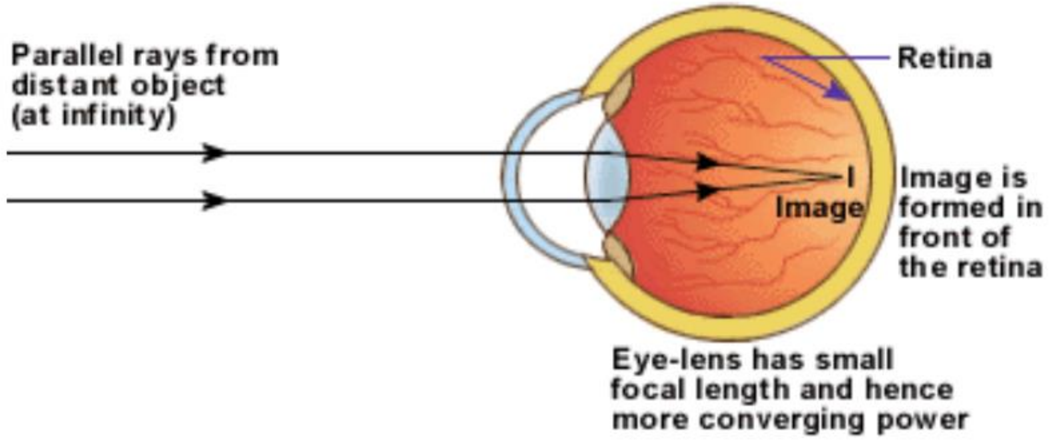
- The figure shows the shape of the eye that is suffering from long sightedness or hypermetropia.

Correction of hypermetropia



(b) Correction of hypermetropia

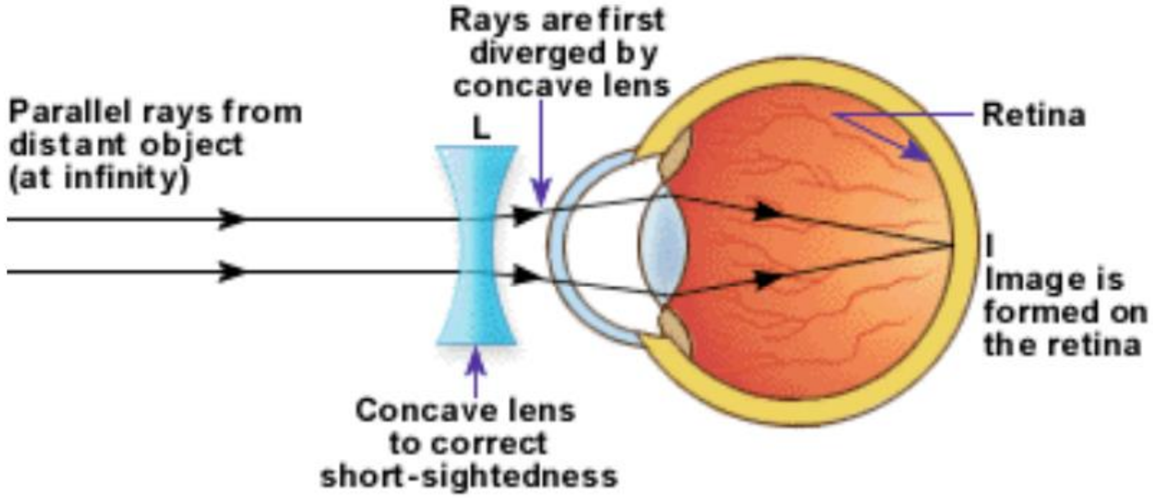
Short sightedness or myopia



(a) An eye suffering from myopia

- The figure shows the shape of the eye that is suffering from short sightedness or myopia.

Correction of myopia



(b) Correction of myopia

How to choose the right sunscreen ?