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

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

CONVEX LENSES

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

1. The rays of the object parallel to the principal axis pass through the lens and are refracted
2. The refracted rays then pass through the principal focus (i.e. they converge there)
3. 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.
4. Finally a line is drawn perpendicularly to the principal axis to meet the point of intersection.

1. For an object before 2f (or at infinity), the image is:
   - Inverted
   - Real
   - Diminished
2. For an object on 2f exactly, the image is:
   - The same size
   - Inverted
   - Real
3. For an object between 2f and f, the image is
   - Magnified
   - Inverted
   - Real
4. For an object at f, the image is:
   - At infinity
5. For an object between f and p, the image is
   - Magnified
   - Erect
   - Virtual

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

LENS FORMULAE

These formulae are used in solving most questions pertaining to mirrors

For the following,

$$u = object\, distance\, (fr\, o\, m\, mirror)$$

$$v = image\, distance$$

$$f = focal\, length\, (length\, of\, the\, principal\, focus | the\, pole)$$

$$m = magnification$$

$$r = radius\, of\, curvature$$

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

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

$$m = \frac{v}{u}$$

$$f = \frac{r}{2}$$

$$r = 2f$$

If we multiply $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ through by u

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

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

But

$$m = \frac{v}{u}$$

Therefore,

$$\frac{1}{m} = \frac{u}{v}$$

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

$$u=f\left(1+\frac{1}{m}\right)$$

If we multiply $\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$through by v

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

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

But

$$m=\frac{v}{u}$$

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

$$v=f\left(1+m\right)$$

<u>SIGN CONVENTION</u>

For all mirrors, the object distance is always positive

For a convex lens,

$$f=+ve$$

For a concave lens,

$$f=-ve$$

$$v=-ve$$

For a real or inverted image,

$$m=+ve$$

$$v=+ve$$

For a virtual or upright image,

$$m=-ve$$

$$v=-ve$$

<u>DISTANCE BETWEEN THE OBJECT AND THE IMAGE</u>

For a virtual image,

$$d=|v|-u$$

For a real image,

$$d=|v|+u$$

<u>POWER OF A LENS</u>

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

If the focal length is in meters

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

If it is in centimeters

$$p=\frac{100}{f}$$

COMPOSITE LENSES

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

$$\frac{1}{f}=(n-1)\left[\frac{1}{r_1}+\frac{1}{r_2}\right]$$

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

$$\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}$$

$$p=\frac{1}{f_1}+\frac{1}{f_2}$$

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, $m=m_1\times m_2$