CH-1

The nature and propagation of light

Light: is that aspect of radiant energy of which a human observer is aware through the visual sensations which arise from stimulation of the eye.

wave front: is defined as the locus of points ,all of which are lie in the same phase.

Huygen's principle: Huygens proposed the rule that each point on a wave front may be represented as a new source of waves.

The velocity of light: the velocity of propagation of light in free space is one of the fundamental constants in nature is about $3*10^{8}$m/s.

Index of refraction: the ratio between the velocity of light in vacuum to the velocity of light in the medium. $n=\frac{c}{v}$,n-index of refraction,

c-velocity of light in space, v-velocity of light in the medium.

wavelength of the light $\lambda=\frac{c}{f}$

$1\mu m=10^{-6}m$

$1nm=10^{-9}m$

$1A^{0}=10^{-10}m$

The electromagnetic spectrum

The range of wavelengths of the electromagnetic waves extends from the waves which have longest wavelength (radio waves),to the waves which have shortest wavelength(Gamma waves).

types of electromagnetic waves:

1-**Radio waves**: These waves were used by Hertz which extends from a few Hz up to about 10^9Hz(λ from many kilometers to 0.3 m or so) ,these are generally emitted by using oscillating electrical circuits, and used in communication systems,TV,radio.

2-**Microwaves**: The microwave region extends from about 10^9Hz up to about $3*10^{11}$Hz,the corresponding wavelength go from roughly 30cm to 1mm.radiation capable of penetrating the earth's atmosphere .microwaves are therefore of interest in space-vehicle communications as well as radio astronomy.

3-**Infrared waves:** the infrared region extends roughly from $3*10^{11}$Hz up to $4*10^{14}$Hz,thisregion is often subdivided to four regions: a-near infrared: i.e near the visible (780-3000)nm.

b-intermediate IR:(3000-6000)nm. c-far IR:(6000-15000)nm.

d-extreme IR:(15000nm-1mm).

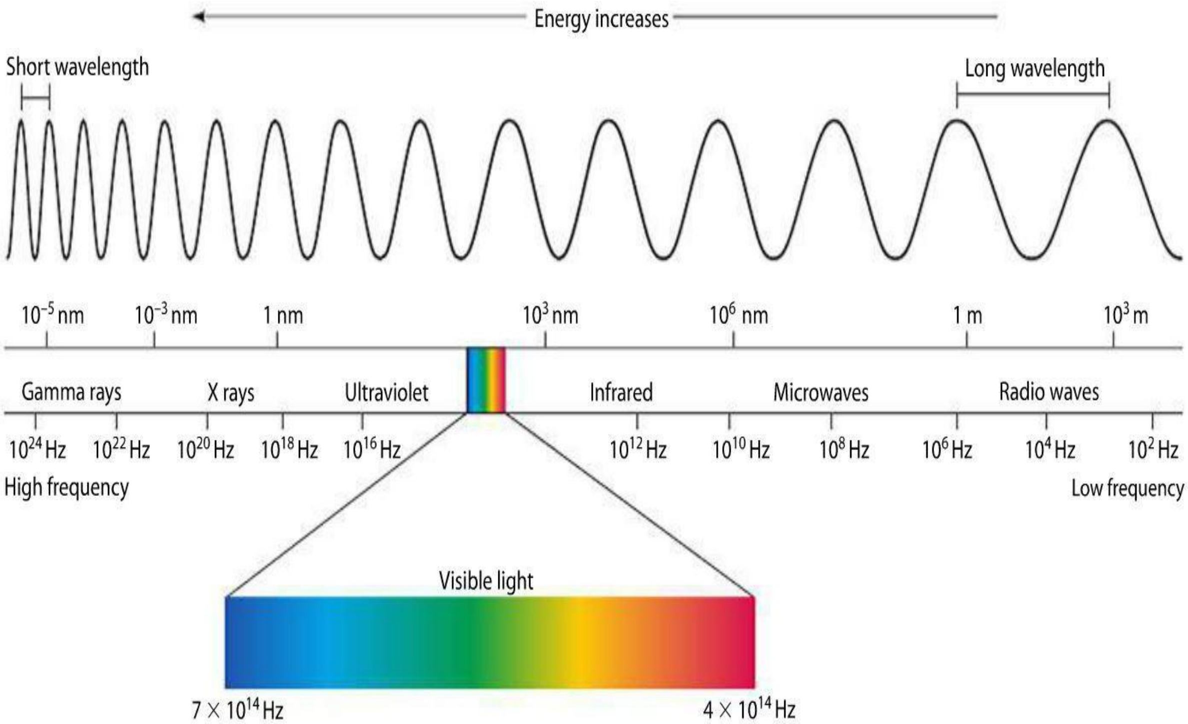
radiant energy at the wavelength extreme can be generated using microwave oscillator in candescent sources.

4-**Visible waves**: visible light corresponds to electromagnetic radiation in the narrow bands of frequencies from about $3.84*10^{14}$Hz to $7.69*10^{14}$Hz.it is generally produced by rearrangement of the outer electrons in atoms and molecules. the human eye can sense this region of the spectrum.

5-**Ultraviolet waves**: this region extends from ($8*10^{14}$Hzto about $3*10^{17}$Hz).ultraviolet or UV rays from the sun will thus has more than enough energy to ionize atoms in the upper atmosphere, and in so doing create ionosphere. ultraviolet is detectable via fluorescent screens, photographic emissions and photocells.

6-**X-rays**:extends in the range frequency from $3*10^{17}$Hz,x-rays photons are emitted by an atom or molecule when the inner, tightly bound electrons undergo transitions. these are the highest energy (10^4ev to about the lowest wavelength electromagnetic radiations10^{19}ev.

7-**Gamma rays**: they are electromagnetic waves of nuclear origin, and emitted by nuclei of the radiant particles, for example,^{137}cs,^{60}co during special nuclear interactions.



The electromagnetic spectrum

The nature and propagation of light until the time(Isshac Newton)(1727)most scientists thought that the light consisted of a stream of particles emitted by light sources and traveled outward from the source in a straight lines .by the middle of 17th century (christian Huygens) showed that the laws of reflection and refraction could be explained on the basis of wave theory .the wave demonstrated the phenomenon of interference and diffraction of light. in 1873Maxwell explained that the oscillating electrical circuit showed radiate electromagnetic waves. the velocity of propagation of the waves could be computed from purely electrical and magnetic measurement and it appeared close to $3*10^8$m/s. the classical electromagnetic theory failed to account for the phenomenon of photoelectric emission that is ejection of electrons from a conductor by light incident on it's surface.

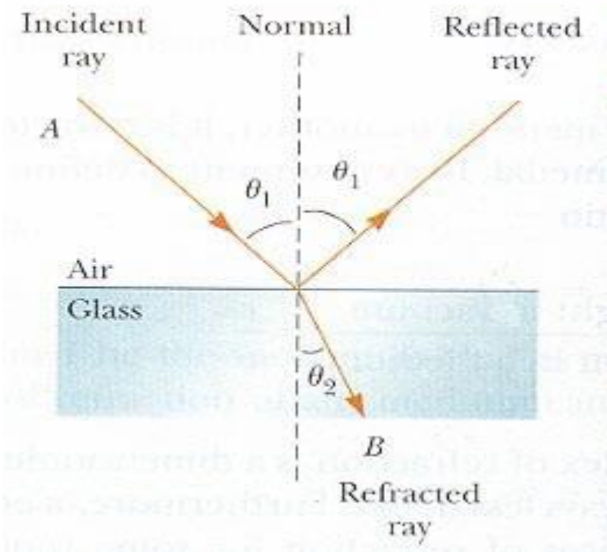
in 1905 Enistein extended an idea proposed five years earlier by plank and postulated that the energy in the light beam.

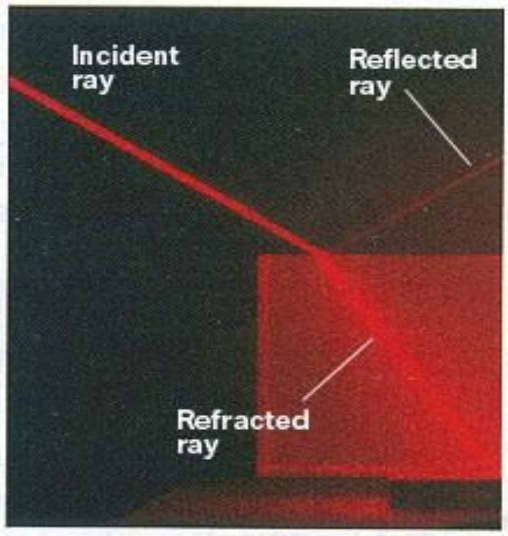
CH-2

Reflection and refraction

Reflection and refraction at plane surface:

The ray of light is incident on the boundary separating two different media, part of the ray is reflected and the remainder is refracted





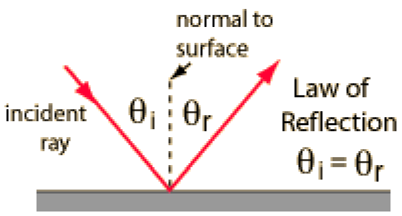
θ_1-angle of incidence,

θ_2-angle of refraction

Laws of reflection and refraction:

1-the incident, reflected and refracted ray and the normal to the surface are all lie in the same plane.

2-the angle of reflection $(\theta_1^-)$is equal to the angle of incidence.



3-the ratio between the sine of the angle of incidence and the sine of the angle of refraction is a constant.

$$\frac{\sin\theta 1}{\sin\theta 2}=\text{constant}$$

$$\frac{n}{n} = \text{constant}$$

$$\frac{\sin\theta 1}{\sin\theta 2} = \frac{n}{n}$$

$$n_1 \sin\theta 1 = n_2 \sin\theta 2$$ snell's law

Ex: Light travels from air into an optical fiber with an index of refraction of 1.44. (a) In which direction does the light bend? (b) If the angle of incidence on the end of the fiber is 22^o, what is the angle of refraction inside the fiber? (c) Sketch the path of light as it changes media

(a) Since the light is traveling from a rarer region (lower *n*) to a denser region (higher *n*), it will bend toward the normal.

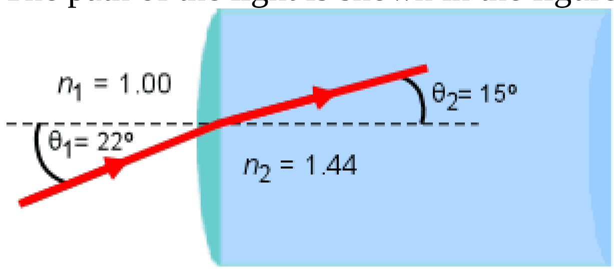
(b) We will identify air as medium 1 and the fiber as medium 2. Thus, n_1 = 1.00, n_2 = 1.44, and θ/font>$_1$ = 22^o. Snell's Law then becomes

$$(1.00) \sin 22^o = 1.44 \sin \theta_2.$$

$$\sin \theta_2 = (1.00/1.44) \sin 22^o = 0.260$$

$$\theta_2 = \sin^{-1} (0.260) = 15^o.$$

(c) The path of the light is shown in the figure below.



EX: Light traveling through an optical fiber (n=1.44) reaches the end of the fiber and exits into air. (a) If the angle of incidence on the end of the fiber is 30^o, what is the angle of refraction outside the fiber? (b) How would your answer be different if the angle of incidence were 50^o?

Solution:

(a) Since the light is now traveling from the fiber into air, we will call the fiber material 1 and air material 2. Thus, n_1 = 1.44, n_2 = 1.00, and θ_1 = 30^o. Snell's Law then becomes

$$(1.44)\sin 30^o = 1.00 \sin \theta_2.$$
$$\sin \theta_2 = (1.44/1.00)\sin 30^o = 1.44\,(0.500) = 0.720$$
$$\theta_2 = \sin^{-1}(0.720) = 46^o.$$

Notice that this time, the angle of refraction is larger than the angle of incidence. The light is bending away from the normal as it enters a rarer material.

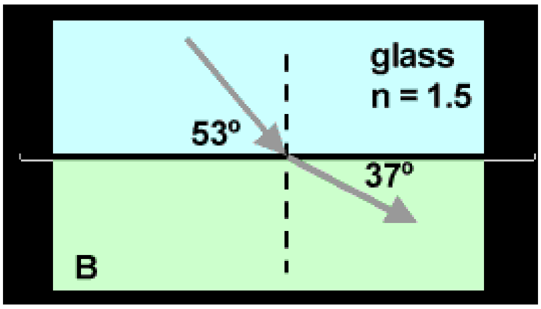
(b) Replacing the angle of incidence with 50° gives

$$\sin \theta_2 = (1.44/1.00)\sin 50^o = 1.44\,(0.766) = 1.103$$

This equality cannot be met, so light cannot exit the fiber under these conditions

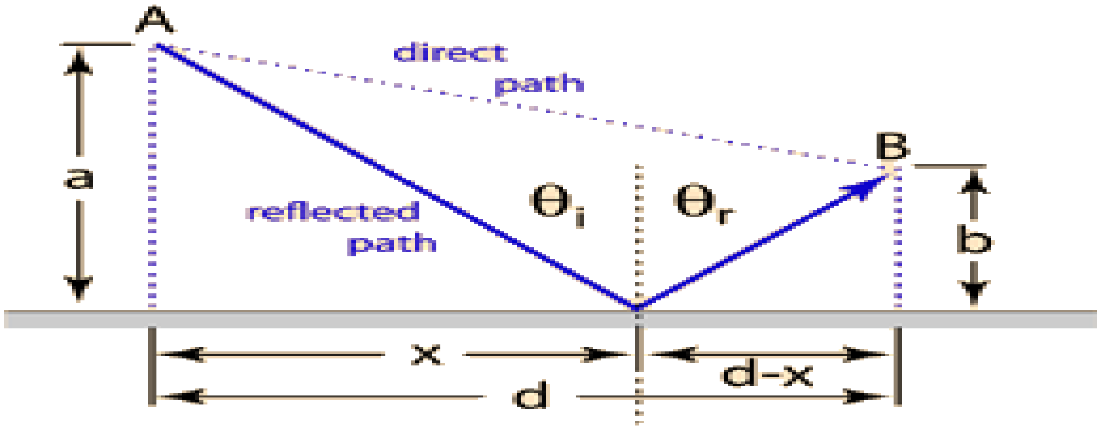
EX:

Calculate the *index of refraction* for medium B.



Fermat's principle: states that light travels between two points along the path that requires the least time, as compared to other nearby path.

Derivation of the laws of reflection law according to Fermat's law:



Consider the light ray as shown in figure, a ray of light starting from point A .we calculate the length of each path and divide the by the speed of light to determine the time required to travel between two points.

The path length from A to B is

$$t = \frac{L}{C} = \frac{\sqrt{x + h}}{c} + \frac{\sqrt{(l-x) + h}}{c}$$

to minimize the time we set the derivative of the time with respect to x equal to zero (Fermat's principle).

$$\frac{dt}{dx} = 0 = \frac{x}{c\sqrt{x + h}} + \frac{l-x}{c\sqrt{(l-x) + h}}$$

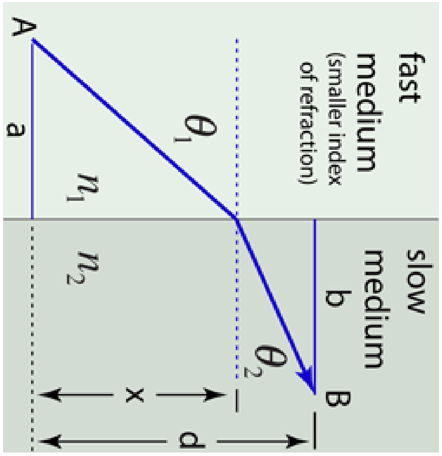
$$\frac{x}{\sqrt{x + h}} = \frac{(l-x)}{\sqrt{(l-x) + h}}$$

$\sin\theta_1 = \sin\theta_2$, when θ_1, θ_2 are very small

$$\boxed{\theta_1 = \theta_2}$$

Derivation of snell's law according to Fermat's law:

Fermat's Principle: Light follows the path of least time. Snell's Law can be derived from this by setting the derivative of the time =0. We make use of the index of refraction, defined as n=c/v.



$$t = \frac{\sqrt{x \quad + h}}{c/n} + \frac{\sqrt{(l-x) \quad + h}}{c/n}$$

to minimize the time required we set the derivative of the time with respect to x equal to zero (Fermt's principle)

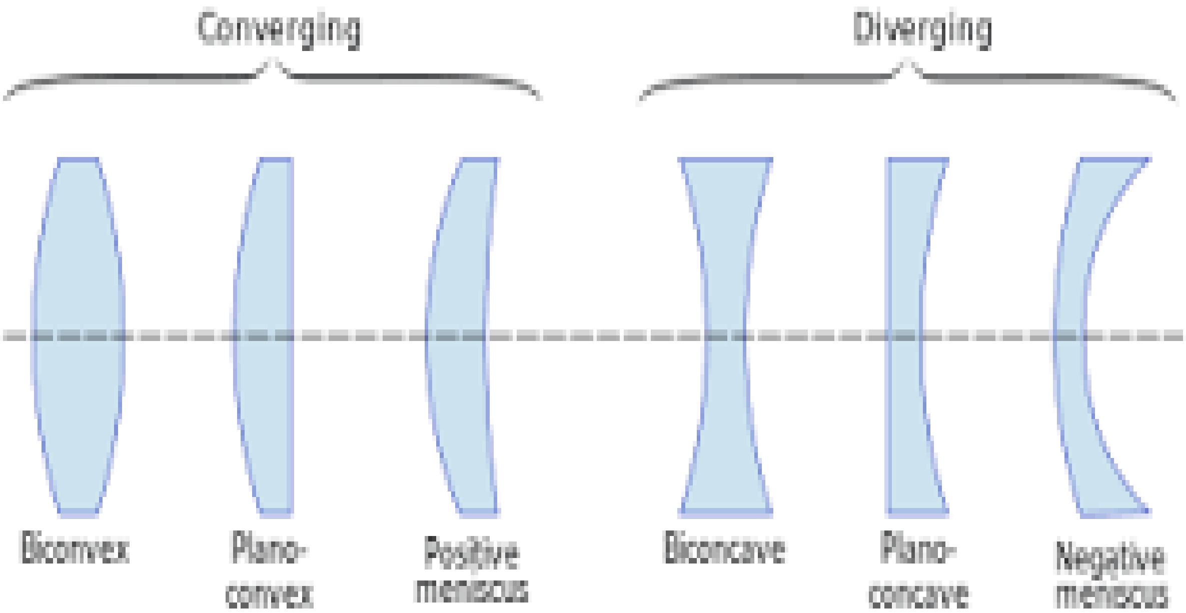
$$\frac{dt}{dx} = \frac{n \; x}{c\sqrt{x \quad + \; h}} + \; = \frac{-n \; (l-x)}{c\sqrt{(l-x \;) \quad + \; h}}$$

$$\frac{n \; x}{\sqrt{x \quad + \; h}} = \frac{-n \; (l-x)}{\sqrt{(l-x \;) \quad + \; h}}$$

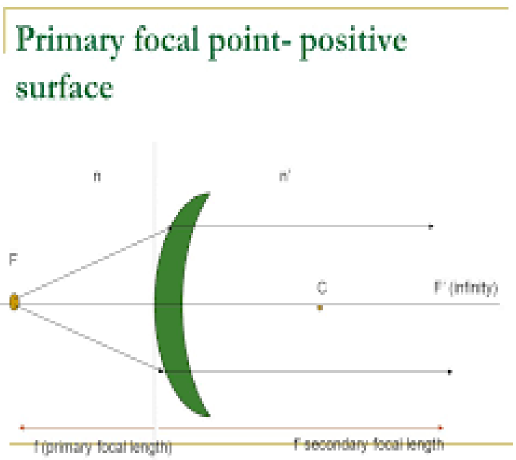
$$n_1 \sin \theta 1 = n_2 \sin \theta 2$$

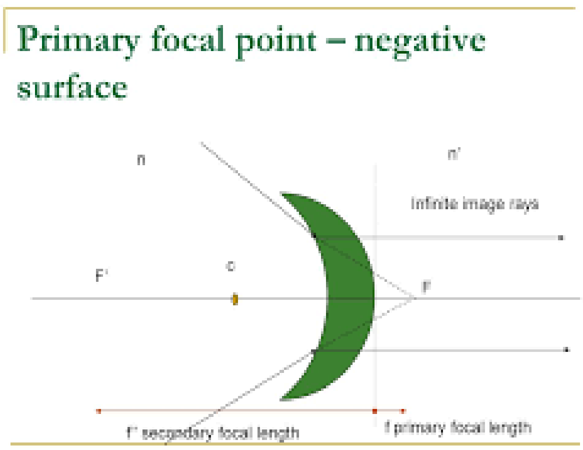
snell's law

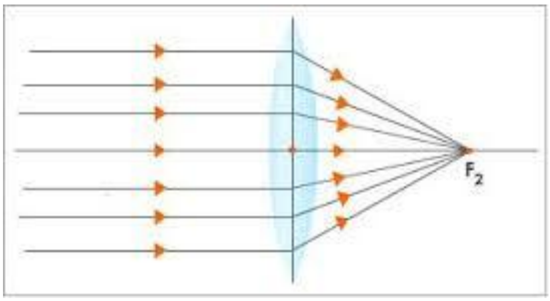
CH3-spherical surfaces

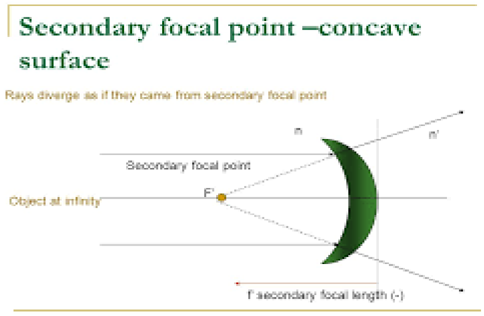


focal points and focal lengths:









principal axis: straight line pass through the center of curvature.

primary focal point(F): is an axial point having property that any ray coming from it or proceeding toward it travel parallel to the axis after refraction.

secondary focal point(F^-): is an axial point having property that any incident ray travelling to the axis will after refraction proceed toward or appear to come from F^-.

$$\frac{f^-}{f} = \frac{n^-}{n}$$

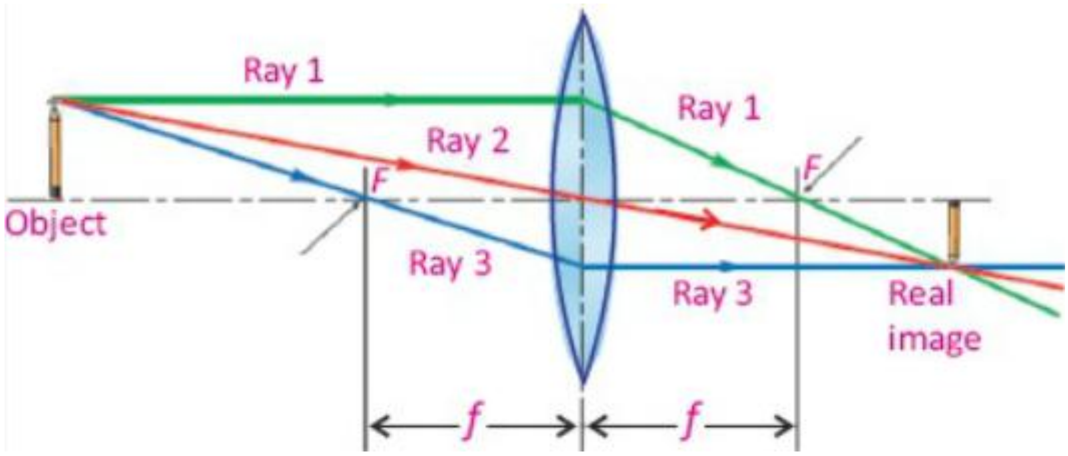
f=primary focal length

f^-=secondary focal length

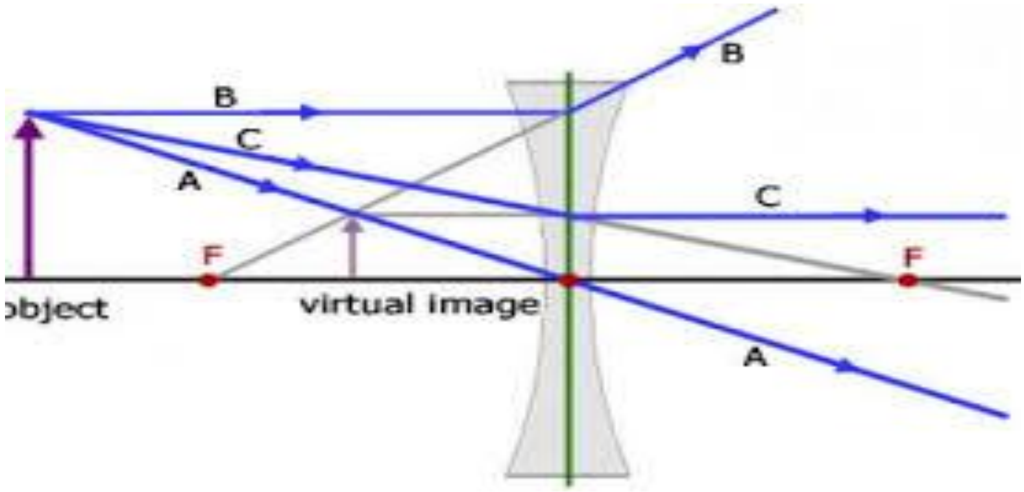
n,n^- =indices of refraction

image formation

1- when the object is moved closer to the primary focal plane the image will be formed farther to the right away from (F^-)and will be larger (magnified).



2-if the object is moved to the left, farther away from (F^-)the image will be formed closer to (F^-) and will be smaller in size.



convention of signs

1-all figures are drawn with the light travelling from left to right.

2-all object distances(S) are considered as positive when they are measured to the left of the vertex and negative when they are measured to the right.

3-all image distances(S^-) are positive when they are measured to the right of the vertex and negative when they are to left.

4-both focal lengths are positive for converging system and negative for diverging system.

5-object and image dimensions are positive when measured upward to the axis and negative when measured downward.

6-all convex surfaces encountered are taken as having a positive radius and all concave surfaces encountered are taken as a negative radius.

we can determine the positionandsize of the image by :

1-graphical method

2-experimental method

3-calculation using Gaussian formula.

for a single spherical surface:

$$\frac{n}{s}+\frac{n}{s}=\frac{n-n}{r}$$

Gaussian formula

n=index of refraction of the first medium

n^-= index of refraction of the second medium

S=distance from object to the surface

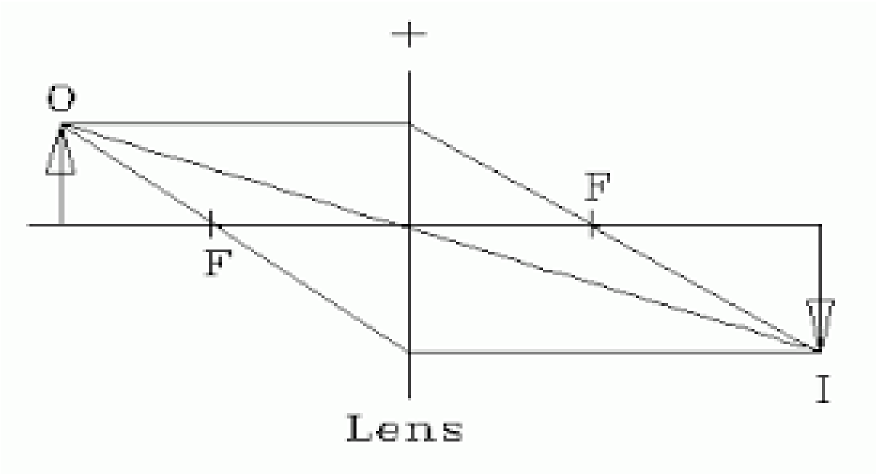
S^- =distance from image to the surface

r = radius of curvature.

2-Graphical constructions:

a- parallel-ray method:

1- convex spherical surface: when $n^{-}>n$



2- concave spherical surface: when $n^{-}>n$

3-oblique-ray method:

Magnification

It is the ratio between the transverse dimension of the final image and the corresponding dimension of the original object.

$$m = \frac{y}{y} = -\left(\frac{s-r}{s+r}\right)$$

note: if m is negative ⇨ the image is real and inverted

if m is positive ⇨ the image is virtual and erect

Reduce vergence:-

$$V = \frac{n}{s} \qquad , \quad V = \frac{n}{s}$$

$$\frac{1}{S} + \frac{1}{S} = \frac{1}{f}$$

power of the surface

$$p = \frac{n}{f} \qquad , \qquad p = \frac{n}{f}$$

curvature of surface : $k = \frac{1}{r}$

note: when all distances are measured in meters the reduced vergence V, V ,the curvature k,and the power (p) ,are in units called (diopter) (D).

$$P = \frac{n - n}{r} = k\,(\,n - n\,)$$

$$V + V = P$$

EX: one end of a glass rod of refractive index 1.5 is ground and polished with a convex spherical surface of radius 10cm.An object is placed in the air on the axis 40cm to the left of the vertex ,find:

a-the power of the surface.

b-the position of the image by Gaussian formula.

c- the position of the image by reduce vergence.

d- curvature of the surface.

sol.

a- $p = \frac{n-n}{r} = \frac{1.5-1}{0.1} = 5$ D

b- $\frac{n}{s} + \frac{n}{s} = \frac{n-n}{r} \Longrightarrow \frac{1}{0.4} + \frac{1.5}{s} = \frac{1.5-1}{0.1}$

$s^{-} = 60$ cm$= 0.6$ m

c- $V = \frac{n}{s} = \frac{1}{0.4} = 2.5D$

$P = V + V$

$5 = 2.5 + V \Longrightarrow V = 2.5$ D

$V = \frac{n}{s}$

$2.5 = \frac{1.5}{s} \Longrightarrow s = 0.6$ m

d- $k = \frac{1}{r} = \frac{1}{0.1} = 10$D

EX: The left end of glass rod of index (1.6) is ground and polished to a convex spherical surface of radius 3cm. A small object is located in the air on the axis 10cm from the vertex, find:

a- the primary and secondary focal lengths.

b- the surface power.

c-the image distance.

d- the lateral magnification.

sol.

a- $\frac{n}{f} = \frac{n-n}{r} \Longrightarrow \frac{1}{f} = \frac{1.6-1}{3} \Longrightarrow$ f= 5cm

$\frac{n}{f} = \frac{n-n}{r} \Longrightarrow \frac{1.6}{f} = \frac{1.6-1}{3} \Longrightarrow$ f = 8 cm

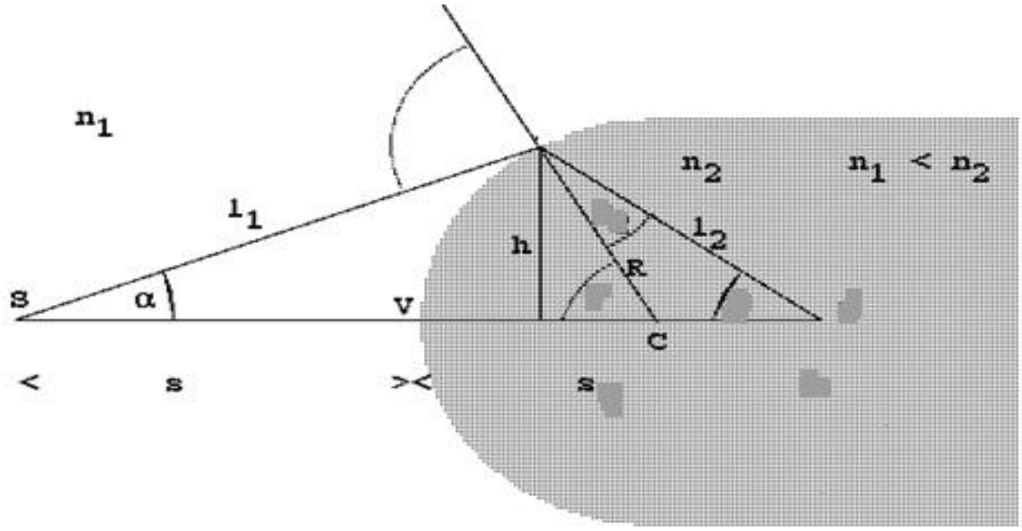
b- P = $\frac{n}{f} = \frac{1}{0.05}$ = 20D

C- $\frac{n}{s} + \frac{n}{s} = \frac{n-n}{r} \Longrightarrow \frac{1}{10} + \frac{1.6}{s} = \frac{1.6-1}{3} \Longrightarrow$ s = 16cm

d- m = - ($\frac{s-r}{s+r}$) = - ($\frac{16-3}{16+3}$) = -1

m is negative $\Longrightarrow$ the image is real and inverted

Derivation of the Gaussian formula



This figure shows the refraction of ray of light at the convex surface to form a real image for the object .

in the figure (TA) is the spherical surface separates between two media.

the first medium: refractive index(n) ,contains the object at point M.

the second medium: refractive index(n^-) ,centre of curvature at point c.

the incident ray MT incident on the convex surface at T with refraction angle ϕ in the medium of refractive index (n),this ray refracts in the second medium of refractive index n^- with refraction angle(ϕ^-).the intersection of the refracted ray with the original axis at M^- (image position).

M- object point

ϕ- incident angle

ϕ^- -refractive angle

when the incident and refracted rays MT,TM^- are paraxial.

the angles ϕ, ϕ^- will be small so,we put the sines of the angles equal to the angles themselves and :

from snell's law:

$n\sin\phi = n^-\sin\phi^-$

$n\,\phi = n^{-}\,\phi^{-} \Longrightarrow \dfrac{\phi}{\phi} = \dfrac{n}{n}$ --------(1)

from the geometry of the fig.:- △ MTC

$\phi = \alpha + \beta$ ------------(2)

ϕ -exterior angle

α , β - are interior angles

for △ TCM^{-} :

$\beta = \phi^{-} + \gamma$

β -is an exterior angle

ϕ^{-} ,γ - are interior angles

$\phi^{-} = \beta - \gamma$ -------------(3)

substitute ϕ, ϕ^{-} in (1):-

$$\frac{\alpha+\beta}{\beta-\gamma} = \frac{n}{n}$$

$n^{-}\beta - n^{-}\gamma = n\,\alpha + n\,\beta$

$n\,\alpha + n^{-}\gamma = (n^{-} - n)\,\beta$ -----------(4)

α , β , γ are very small angles

$\alpha = \dfrac{h}{s}$, $\beta = \dfrac{h}{r}$, $\gamma = \dfrac{h}{s}$ ----------------(5)

substitute (5) in (4) :-

$$n\,\frac{h}{s} + n^{-}\,\frac{h}{s} = (n^{-} - n)\,\frac{h}{r}$$

by cancelling (h):-

$$\frac{n}{s} + \frac{n}{s} = \frac{(n-n)}{r}$$

Gaussian formula

this relation connects between the object and it's image which is formed by refraction at convex surface.

$\dfrac{(n-n)}{r}$ = power of the surface

= positive if the surface converge the incident rays.

= negative if the surface diverge the incident rays

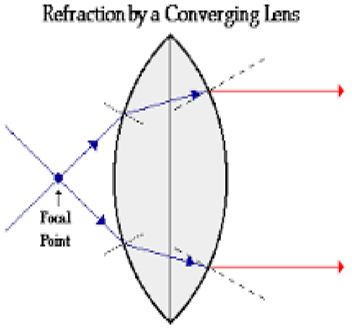
CH-4

THIN LENSES

THIN LENS: A thin lens may be defined as one whose thickness is considered small in comparison with the distance generally associated with optical properties.

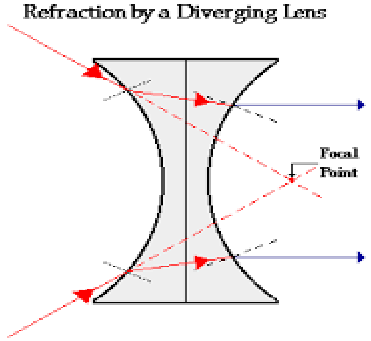
such distances are for example radii of curvature of two spherical surfaces ,primary and secondary focal length and object and image distances.

Refraction by a Converging Lens

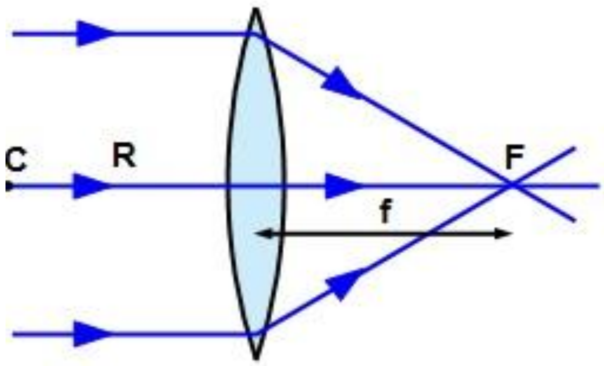


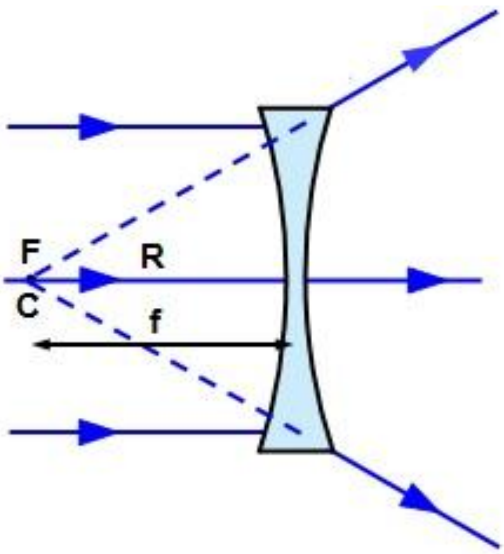
Incident rays which travel through the focal point will refract through the lens and travel parallel to the principal axis.

Refraction by a Diverging Lens



Incident rays traveling towards the focal point will refract and travel parallel to the principal axis.



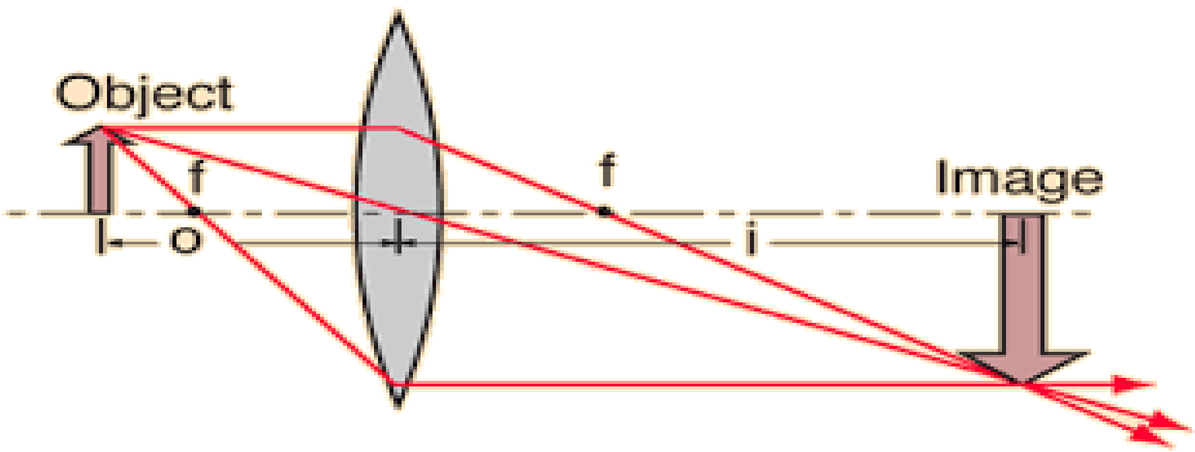


The primary focal point((F)): is an axial point having the property that any ray coming from it or proceeding toward it, travels parallel to the axis after refraction.

secondary focal point((F^-)): is an axial point having the property that any incident ray travelling parallel to the axis will after refraction proceed toward or appear to come from F^- .

F,F^- are measured in centimeter or inches, having a positive sign for converging lenses, and negative sign for diverging lenses.

Image formation



when an object is placed on one side or the other of a converging lens and beyond the focal plane an image is formed on the opposite side.

1-if the object is moved closer to the primary focal plane, the image will be formed farther away from the secondary focal plane and will be larger (magnified).

2-when the object moved farther away from (F),the image will be formed closer to (F^-)and will be smaller in size.

conjugate points and planes

any points of object and image points such as M and M^- are called conjugate points, and planes passes through these points perpendicular to the axis are called conjugate planes.

Determination the position of the image

There are three methods to determine the position of the image:-

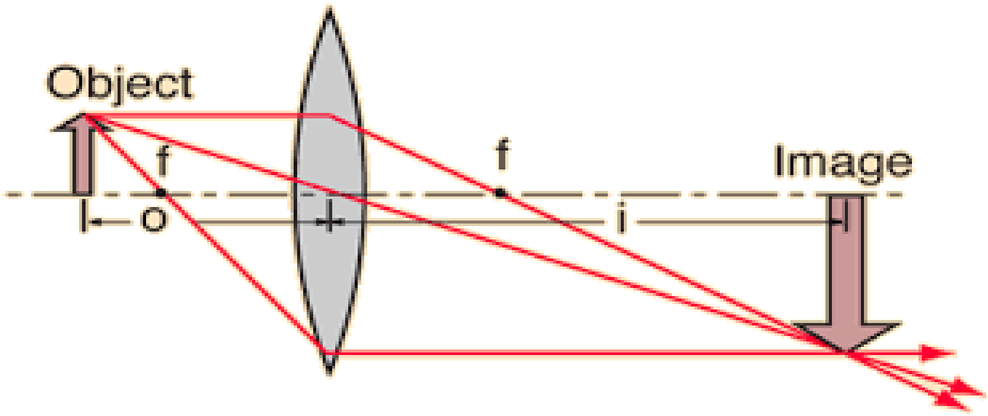
1- graphical construction

2- experimental method

3-the lens formula ($\frac{1}{s} + \frac{1}{s} = \frac{1}{f}$)

1- graphical construction

a- the parallel-ray method



b- the oblique-ray method

3- use of the lens formula

$$\frac{1}{s}+\frac{1}{s}=\frac{1}{f} \quad \Rightarrow \quad s^{-}=\frac{s\,.\,f}{s-f}$$

convention of signs

the sign convention of thin lens are identical to those for a single spherical surface.

lateral magnification

from fig. b $\qquad$ $y= MQ$, $y^{-} = M^{-}Q^{-}$

$$m=\frac{y}{y}$$

when : m is negative $\Rightarrow$ inverted image

m is positive $\Rightarrow$ erect image

note: in converging lens the virtual image will be formed when the image locates between the primary focal point and the lens.

LENS MAKERS FORMULA

A lens is to be ground to some spherical focal length, refractive index of the glass must be known.

supporting the index to be chosen so as to satisfy the equation:

$$\frac{1}{f} = (n - 1)\left(\frac{1}{r} - \frac{1}{r}\right)$$

substituting ($\frac{1}{s} + \frac{1}{s} = \frac{1}{f}$)

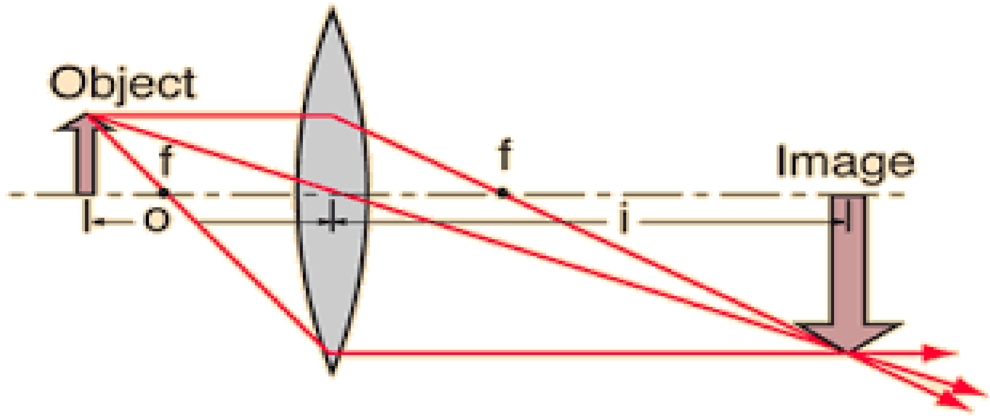
$$\frac{1}{s} + \frac{1}{s} = (n - 1)\left(\frac{1}{r} - \frac{1}{r}\right)$$

r_1 = positive for convex lens

r_2 = negative for concave lens

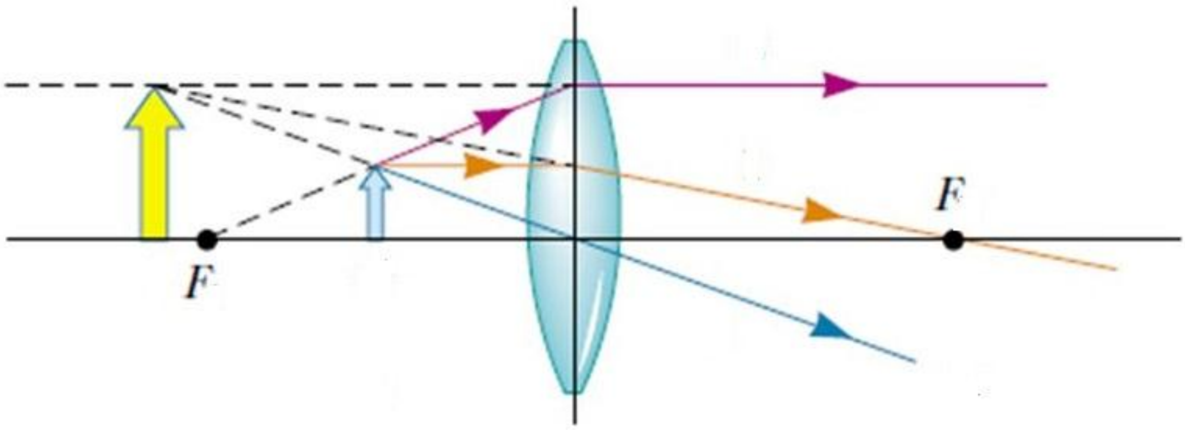
virtual image

1- the image formed by the converging lens is real and can be made visible on a screen.



real image formed by converging lens

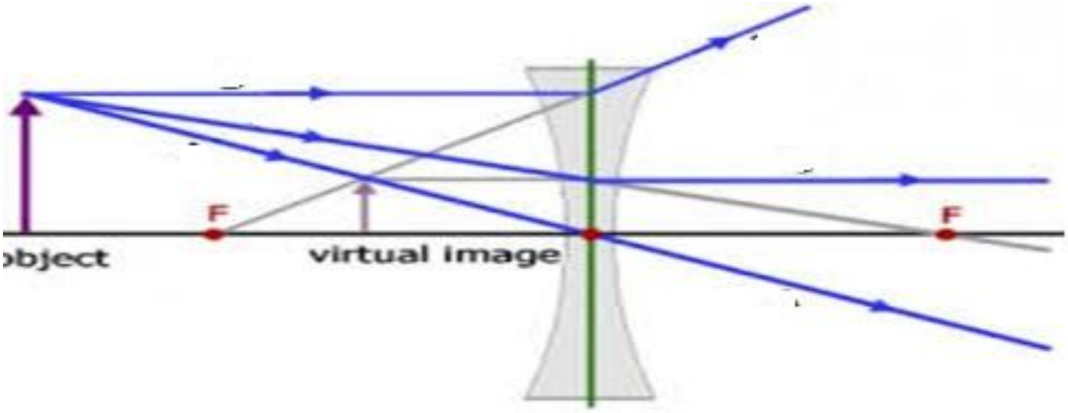
A virtual image cannot be formed on a screen, **the virtual image with converging lens may be formed just in the case when the object locates between the primary focal point and the lens.**



virtual image by converging lens

2-**With diverging lens, the image will be always virtual**

i.e cannot be viewed on a screen since rays are diverging on the right of the lens.



virtual image by diverging lens

Ex:Aplano-convcave lens having afocal length of 25cm isto be made of glass of index(n=1.52).calculate theradii of curvature of the grinding and polishing tools that must be used to make this lens.

sol:

$r_2 = \infty$

$\frac{1}{f} = (n-1)\left(\frac{1}{r} - \frac{1}{r}\right)$

$\frac{1}{25} = (1.52 - 1)\left(\frac{1}{r} - \frac{1}{\infty}\right)$

$r_1 = 13$ cm

The power of thin lens

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

is the reciprocal of the focal length in meters, the power of thin lens measured with Diopters .

$$\text{Diopter} = \frac{1}{m}$$

converging lens have positive power

diverging lens have negative power

$$p = \frac{1}{f} = (n-1)\left(\frac{1}{r} - \frac{1}{r} \right)$$

Ex: The radii of both surfaces of an equiconvex lens of n= 1.6,r_1=0.08m,

r_2=- 0.08m,find the lens power.

$$p = (n-1)\left(\frac{1}{r} - \frac{1}{r} \right)$$

$$p=(1.6 -1) \left(\frac{1}{0.08} - \frac{1}{-0.08}\right)$$

$$p = o.6 \left(\frac{1}{0.08} + \frac{1}{0.08} \right)$$

$$p=0.6*25 =15D$$

Thin lens combination

1- apply imaging formula to the first lens to find image for this lens

$$s_1^- = \frac{s \quad f}{s - f}$$

2- find object distance for the second lens(negative sign means virtual object)

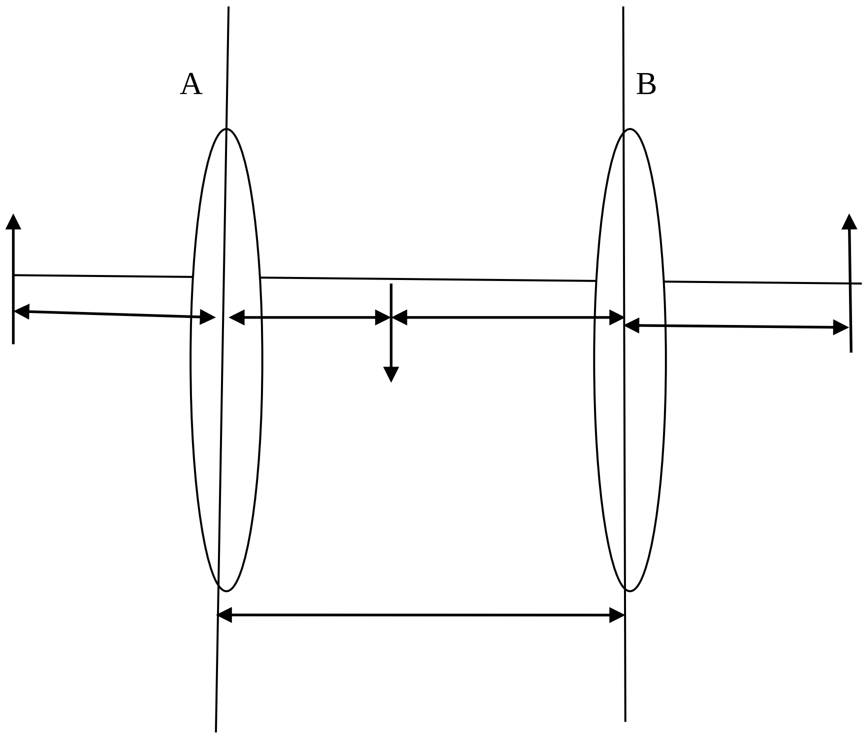
$$s_2 = d - s_1^-$$

3- use imaging formula again to find the final image.

$$s_2^- = \frac{s \quad f}{s - f}$$

Ex: two converging lenses, A and B, with focal lengths f_A =20cm, f_B= 25cm,are placed 80cm apart. An object is placed 60cm in front of the first lens.

determine : a- position, and b- the magnification of the final image formed by the combination of the two lenses.



$$S_1^- = \frac{s\ f}{s - f} = \frac{60*20}{60-20} = \frac{1200}{40} = 30cm$$

s_2 =50cm

$$S_2^- = \frac{s\ f}{s - f} = \frac{50*25}{50-25} = \frac{1250}{25} = 50\ cm$$

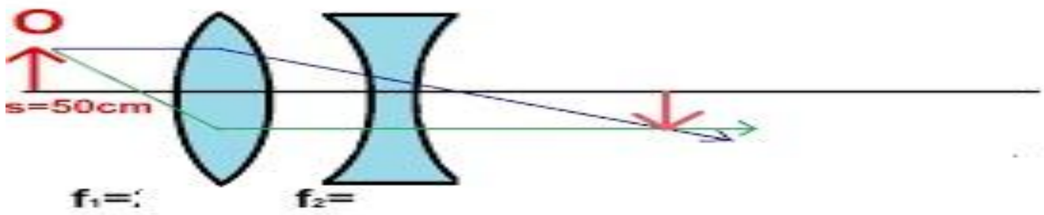
$$m_2 = -\frac{50}{50} = -1$$

$m = m_1 * m_2$

$m = -0.5 * -1 = +0.5$

the image is the half the size of the object and upright.

Ex: two lenses, a converging lens A and a diverging lens B with f_A= 30cm,f_B=50cm,are placed 50cm apart.An object is placed 50cmin front of the first lens. determine the position and the magnification of the final image formed by the combination of the two lenses.



$$s_1^- = \frac{s\ f}{s-f} = \frac{50*30}{50-30} = \frac{1500}{20} = 75cm$$

s_2 =50cm

$$s_2^- = \frac{s\ f}{s-f} = \frac{-25*50}{-25*50} = \frac{-1250}{25} = -50cm$$

magnification:

$$m_1 = -\frac{75}{50} = -1.5$$

$$m_2 = \frac{-50}{-25} = 2$$

$$m = m_1 * m_2$$

$$m = -1.5 * 2 = -3$$

CH-5

THICK LENSES

1- **we find the primary focal length for the first surface**

$$\frac{n}{f} = \frac{n-n}{r} \Longrightarrow f_1 = ?$$

2-- **we find the secondary focal length for the first surface**

$$\frac{n}{f} = \frac{n-n}{r} \Longrightarrow f_1^- = ?$$

3-- **we find the primary focal length for the second surface**

$$\frac{n}{f} = \frac{n-n}{r} \Longrightarrow f_2^- = ?$$

4-- **we find the secondary focal length for the second surface**

$$\frac{n}{f} = \frac{n-n}{r} \Longrightarrow f_2^- = ?$$

5-- **we find the primary and secondary focal lengths for the system**

$$\frac{n}{f} = \frac{n}{f} + \frac{n}{f} - \frac{d\,n}{f\;f}$$

$\Longrightarrow$ primary focal length for the system $f = ?$

$$\frac{n}{f} = \frac{n}{f}$$

$f_2^- = ?$

6-**we find the and secondary focal points for the system**

$A_1F = -f\left(1 - \frac{d}{f}\right)$ primary focal point for the system

$A_2F = +f\left(1 - \frac{d}{f}\right)$ secondary focal point for the system

7-**we find the primary principal point and secondary principal point**

$$A_1H = + f \frac{d}{f}$$

$$A_2 H = - f \frac{d}{f}$$

For the purpose of confirming the accuracy of the results:

a- $A_1F - A_1H = FH = f$ (primary focal length for the system)

b- $A_2F - A_2H = F H = f_2$ (secondary focal length for the system)

Ex: A lens has the following specifications: $r_1 = +1.5$ cm, $r_2 = 1.5$cm, $d = 2$cm, $n = 1$, $n^- = 1.6$, and $n = 1.3$.

find: a-the primary and secondary focal lengths of the separate surfaces.

b-the primary and secondary focal lengths of the system. and c- the primary and secondary principal point

solution: **لكي نجد البعد البؤري الاولي للسطح الاول:**

a- $$\frac{n}{f} = \frac{n-n}{r} = \frac{1.6-1}{1.5} = 0.4$$

$$\frac{1}{f} = 0.4 \Longrightarrow f_1 = 2.5\text{cm}$$

لكي نجد البعد البؤري الثانوي للسطح الاول:

$$\frac{n}{f} = \frac{n-n}{r} = \frac{1.6-1}{1.5} = 0.4$$

$$\frac{1.6}{f} = 0.4 \Longrightarrow f_1^- = 4\text{cm}$$

لكي نجد البعد البؤري الاولي للسطح الثاني:

$$\frac{n}{f} = \frac{n-n}{r} = \frac{1.3-1.6}{1.5} = -0.2$$

$$\frac{1.6}{f} = -0.2 \Longrightarrow f_2 = -8 \text{ cm}$$

لكي نجد البعد البؤري الثانوي للسطح الثاني:

$$\frac{n}{f} = \frac{n-n}{r} = -0.2$$

$$\frac{1.3}{f} = -0.2 \Longrightarrow f_2 = -6.5 \text{ cm}$$

حساب الابعاد البؤرية الاولية والثانوية للنظام:

$$\frac{n}{f} = \frac{n}{f} + \frac{n}{f} - \frac{d\,n}{f\quad f}$$

$$\frac{n}{f} = \frac{1.6}{4} + \frac{1.3}{-6.5} - \frac{2*1.3}{4*\ (-6.5)}$$

$$\frac{n}{f} = 0.4 - 0.2 + 0.1 = 0.3$$

$\frac{1}{f} = 0.3 \Longrightarrow$ **f** $= \frac{1}{0.3} = 3.333$ cm **البعد البؤري الاولي للنظام**

$$\frac{n}{f} = \frac{n}{f} = 0.3$$

$$\frac{n}{f} = 0.3 \Rightarrow \frac{1.3}{f} = 0.3$$

$$\mathbf{f_2} = \frac{1.3}{0.3} = 4.333\ \text{cm}$$ **البعد البؤري الثانوي للنظام**

لحساب النقاط البؤرية الاولية والثانو ية للنظام:

$$\mathbf{A_1 F = - f\ (\ 1 - \frac{d}{f}\ )} = -3.33\ (1 - \frac{2}{-8}) = -4.166\ \text{cm}$$ **النقطة البؤرية الاولية للنظام**

$$\mathbf{A_2 F = - f\ (\ 1 - \frac{d}{f}\ )} = +4.333\ (1 - \frac{2}{4}) = 2.167\ \text{cm}$$ **النقطة البؤرية الثانوية للنظام**

problem 1(ch-5):

An equiconvex lens has an index of 1.8,radii of 4 cm and a thickness of 3.6 cm. calculate : a- the focal length. b- the distances from the vertices to the corresponding focal points and principal points.

n =1, n = 1, n =1.8,d= 3.6 cm, r_1= r_2 =4 cm

$$\frac{n}{f} = \frac{n}{f} = \frac{n - n}{r}$$

$$\frac{1}{f} = \frac{1.8 - 1}{4} \Rightarrow f_1 = 5\ \text{cm}$$

$$\frac{n}{f} = \frac{1.8 - 1}{4} \Rightarrow \frac{1.8}{f} = \frac{1.8 - 1}{4}$$

$f_1^- = 9$ cm

$$\frac{n}{f} = \frac{n}{f} = \frac{n - n}{r}$$

$$\frac{n}{f} = \frac{n - n}{r} \Rightarrow \frac{1.8}{f} = \frac{1 - 1.8}{4}$$

$\Rightarrow f_2 = -9$cm

$$\frac{n}{f} = \frac{n - n}{r} = \frac{1}{f} = \frac{1 - 1.8}{4}$$

$\Rightarrow f_2 = -5$cm

b- $p = \dfrac{n}{f}$

$$\frac{n}{f} = \frac{n}{f} = \frac{n}{f} + \frac{n}{f} - \frac{d\,n}{f\ \ f}$$

$$\frac{1}{f} = \frac{1.8}{9f} + \frac{1}{-5} - \frac{3.6*1}{-5*9} = 0.2-0.2+0.08$$

f=12.5 cm= f

c- **لحساب النقاط الاساسية الاولية والثانوية**

$A_1H = +f\ \frac{d}{f} = +3.33\ \frac{2}{-8} = -0.833$cm

$A_2H = -f\ \frac{d}{f} = -4.33\ \frac{2}{4} = -2.167$cm

<u>وكتحقيق لقيمة البعد البؤرى الاولى للنظام:</u>

$A_1F - A_1 H = -4.166- (-0.833)$

F H = -3.333cm **البعد البؤري الاولي للنظام**

$A_2 F - A_2 H = 2.167 - (-2.165)$

F H = 4.334 cm **البعد البؤري الثانوي للنظام**

CH-6

SPHERICAL MIRRORS

A spherical reflecting surface has image forming properties similar to those of a thin lens or of a single reflecting surface. The image from a spherical mirror is in some respects superior to that from a lens ,notably in the absence of chromatic white light. Therefore mirrors are occasionally used in place not so broad as those of lenses because they do not offer aberrations of the image.

Because of the simplicity of the law of reflection as compared to the law of refraction, the quantitative study of image formation by mirrors is easier than in the case of lenses. many features are the same of lenses, and there are some characteristics which are different.

Focal point and focal length

Diagrams showing the reflection of a parallel beam of light by a convex mirror and by a concave mirror .

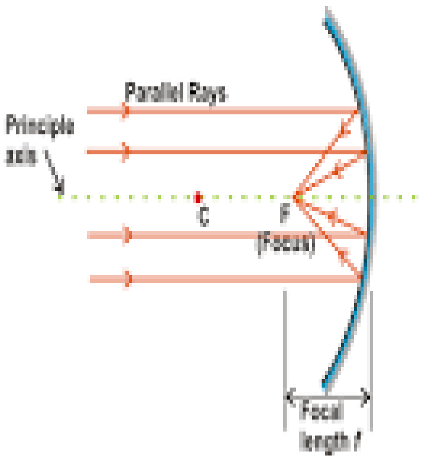


Figure 3a. Concave Mirror

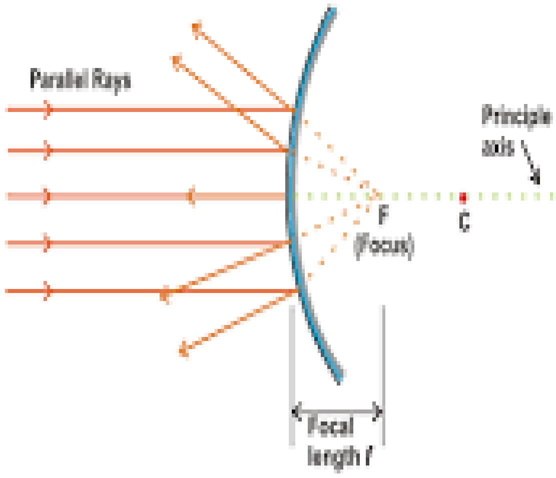


Figure 3b. Convex Mirror

A ray striking the mirror at some point such as T obeys the law of reflection $\phi = \phi$ .All rays are shown as brought to a common focus at F, although this will be strictly true for paraxial rays. The point F is called the focal point and the distance FA the focal length.

In the second diagram the reflected rays diverge as though they come from a common point F. since the angle TCA also equal ϕ, the triangle TCF is an isosceles one, and in general CF=FT, but for very small angles ϕ (paraxial rays),FT approaches equality with FA, hence

$$FA=\frac{1}{2}(CA) \text{ or } f=-\frac{1}{2}r$$

and for focal length equals one-half the radius of curvature.

for concave mirror : focal length ⇨ is positive

radius of curvature ⇨ is positive

for convex mirror: focal length ⇨ is negative

radius of curvature ⇨ is negative

and for mirror there is one focal point.

object distance S and image distance are measured for the object and for image respectively to the vertex. this make both S and S^- ,positive and the object and image real when they lie to the left of the vertex, while they are negative and virtual when they lie to the right.

DERIVATION OF MIRROR FORMULA

by the law of reflection the radius CT bisects the angle M T M $^{-}$,using geometrical theorem we may can write the proportion:

$$\frac{MC}{MT} = \frac{C\ \ M}{M\ \ T} \quad \text{--------(1)}$$

Now, for paraxial ray, MT - MA = S, and M T - M A= S ,

MC= MA- CA =s- (-r) = s + r -----------(2)

CM =CA- M A = -r - s = - (s + r) --------(3)

by substituting eq.(2),and eq.(3) in eq.(1):

$$\frac{s+r}{s} = -\frac{s+r}{s}$$

$$\frac{s}{s} + \frac{r}{s} = -\frac{s}{s} - \frac{r}{s}$$

$$1 + \frac{r}{s} = -1 - \frac{r}{s}$$

$$\frac{r}{s} + \frac{r}{s} = -2 \Longrightarrow r\left(\frac{1}{s} + \frac{1}{s}\right) = -2$$

$$\boxed{\frac{1}{s} + \frac{1}{s} = \frac{-2}{r}}$$ -------(4) mirror formula

The primary focal point is defined as that axial point object point for which the image is formed at infinity, so substituting s = f , s = ∞, in eq.(4),we have:

$$\frac{1}{f} + \frac{1}{\infty} = \frac{-2}{r}$$

from which $\frac{1}{f} = \frac{-2}{r}$ or f = $-\frac{r}{2}$ -------(5)

The secondary focal point is defined as the image point of an infinite distant object point. this is, s = f , s = ∞ , so that:

$$\frac{1}{\infty} + \frac{1}{f} = \frac{-2}{r}$$

$$\frac{1}{f} = \frac{-2}{r} \Longrightarrow f = -\frac{r}{2}$$ ------(6)

$$\frac{1}{f} = \frac{1}{f} = \frac{-2}{r} \quad \text{------(7)}$$

substitute eq.(7) in eq.(4) ,we have:

$$\boxed{\frac{1}{s} + \frac{1}{s} = \frac{1}{f}} \quad \text{---------(8)}$$

just as for lenses.

from the proportionality of sides in the similar triangles Q A M ,and QAM in fig.

( ) ,we find $\frac{-y}{y} = \frac{s}{s}$ giving:

$$m = \frac{y}{y} = -\frac{s}{s}$$

EX: An object is located 20cm in front of a convex mirror of radius 50cm. calculate (a) the power of the mirror.(b) the position of the image,(c) it's magnification.

sol.

a- k = $\frac{1}{r} = \frac{1}{0.5} = +2$ D and V= $\frac{1}{S} = \frac{1}{0.2} = +5$D

P= - 2 k = - 2*2= - 4 D

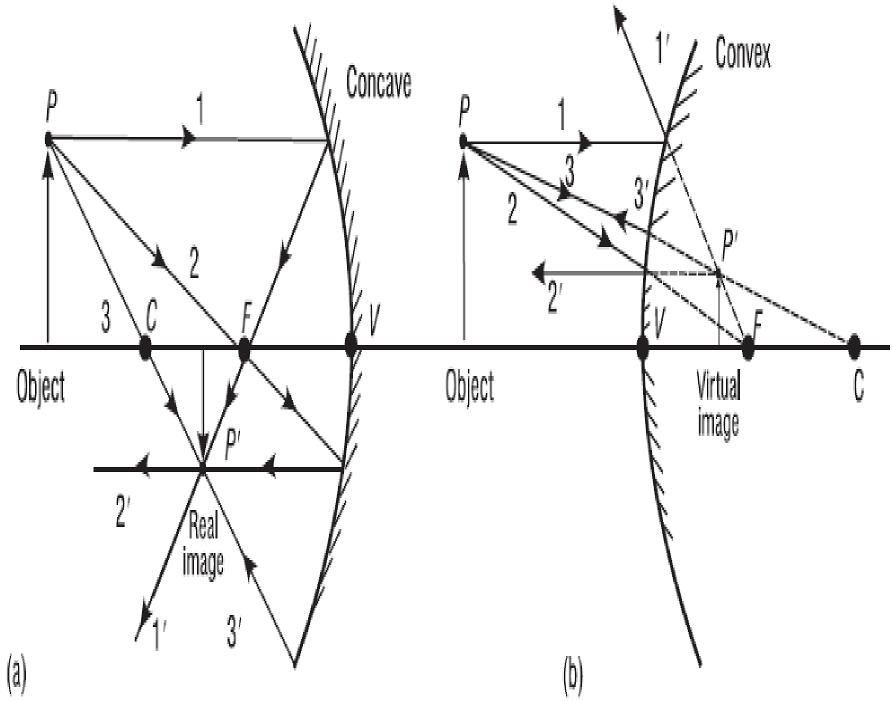
V+ V =P

5+ V = - 4 or V = -9 D

S = $\frac{1}{V} = -\frac{1}{9} = -0.111$m = -11.1cm

m = $-\frac{s}{s} = -\frac{v}{v} = -\frac{5}{-9} = 0.555$

the image is virtual and erect located at 11.1cm to theright of the mirror and has magnification 0.555x.



concave mirror **convex mirror**

image formation by convex and concave mirror