REFRACTION OF LIGHT ON PLANE SURFACE

Refraction is defined as the apparent change in the direction of a (light) wave when it travels from one medium to another.

During refraction, frequency remains unchanged but the direction, velocity and wavelength all change. Optical density increases from gases (air) to liquid (water) and to solids (glasses)

The following equation shows the optical densities relation of the following objects

When light travels from a less dense medium to a denser medium, like from gas to liquid or liquid to solid or gas to solid, the light bends towards the normal. However, if the light travels from a denser medium to a less dense medium, it bends away from the normal.

LAWS OF REFRACTION

1. The incident ray, refracted ray and the normal all lie on a common point

2. The ratio of the sine of the incident ray to the sine of the refraction angle is equal to the ratio of the refractive indices of the materials at the interface and is constant for any given pair of media. This statement is known as **Snell’s law**.

The angle that the incident ray makes with the normal is called the angle of incidence

Let the refractive index of medium A be and let the refractive index of medium “B” be

If the light is incident at medium A and is refracted at medium B, let the angle of incident (at medium A) be and the angle of refraction be

From Snell’s law,

Let n be a constant known as the refractive index (of the second medium with respect to the first)

We have

Therefore,

The refractive index (n) of a medium can also be defined as the ratio of the velocity of light in air to the velocity in that medium

But

Since in refraction, frequency remains unchanged, that means it is constant

Therefore,

REFRACTIVE INDEX OF A LIQUID

When a metallic coin is in a beaker of water, the coin appears to be (displaced) above its normal level when viewed vertically from above (the beaker of water). Similarly, a swimming pool appears to be shallow when viewed from vertically above the pool. All these effects are due to the refraction of light in the water.

The distance between the top of the liquid (water) and the real position of object (in the liquid) is called the Real depth (R). The distance between the top of the liquid and the where it appears to be (i.e. its apparent position) is called the apparent depth (A). The distance between the real depth and the apparent depth is called the displacement (d).

The refractive index of the liquid is defined as the ratio of the real depth to the apparent depth

Since

CRITICAL ANGLE AND TOTAL INTERNAL REFLECTION

When a ray of light travels from a denser medium to a less dense medium, the ray bends away from the normal; as the angle of incidence increases, there is also an increase in the angle of refraction.

The largest angle of incidence that will give a maximum angle of refraction is called the critical angle. The largest angle of refraction is 90 degrees

Critical angle can now be defined as the highest incident angle (which produces the highest angle of refraction) below which light rays can escape from an optically denser medium to a less dense medium.

If the angle of incidence becomes greater than the critical angle, there will be no more refraction but a strong reflection call Total Internal Reflection

CONDITIONS FOR TOTAL INTERNAL REFLECTION

1. Light must travel from an optically denser medium to a less dense medium

2. The incident angle must be greater than the critical angle.

3. The relationship between the critical angle (c) and the refractive index (n) is expressed as

MIRAGE

This happens when the ground is very hot and the air is cool. The hot ground warms a layer of air just above the ground and makes it optically less dense than the cool air above it. When light moves through the cold air into the layer of hot air it is refracted. A layer of very warm air near the ground refracts the light from the sky nearly into a U-shaped bend.

Mirage is caused by the total internal reflection of light at layers of air of different densities and the sky which looks like a pool of water when viewed from a distance is produced.

LENSES

A lens can be defined as a piece of glass or other transparent material with curved sides for concentrating or dispersing light rays, used singly (as in a simple magnifying glass) or with other lenses (as in a telescope)

There are two major types of lenses

Convex lenses: These have a lot of similarities with concave mirrors. They are called converging lenses. When (parallel) rays of light pass through a convex lens, they are refracted and they converge at a point called the principal focus. These lenses are thicker at the center than at the rim

USES

1. Convex lenses are used in making magnifying glasses
2. They are also used to make eyeglasses
3. They are used in cameras
4. They are used in multi-junction star cells
5. They are used in telescopes
6. They are used in projectors
7. They are also used in making side-view mirrors

Concave lenses: These have a lot of similarities with convex mirrors. They are called diverging lenses. They are thinner at the center than at the rims.

USES OF CONCAVE LENSES

1. They are used in lasers
2. They are also used in cameras
3. They are used in flashlights
4. They are used in peepholes
5. They are also used in making eyeglasses

TERMS USED IN LENSES

1. Pole (p): This is the center of the lens
2. Principal focus (x): This is where parallel rays of light converge (at the back of the lens for convex lenses) and diverge (for concave lenses).
3. Center of curvature (2f)
4. Principal axis (x): This is an imaginary line that joins the pole to the center of curvature.
5. The focal length of a lens depends on the refractive index of the lens and the radius of curvature of the lens/

FORMING IMAGES IN CONVEX LENSES

Similar to mirrors, images formed can also be represented with ray diagrams

The following rules should be followed when drawing ray diagrams for convex lenses

The rays of the object parallel to the principal axis pass through the lens and are refracted

The refracted rays then pass through the principal focus (i.e. they converge there)

Then a line is drawn from the top of the object which passes through the exact center (pole) of the lens and it intercepts the line that passed the principal focus.

Finally a line is drawn perpendicularly to the principal axis to meet the point of intersection.

For an object before 2f (or at infinity), the image is:

Inverted

Real

Diminished

For an object on 2f exactly, the image is:

The same size

Inverted

Real

For an object between 2f and f, the image is

Magnified

Inverted

Real

For an object at f, the image is:

At infinity

For an object between f and p, the image is

Magnified

Erect

Virtual

RAY DIAGRAM FOR A CONCAVE LENS

LENS FORMULAE

These formulae are used in solving most questions pertaining to mirrors

For the following,

If we multiply through by u

But

Therefore,

If we multiply through by v

But

SIGN CONVENTION

For all mirrors, the object distance is always positive

For a convex lens,

For a concave lens,

For a real or inverted image,

For a virtual or upright image,

DISTANCE BETWEEN THE OBJECT AND THE IMAGE

For a virtual image,

For a real image,

POWER OF A LENS

This is defined mathematically as the reciprocal of the focal length of the lens.

If the focal length is in meters

If it is in centimeters

COMPOSITE LENSES

A composite lens is the combination of two or more lenses. The average focal length of the lens can be obtained from

r = radius of curvature for each lens

n = refractive index/ indeces

That formula is called the lens maker equation.

The power of composite lenses (or lenses in close contact) is expressed as

JOINING TWO LENSES

For example, you have two converging lenses A and B placed at a distance D from each other. The focuses are f1 and f2. Distance of the object from lens 1 is d\_{oa}. The image formed by lens A

Total magnification,