Chapter 10 light

21 March 2020 15:24

Light: Definition

Light is a form of energy that enables us to see things. Light starts from a source and bounces off objects then reach our eyes and our brain processes this signal, which enable us to see.

Nature of Light

Light has dual nature :

- Wave form.
- Particle form.

" When light is incident on a medium, it either gets **absorbed, reflected , or refracted** "

"Black materials absorb all the light and emit infrared radiation, thus looks black in colour"

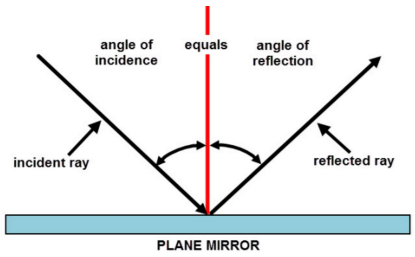
"Transparent materials like glass, water etc. Reflect some part of the light beam and refract rest of the part through the medium"

Characteristics of light

- Speed of light **c = λ× μ**, where λ is its wavelength and μ is its frequency.
- Speed of light is a constant = 2.998×10^{8}m/s or approximately **3.0×10^{8}m/s.**

*" Light is slowed down and bend in transparent media such as air, water and glass etc. The ratio by which it is slowed is called the **refractive index** of the medium. Refractive index of vacuum is 1."*

Laws of Reflection



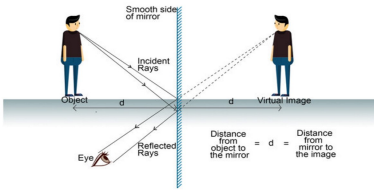
- The incident ray, reflected ray and the normal all lie in the same plane.
- *(Angle of incidence)* **<i =< r** *(Angle of reflection)*

Principle of Reversibility of light

If the direction of a ray of light is r**eversed, then it will retrace its path**.

Image formation by a plane mirror

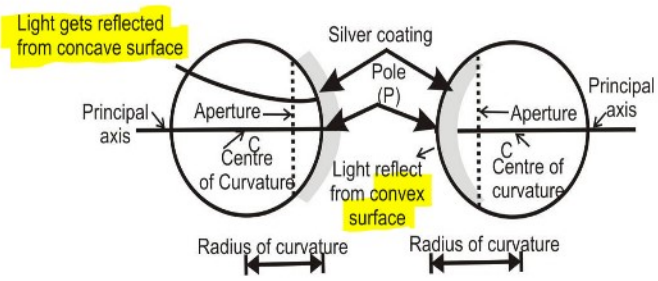
- The image formed by a plane mirror is **always virtual and erect**.
- Object and image are **equidistant** from the mirror.



Spherical mirror:

- Concave mirrors - A spherical mirror with the reflecting surface that bulges inwards.

- Convex mirrors - A spherical mirror with the reflecting surface that bulges outwards.



Relationship between focus and radius of curvature

Focal length (F) is half the distance between pole(P) and radius of curvature(R).

$$F = R/2$$

Important terms related to spherical mirror

- **Pole (P)**: The **midpoint** of a spherical mirror.
- **Centre of curvature (C)**: The **centre of the sphere** that the spherical mirror was a part of.
- **The radius of curvature (r)**: The **distance between the centre of curvature and the spherical mirror**. This radius will intersect the mirror at the pole (P).
- **Principal Axis**: The **line passing through the pole and the centre of curvature** is the main or principal axis.
- **Focus (F)**: All rays parallel to the principal axis converge at a point between the pole and the centre of curvature. This point is called as the focal point or focus.
- **Focal length**: **Distance** between pole and focus.

Image formation by spherical mirrors

Concave mirror:

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F	Highly diminished, point-sized	Real and inverted
Beyond C	Between F and C	Diminished	Real and inverted
At C	At C	Same size	Real and inverted
Between C and F	Beyond C	Enlarged	Real and inverted
At F	At infinity	Highly enlarged	Real and inverted
Between P and F	Behind the mirror	Enlarged	Virtual and erect

" Refer text for diagrams and practice drawing for all the positions "

Convex Mirror:

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F, behind the mirror	Highly diminished, point-sized	Virtual and erect
Between infinity and the pole P of the mirror	Between P and F, behind the mirror	Diminished	Virtual and erect

" Refer text for diagrams and practice drawing for all the positions "

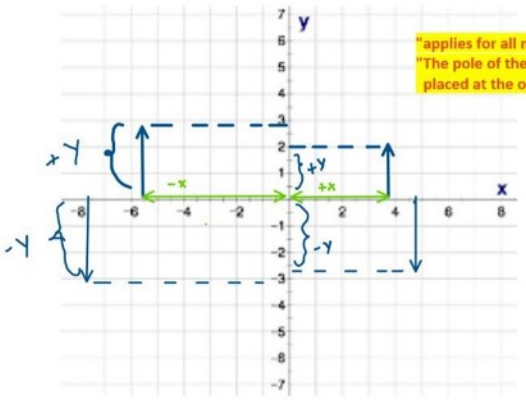
Uses of spherical mirror based on the image formed

Concave and Convex mirrors are used in many daily purposes.

Example: *Rear view mirrors in vehicles, lamps, solar cookers.*

Mirror Formula and Magnification

Sign Conventions:



"applies for all mirrors and lens "
"The pole of the mirror and the optical centre of the lens are placed at the origin of the graph"

Mirror Formula

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

"valid for all spherical mirrors"

u - displacement of the object from the pole.
v - displacement of the image from the pole
f - focal length

Magnification(m)

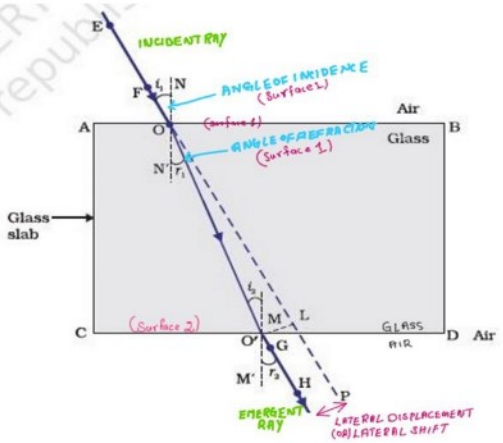
$$m = \frac{h_i}{h_o} = -\frac{v}{u}$$

h_i - height of the image
h_o - height of the object

Absolute and Relative Refractive Index

Refractive index of **one medium with respect to another medium** is called relative refractive index. When taken **with respect to vacuum**, it's known as an absolute refractive index.

Refraction through a rectangular glass slab



Laws of refraction of light

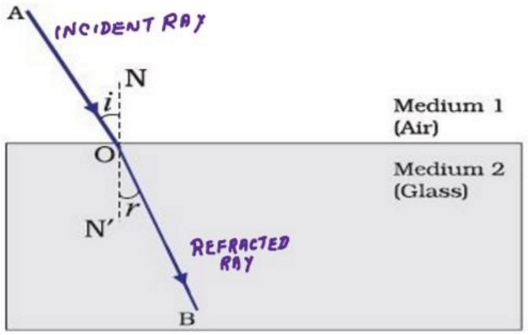
- The incident ray, the refracted ray and the normal to the interface of two transparent media at the point of incidence, **all lie in the same plane**.
- The ratio of sine of **angle of incidence (< i)** to the sine of **angle of refraction(< r)** is always constant **(Snell's Law)**

$$\frac{\sin < i}{\sin < r} = constant\ (Refractive\ index)$$

Refractive index

Absolute refractive index : the ratio of the **velocity of light in vacuum** 3.0×10^8 m/s to its **velocity in a specified medium**.

Relative refractive index : the refractive index of **any medium with respect to that of any other medium**.



$$n_{21} = \frac{\text{Speed of light in medium 1}}{\text{Speed of light in medium 2}}$$

n_{21} → Refractive index of medium2 w.r.t medium1

Optical Density:

It is the ability of a material to slow down the speed of light, higher the optical density higher the refractive index of the material

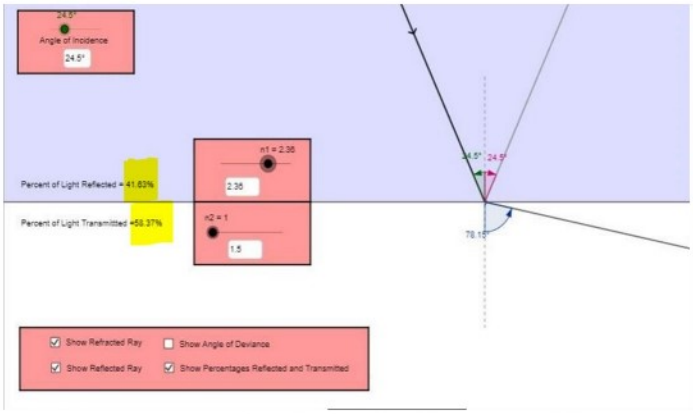
Material	Index of Refraction	
Vacuum	1.0000	<--lowest optical density
Air	1.0003	
Ice	1.31	
Water	1.333	
Ethyl Alcohol	1.36	
Plexiglas	1.51	
Crown Glass	1.52	
Light Flint Glass	1.58	
Dense Flint Glass	1.66	
Zircon	1.923	
Diamond	2.417	
Rutile	2.907	
Gallium phosphide	3.50	<--highest optical density

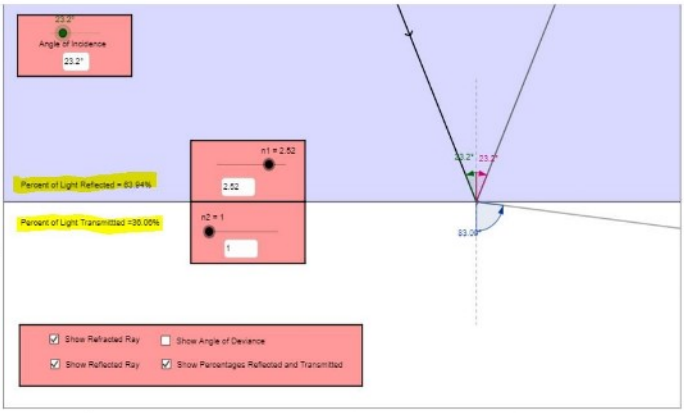
Total internal reflection

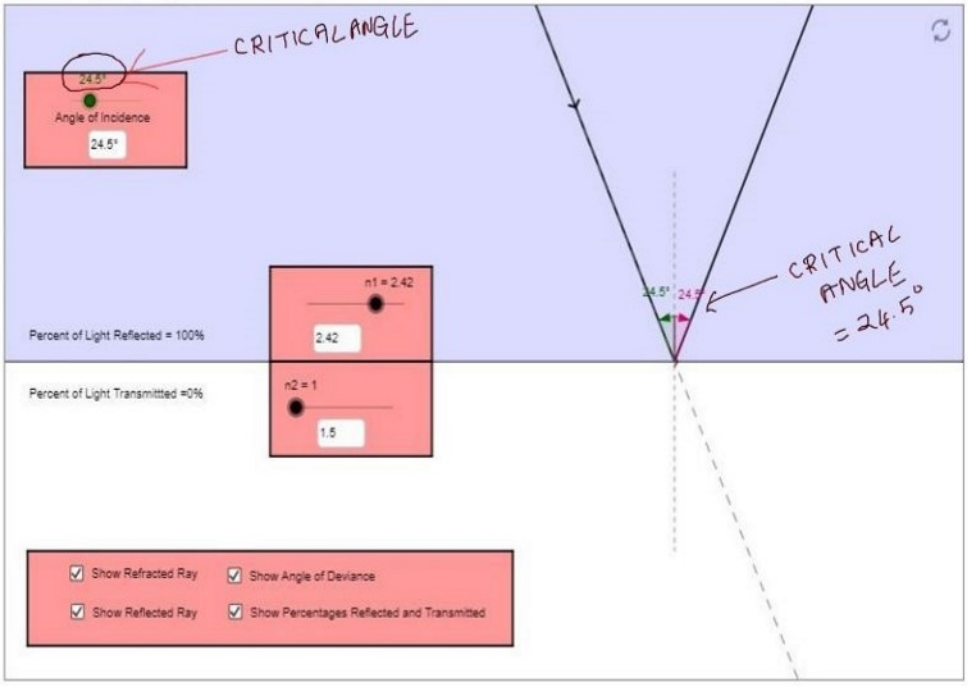
It takes place when the **angle** of incidence for the light ray is greater than the so-called **critical angle**.

Critical angle

The angle of incidence at which the **percentage of refraction of the incident light ray becomes 0 %** and the percentage of light reflected becomes 100%.
Or
It is the angle of incidence at which the **angle of refraction is 90^0** in a medium.

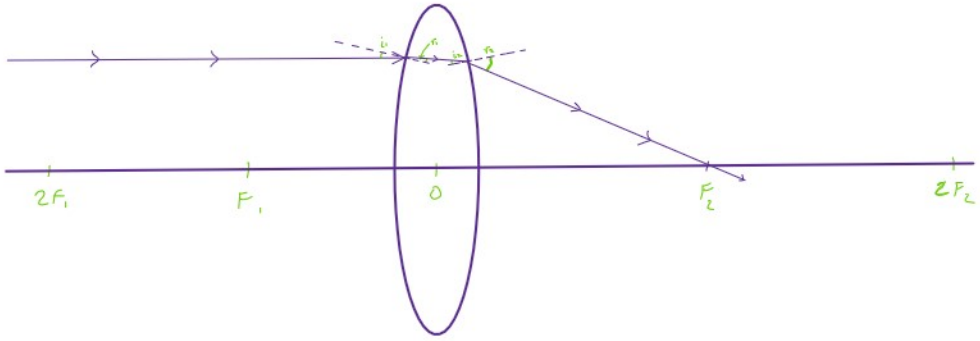






Spherical Lens

Refraction in convex lens



Important terms related to spherical lenses

- ***Optical Centre*** : The **midpoint of a spherical lens** is known as its .
- **Principal Axis**: The **line passing through the optical centre and the centre of curvatur**e.
- **Centre of curvature (C)**: The centres of the spheres that the spherical lens was a part of. **A spherical lens has two centres of curvatures.**
- **Focus (F)**: It is the point on the axis of a lens to **which parallel rays of light converge or from which they appear to diverge after refraction.**
- **Focal length**: **Distance between optical centre and focus.**
- **Concave lens:** Diverging lens
- **Convex lens:** Converging lens

"A ray passing through the optical centre undergoes zero deviation."

Lens Formula:

$$\frac{1}{V} - \frac{1}{u} = \frac{1}{f}$$

"valid for all spherical lenses"

u - displacement of the object from the optical centre
V - displacement of the image from the optical centre
f - focal length

Magnification

It is a ratio between the image height and object height

$$m = \frac{h_i}{h_o} = \frac{V}{u}$$

h_i - height of the image
h_o - height of the object
v - displacement of the image from the optical centre
u - displacement of the object from the optical centre

Power of a Lens

Power of a lens is the reciprocal of its focal length(f) in metre. The SI unit of power of a lens is dioptre(D).

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

"f in metre"

Resultant Focal length of lenses

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \cdots \frac{1}{f_n} - \frac{d}{f_1 f_2 \cdots f_n}$$

f - Resultant focal length
f_n - focal length of lens "n"
d - Displacement between the lens.

"d = 0 for thin lenses kept close to each other"

Uses of spherical lens

Applications such as visual aids: spectacles, binoculars, magnifying lens, telescopes.