Light

It is a matter of common experience that the objects inside a dark room, which are invisible, become visible when the room is illuminated by a source of light. Thus light can be defined as the external cause responsible for the sensation of vision.

The branch of Physics dealing with the nature and properties of light and vision is called **optics**.

Nature of Light - Theories

Light is a form of energy. Energy can be transferred from one point to another point either by particle motion or by wave motion. Accordingly, different theories on the nature of light have been proposed.

The important theories are as follows:

1. Newton's Corpuscular Theory
2. Huygens' Wave Theory
3. Maxwell's Electromagnetic Theory
4. Planck's Quantum Theory

Newton'sCorpuscularTheory

According to Sir Issac Newton's Corpuscular Theory, a luminous body continuously emits tiny, light and elastic particles called corpuscles in all directions. When these particles fall on the retina of the eye, they produce the sensation of vision.

This theory could explain a number of phenomena concerning light like rectilinear propagation, reflection and refraction. Reflection was explained by assuming that the corpuscles which fall on a smooth surface would bounce back like rubber balls hitting a wall. When this theory was used to explain refraction scientists found that the velocity of light in a denser medium would be more than that in a rarer medium. However, the experimental findings of Foucault pushed back the corpuscular theory of Newton. This corpuscular theory could not explain satisfactorily certain other phenomena.

Huygens' Wave Theory

In 1967 Christian Huygens proposed the wave theory of light. According to this, a luminous body is a source of disturbance in hypothetical medium called ether. The disturbance from the source is propagated in the form of waves through space and the energy is distributed equally in all directions. Even though this theory could satisfactorily explain several optical phenomena, the presence of ether could not be detected.

Maxwell's Electromagnetic Theory

Electromagnetic theory of light was put forward by James Clerk Maxwell in 1873. According to this theory, light consists of fluctuating electric and magnetic fields propagating in the form of electromagnetic waves. But this theory failed to explain the photoelectric effect.

Planck's Quantum Theory

According to Max Planck's Quantum theory, radiation is not continuous but is made up of tiny packets of energy called photons. However, this theory could not explain other optical phenomena.

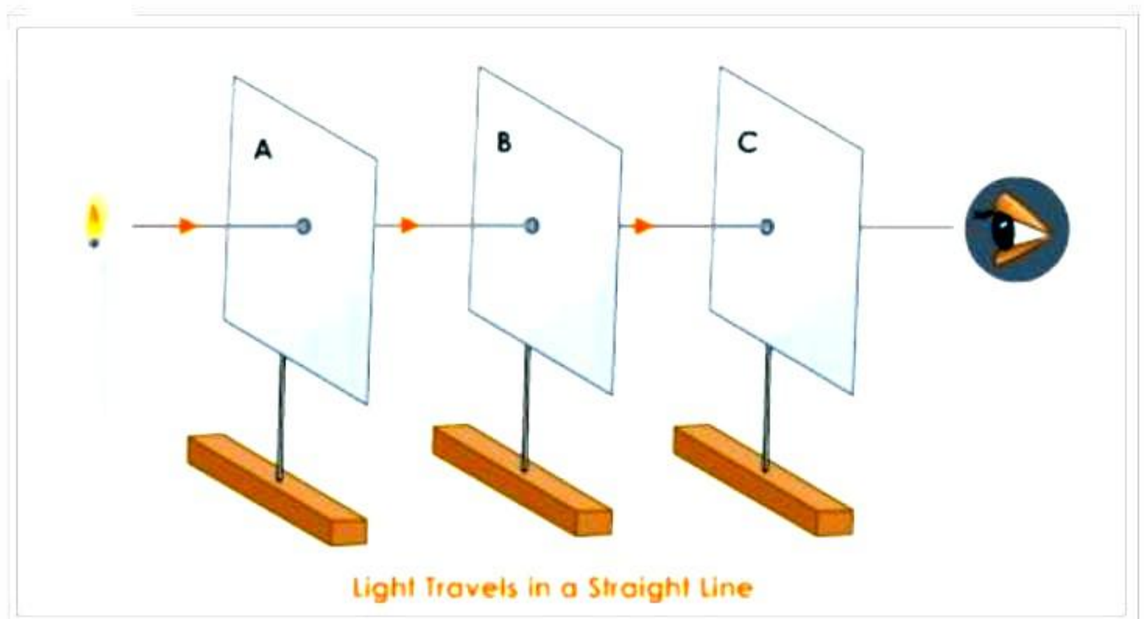
From all the above theories it is clear that certain optical phenomena can be explained clearly only if light is considered to be made up of particles, while certain other phenomena can be explained only if we consider light as a wave. Thus light appears to have a dual nature.

Characteristics of Light

- Light can penetrate through transparent materials but cannot pass through opaque objects.
- Light travels in a straight line in an optically homogeneous medium.
- Light bounces back when made to fall on polished surfaces such as mirrors or metal surfaces. This bouncing back of light is described as reflection.
- The change in the velocity of light when it travels from one transparent medium to another is described as refraction.
- Light takes the path of least time in passing from one point to the other. This is nothing but Fermat's principle. The shortest distance between any two given points is a straight line. Thus Fermat's principle proves the rectilinear propagation of light.
- Light appears to have a dual nature. During propagation, light exhibits wave characteristics but when it interacts with matter, it behaves like particles.

Rectilinear Propagation of Light

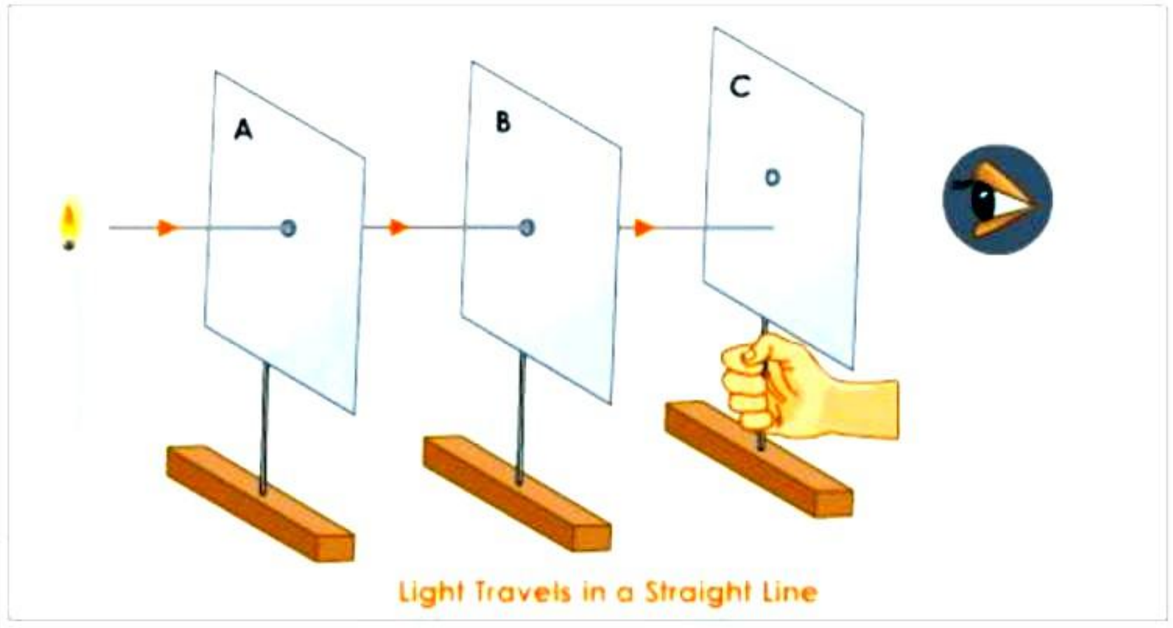
In a homogenous transparent medium light travels in a straight line and this is known as rectilinear propagation of light. This can be demonstrated by the following experiment:



Light Travels in a Straight Line

Take three cardboards A, B and C and make a pinhole at their centres. Place a burning candle on one side of the cardboard A and arrange the cardboards in such a way that the three pinholes and the candle flame are in a straight line. The candle flame will be visible through the pinhole of the cardboard C.

Now slightly displace any one of the cardboards and try to see the flame through the pinhole of the cardboard C. The flame will not be visible. From this it is clear that light travels in a straight line. This is one of the examples of rectilinear propagation.



Question: Choose the only wrong statement from the following

a. Light is a form of energy.
b. Light travels in the form of waves
c. The speed of light is greater than that of the sound
d. Like sound light cannot travel through vacuum

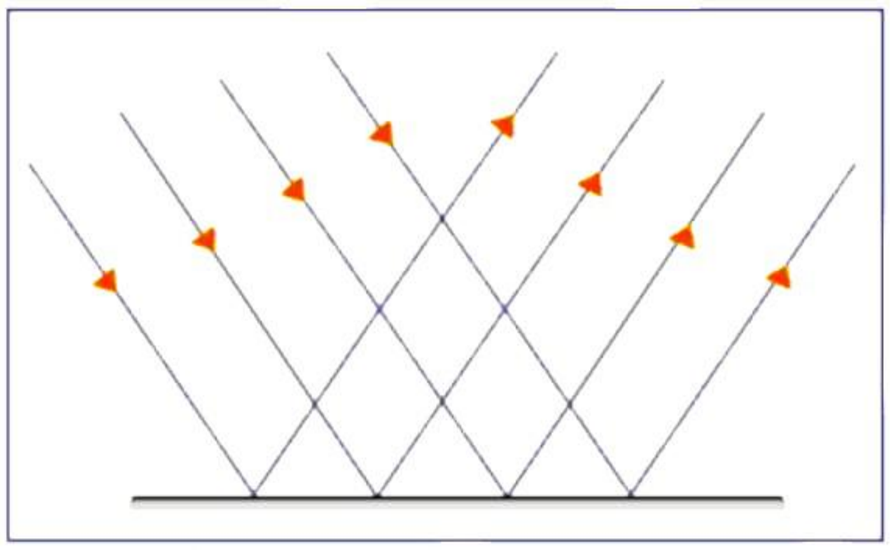
Reflection of Light

When a ray of light falls on any surface, a part of the light is sent back to the same medium. This phenomenon where the incident light falling on a surface is sent back to the same medium is known as reflection.

There are two types of reflection of light:

- Regular reflection
- Irregular reflection

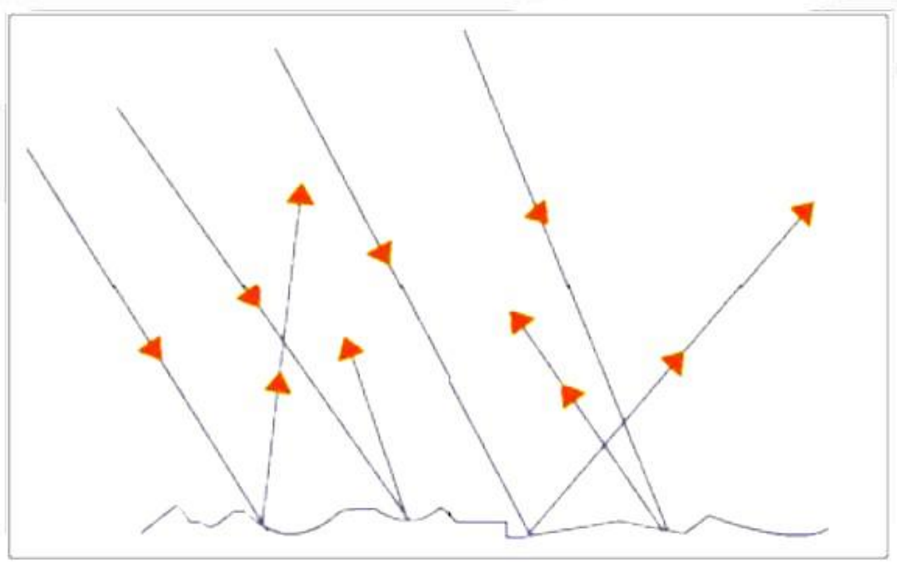
Regular Reflection



Regular Reflection on a Smooth Surface

Regular reflection takes place when a ray of light is incident on a polished smooth surface like a mirror. Here the reflected ray of light moves only in a fixed direction.

Irregular Reflection or Diffused Reflection



Diffused Reflection on a Rough Surface

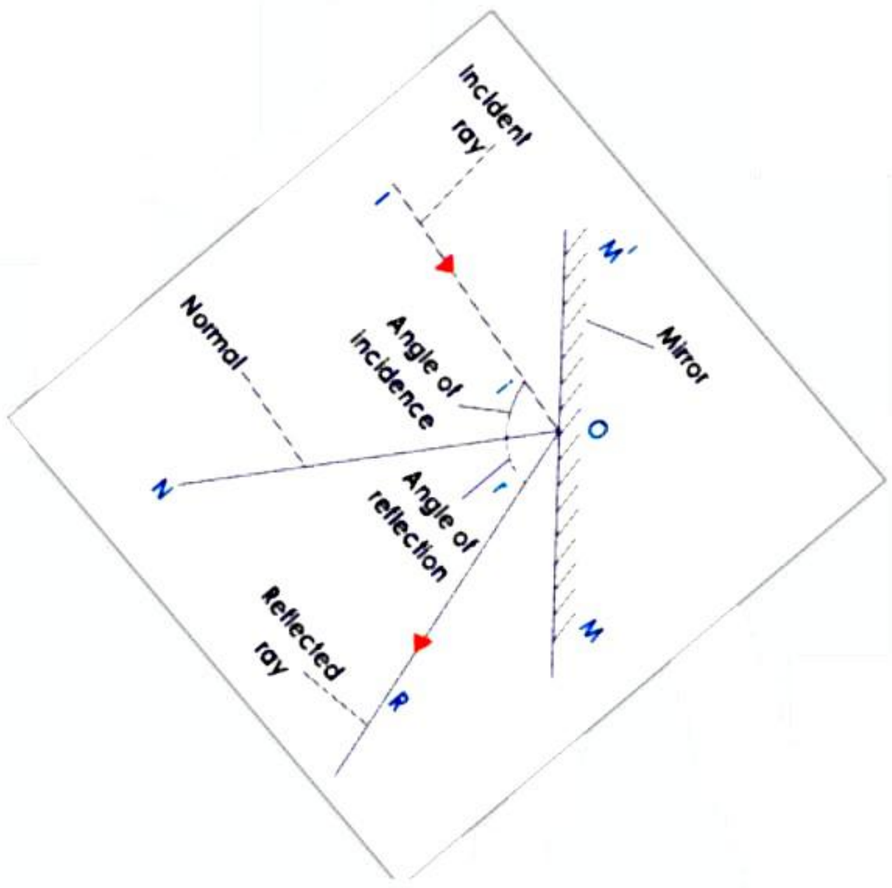
Irregular reflection or diffused reflection takes place when a ray of light is incident on a wall or wood, which is not smooth or polished. In this case, the different portions of the surface reflect the incident light in different directions. In such cases no definite image is formed, but the surface becomes visible. It is commonly known as scattering of light. Thus diffused reflection makes non-luminous objects visible.

Not all light, which hits an object, is reflected. Some of the incident light is absorbed. The brightness of an object depends on the intensity of the incident light and also on the reflectivity of the object.

If a surface allows the entire incident light to undergo regular reflection then it will become invisible.

Reflection of Light by a Plane Surface

The figure shows how a ray of light is reflected by a plane surface. Let MM' represent a reflecting surface. When a ray of light is incident on MM' in the direction IO it gets reflected along the direction OR. IO is the incident ray; O is the point of incidence and OR is the reflected ray.



Reflection of a Ray Light by a Plane Mirror

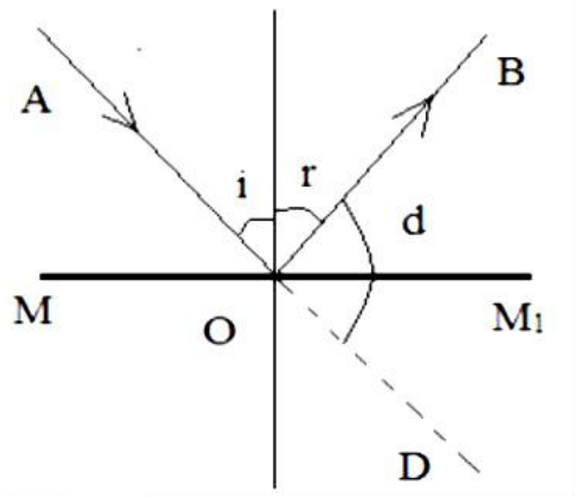
Let ON be the normal drawn perpendicular to the surface MM' at the point of incidence. The angle which the incident ray makes with the normal at the point of incidence is called the ***angle of incidence*** and is denoted by the letter 'i'. The angle that the reflected ray makes with the normal at the point of incidence is called the ***angle of reflection*** and is denoted by the letter 'r'. Mirror is an example of a reflecting surface.

The Laws of Reflection

The reflection at any plane surface is found to obey the laws of reflection. The laws of reflection are:

- The incident ray, the reflected ray and the normal at the point of incidence lie in the same plane.
- The angle of incidence is equal to the angle of reflection.

Example: For an angle of incidence i, what will be the angle of deviation.



Sol: Given angle of incidence = i

Angle of deviation = d

Consider the straight line AOE, $i + r + d = 180^0$

$d = 180 - (i + r)$

$= 180 - (I + i)$

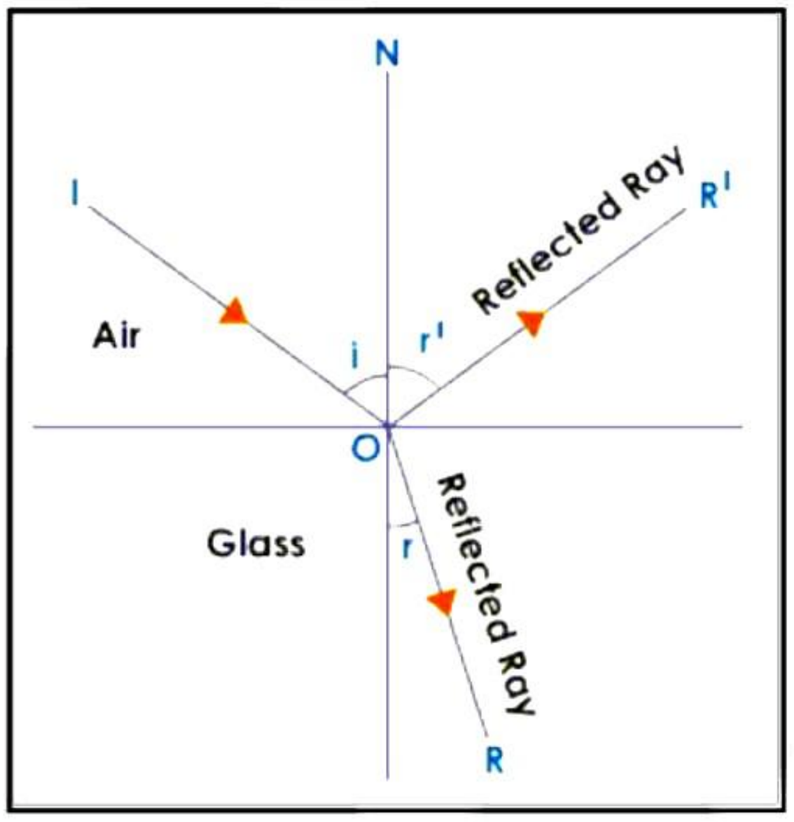
$= 180 - 2i$

Therefore for an angle of incidence i, the angle of incidence is equal to 180 -2i.

Refraction of Light

Let us now see what happens when a ray of light is incident on the boundary separating the two mediums having different densities.

A part of the light gets reflected and rest of the light changes its direction as it enters the second medium.



IO incident ray

OR' reflected ray

OR refracted ray

The diagram shows how the light gets refracted when it is traveling from one optical medium to another.

Like reflection, refraction of light takes place according to certain laws. Before we state these laws let us get familiar with certain terms which are commonly used to explain the phenomenon of refraction.

Incident Ray

The ray of light striking the surface of separation of the media through which it is traveling is known as the incident ray.

Point of Incidence

The point at which the incident ray strikes the surface of separation of the two media is called the point of incidence.

Normal

The perpendicular drawn to the surface of separation at the point of incidence is called the normal.

Refracted Ray

The ray of light which travels into the second medium, when the incident ray strikes the surface of separation between the media 1 and 2, is called the refracted ray.

Angle of Incidence (i)

The angle which the ***incident ray*** makes with the ***normal*** at the point of incidence, is called angle of incidence.

Angle of Refraction (r)

The angle which the ***refracted ray*** makes with the ***normal*** at the point of incidence is called angle of refraction.