Light: Reflection & Refraction

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Light is a means (way) by which we are able to see any object. In other words if there is no light we can't see anything .Now the question comes how we are able to see any object. When a beam of light from any source falls on any body some parts of it returns back and some parts of it get absorbed. The part which returns back to our eyes are responsible for seeing any object.

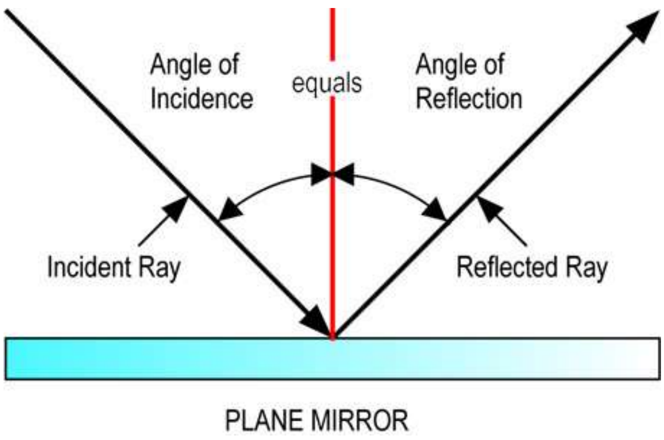
How you are able to see your face in a mirror? Again the same thing. Light from any source fall on your face. Your face returns some part of that light back which strikes to mirror and then come back to your eyes. In this way you are able to see your face. Again one question what will you do if u have a torch and u r standing in front of a mirror in a dark room, what will you do to see your face?

For normal saying we can say that light travel in a straight line and we can easily prove it also. Take a long hollow rubber pipe and see any object through it, now bend the pipe and then se again what will you observe, you can't see the object. For second example we can take three rectangular pieces of plywood and make a small hole in all of them. We light a candle and position all the three pieces so that we can see that candle flame. Now we shift middle piece a little bit and then we saw it. We are not able to see the flame again. These experiments prove that light travel in a straight line.

Bending of light is proved by phenomena known as ***Diffraction*** which is a wave characteristic. For making knowledge just remember for now that light behave as a wave as well as particle nature. We can say that light have ***Duel Character***.

Interference and ***Diffraction*** of light shows its wave nature. Particle nature is proved by ***Photoelectric Effect***.

Reflection:- When a light ray falls on any object some part of its get absorbed and some part it returns back. This returning back phenomenon is called Reflection of light. In other words we can say that changing the



direction of light after falling on any body is called **Reflection**.

For simplicity we take example of a plane surface and take a single beam of light

The ray which come from any source and falls on the mirror is called incident ray and the ray which goes back after reflection is called reflected ray. If we draw a perpendicular on the point of contact that is called **Normal** to that surface. The angle made by incident ray and normal is called incident angle and angle made by reflected ray and normal is called angle of reflection.

Laws Of Reflection:-

1) *Incident Ray, Reflected Ray, and normal drawn on the point of incidence all should be in same plane.*
2) *Angle of incidence = Angle of reflection.*

These laws are applicable for any kind of surfaces. We can apply this to spherical mirror as well.

Regular Reflection:- When a beam of light falls on a surface and if they reflected without any distortion then it is called as regular reflection. In this reflection the image of the source object did not get distorted and it occurs only in smooth surfaces like mirror.

Irregular Reflection/ Diffused Reflection:-The reflection in which incident rays fall on a rough surface and reflected with distortion then it is said to be irregular reflection. In this case the image of the source object is not formed as rays intersect each other irregularly after reflection and destroy the image. This is the reason why we are not able to see our face in a wall and we can see that in a mirror.

In the same way we can explain why a white paper looks white but we a mirror has no colors. White paper looks white because it reflect all the colors fall on it but irregularly and in case of mirror it also reflect all colors but it possesses regular reflection so it shows the image of the object from which light is coming.

Images are formed when light rays coming from any object after a regular reflection meets on any point or appear to diverge from any point.

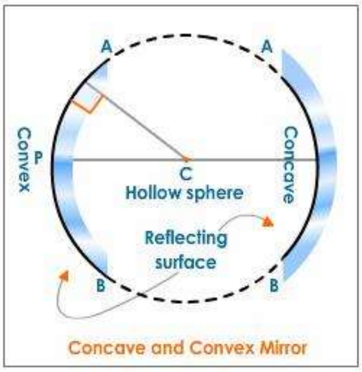
They are of two types **1) Real Image** **2) Virtual Image**.

In case of real image reflected ray meets in real while in case of virtual image they appear to meet at a certain point.

Plane mirror always forms virtual images. In case of spherical mirror convex mirror always form virtual image but in case of concave mirror both kind of images are possible.

Ideally speaking if we are going to make an image of an object we should take care of all rays coming from that source but if we do that then it will be very difficult. So we take minimum number of light rays to form an image.

Spherical mirrors: Mirrors that are a part of a sphere and reflection of light takes place at the curved surface.



They are basically two types

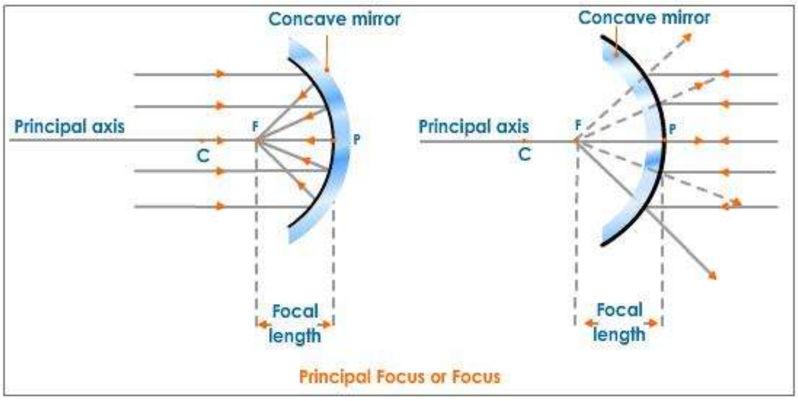
1. ***Concave Mirror:*** *Where reflection takes place from inside wall and outside is layered.*
2. ***Convex Mirror:*** *Where reflection takes place from outside wall and inside wall is layered.*

Image Formation in Spherical Mirrors: *Both virtual and real images can be formed.* ***In case of convex mirror always virtual image is formed*** *and in case of concave mirror both types of images are formed.*

Different rays that we are going to consider for making an image are as follows.

1) Rays parallel to principle axis
2) Rays passing from focus
3) Rays which coming from centre of curvature.

Different terms/definitions you should know before going into details.



Pole: - It is the middle point of aperture of the mirror.

Principle Axis: - It is an imaginary line we draw which passes through pole and is perpendicular to the tangent at pole.

Focus: - Rays parallel to principle axis after getting reflected from the mirror *passes through a single point or appears to meet at a point on principle axis ,that point is called principle focus for that mirror*.

For general purpose we can place any object at any place on a principle. But for this class we discuss some special cases where we try to find out how and where images are going to formed.

Different position of images formed in case of a concave mirror.

Position of Object	Position of Image	Image Type	Size
P	P	Virtual	Equal
Between P and F	Between C And ∞	Virtual	Large
On F	At ∞	Real	Very Large
Between F and C	Between C and ∞	Real	Large
On C	At C itself	Real	Equal
Between ∞ And C	Between C and F	Real	Small
At ∞	At F	Real	Very Small

Uses of Spherical Mirror:-

1) Concave Mirror
   a) Torches and headlights of a vehicle-Explanation.
   b) Used as a shaving mirror-Explanation
   c) Dentists use it to see cavity-Explanation
   d) To produce Heat from solar radiation-Explanation
2) Convex Mirror
   a) For rear view mirror in vehicle-Explanation
   b) In case of street-lamp to diverge the light- Explanation

Sign Convention :

For this we always take pole as our origin and as we do in ***Rectangular Co-ordinate system*** we take the +ve and –ve. In other words for right hand side we take +ve and for left hand side we take –ve, In the same way we take above of principle axis as +ve and lower as –ve.

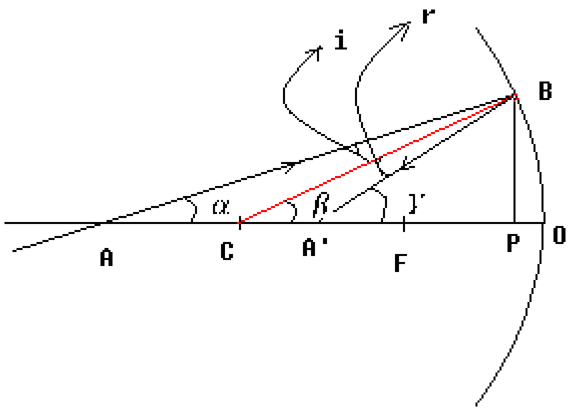
Mirror Formula :- $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

Where *v=image distance from pole*

u=object distance from pole

f=focal length.

Derivation of Mirror Formula:



As we can see from the figure when a beam of light AB strikes at a point B on the mirror it reflect back. We take AO = u, A'O = v, CO = R (radius of curvature) ,BP = h

We are talking about paraxial rays which are very close to principle axis and make a very small angle so in that case PO is get smaller and it can be neglected. That means the arc length BO and BP will be nearly the same.

$$\angle ABC = \alpha$$

$$\angle CBA' = \beta$$

$$\angle A'BP = \gamma$$

i = r = θ (angle of incidence = angle of reflection)

$\beta = \alpha + i = \alpha + \theta \implies \theta = \beta - \alpha$ ----- (1)

$\gamma = \beta + r = \beta + \theta$ --------------------------(2)

By 1 &2, $\gamma = \beta + \beta - \alpha \implies 2\beta = \alpha + \gamma$ -------(3)

As we know from the definition of radian $\theta = \frac{l}{r}$ where l is arc length and r is the radius of that arc.

So, $\beta = \frac{h}{r}, \alpha = \frac{h}{u}, \gamma = \frac{h}{v}$

Putting all these values in equation. (3)

$$\frac{2h}{r} = \frac{h}{u} + \frac{h}{v}$$

$$\frac{h}{\frac{r}{2}} = \frac{h}{v} + \frac{h}{u}$$

$\frac{h}{f} = \frac{h}{v} + \frac{h}{u}$ (since focal length is half of the radius of curvature)

$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ (The Required Mirror Formula)

Lateral Magnification:- When we see the image on any object in a mirror sometimes it shows smaller image sometime bigger. But the shape or the configuration of the image going to b the same in any case. For example if we see the image of palm it will show all the fingers, may be the size smaller or bigger the shape going to remain same.

This is actually magnification is, by what fraction the size of an image increased or decreased.

Formula for magnification is $\frac{h'}{h}$ or $-\frac{v}{u}$

Where *h'=image height*

h= object height

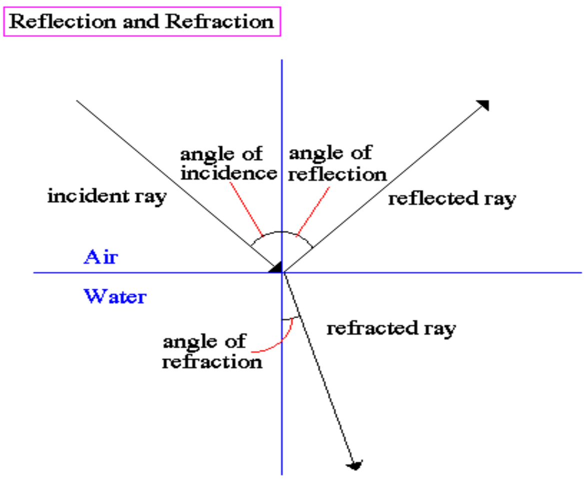
v=image distance from pole

u=object distance from pole.

Refraction: This is the phenomena of bending or deviating a light ray from its original path when its changes the medium.

Mainly two types of medium we are talking about. ***(1) Rare (2) Denser.***

When a light rays goes from rare medium to denser medium then it bends towards the normal and in reverse when a light ray goes from rare to denser then its goes away from the normal.



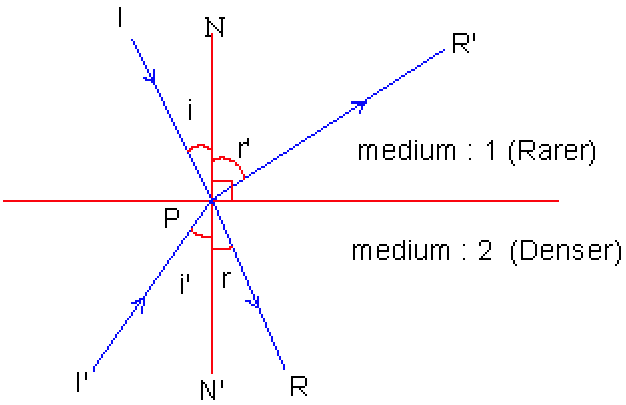


Figure 9

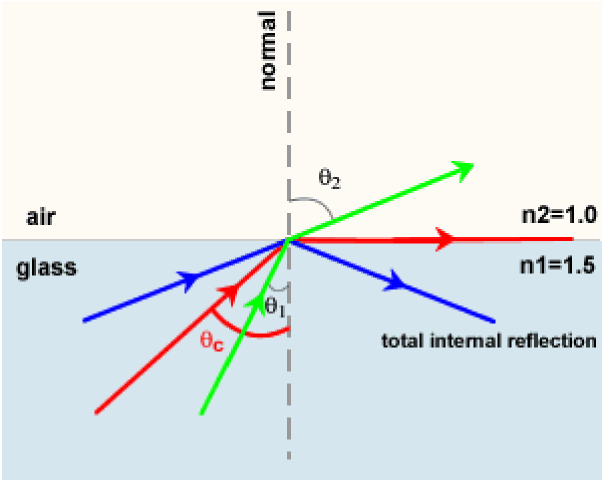
Laws of Refraction:

1) *Incident ray, refracted ray, and normal drawn on the point of incidence will be on the same plane.*
2) *Ratio of sin of angle of incidence and refraction will be constant. i.e* $\frac{sini}{sinr}=const.$

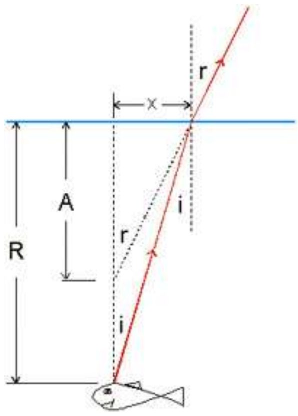
Snell's Law: **Second law of refraction is also known as Snell's Law.**

In other words **μ.sinθ = constant.**

(where $\theta$is the angle at interface)



Total Internal reflection: As we know that when *a light ray goes from rare medium to denser then it goes away from the normal*. As we keep on increasing the angle of incidence then the refracted rays gets more deviated away from the normal. At some angle i.e θ_c the refracted ray gets *parallel to the medium interface*, and if we increase more the total ray *reflected back in to the same medium*. The transparent medium acts as a reflected surface after that angle of incidence. This phenomenon of a light ray to totally get reflected in the same medium is called **Total internal reflection.**



When we saw any object inside water, it appears to be above than the actual depth. This is due to refraction phenomenon. Apparent depth will be 1/μ times the actual depth of the object. As shown in the figure fish will look above the actual depth.

i.e Apparent Depth = Actual Depth / μ .

Proof:

By laws of refraction: μ sin i = sin r (take R.I of air as 1 & R.I of medium with respect to air is μ)

So, $\sin r / \sin i = \mu$

When i and r are very small we can take sin i ≈ i ≈ tan i

Similarly, sin r ≈ r ≈ tan r.

$\tan r = \frac{x}{A}$, $\tan i = \frac{x}{R}$

so, $\tan r \,/\, \tan i = \mu$,

$\Rightarrow \frac{R}{A} = \mu,$

$\Rightarrow \mathbf{A} = \frac{\boldsymbol{R}}{\boldsymbol{\mu}}.$

And shift is $R - \frac{R}{\mu} = R(1 - \frac{1}{\mu})$. Where R = real depth.

A= apparent depth.

Thin Lenses: Lens is a transparent medium bounded by two surfaces, at least one of them must be curved. We have to study about thin lens. A lens is said to be thin if the gap between two surfaces is very small.

Sign Convention: *The sign convention will be same as in case of mirror*.

Lens Formula: $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Transverse Magnification: Transverse magnification (**m**) (of dimension perpendicular to principal axis) is given by $m = \frac{h'}{h} = \frac{v}{v}$. *One point here should be noted is that in case of mirror there was a negative sign. But in case of lens no –ve sign will be there.* You can easily prove it too.

Just like the mirror we can define the different terms in the same way like Principle axis, Focus, Optical centre. Radius of curvature, etc.

One thing here is taken into consideration that here we have two spherical surfaces so we have two optical centre, two radius of curvature and two focus because there are two spherical surfaces. But we don't have to confuse for that.

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On F	At ∞	Real	Very Large
Between F and C	Between C and ∞	Real	Large
On C	At C itself	Real	Equal
Between ∞ And C	Between C and F	Real	Small
At ∞	At F	Real	Very Small

Power of a Lens: It is defined as a reciprocal of focal length where length is in meter. This is mainly because if we have two or more thin lenses placed close to one another then we simply add the powers to get the net power of the combination. It is measured in Diopter.

So power of a lens (p) = 1/f .

And for combination of lenses it wil be simply algebraic addition

i.e $P_{combined} = P_1 + P_2 + P_3 + P_4 + \ldots\ldots\ldots\ldots\ldots\ldots$

In other words $\frac{1}{f_{combined}} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + \frac{1}{f_4} + \ldots\ldots\ldots$

Remember one thing that focal length must be in meter only.