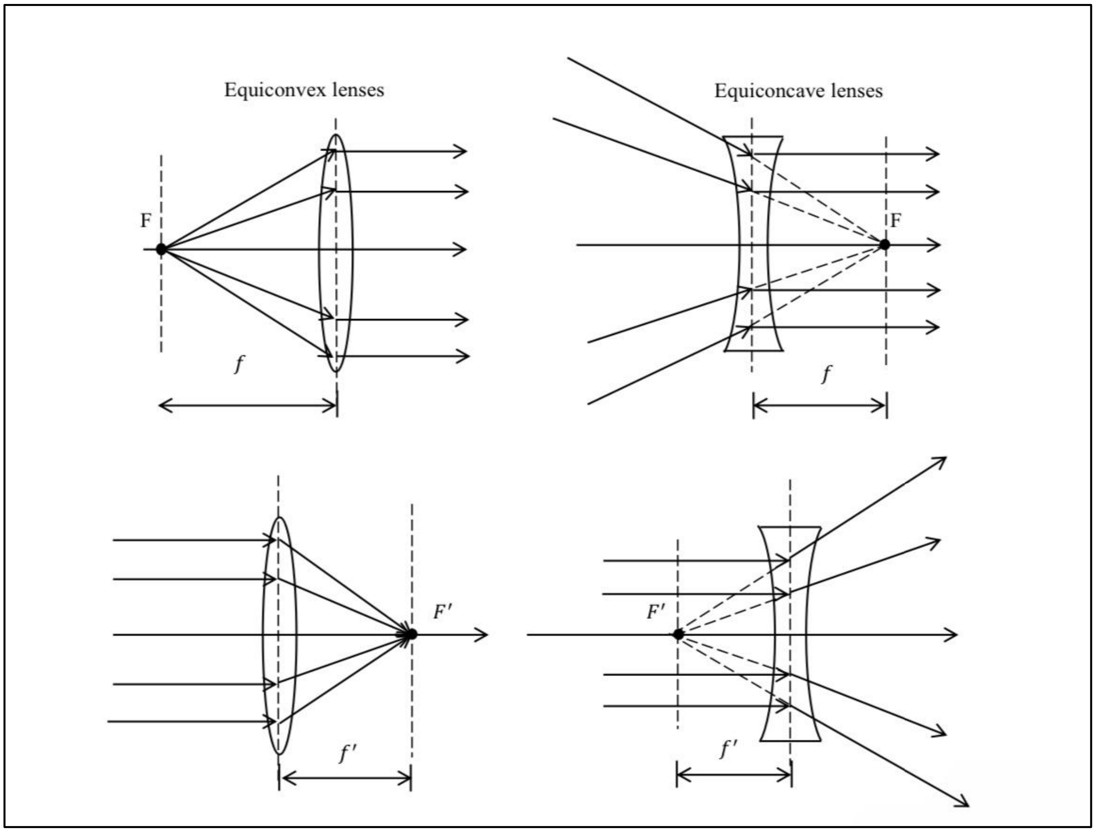
Optics

Second year / First semester
Lecture 5

Assist .lec. Mena Luay

Lenses

The fact that most lenses have surfaces that is spherical in form. Some surfaces are convex, others are concave. When light passes through any lens, refraction at each of its surfaces contributes to its image-forming properties. Diagrams showing the refraction of light by an equiconvex lens and by an equiconcave lens are given in Figure.



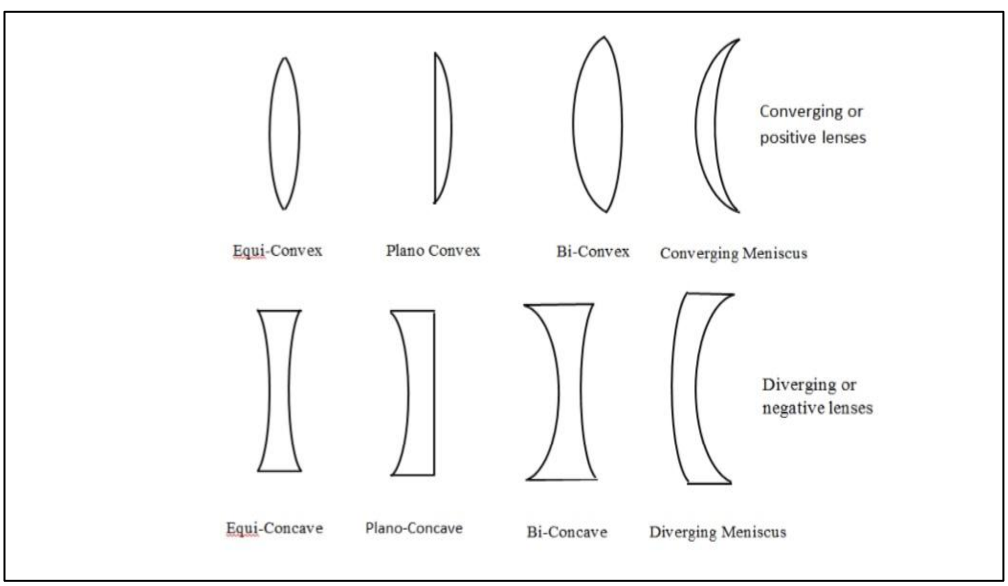
- The axis in each case is a straight line through the geometrical center of the lens and perpendicular to the two faces at the points of intersection.

- The primary focal point F is an axial point having the property that any ray coming from it or proceeding toward it . Every thin lens in air has two focal points, one on each side of the lens and equidistant from the center.
- The secondary focal point F' is an axial point having the property that any incident ray traveling parallel to the axis will, after refraction, proceed toward, or appear to come from F'.
- A plane perpendicular to the axis and passing through a focal point is called a focal plane.
- The distance between the center of a lens and either of its focal points is its focal length.

Types of lenses

Lenses are classified by the curvature of the two optical surfaces.

- is biconvex (or double convex).
- concave surfaces.
- plano-convex or plano-concave
- convex concave or meniscus.(It is this type of lens that is most commonly used in corrective lenses)



- If the lens is biconvex or plano-convex, a collimated beam of light passing through the lens converges to a spot (a focus) behind the lens.
- If the lens is biconcave or plano-concave, a collimated beam of light passing through the lens is diverged (spread); **the lens is thus called a negative or diverging lens.**

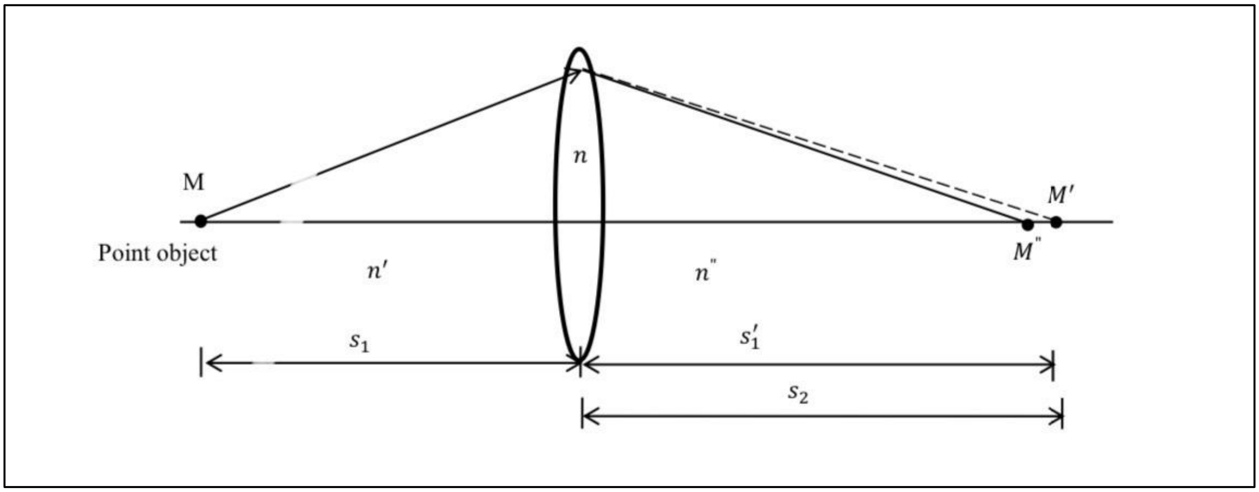
Image Formation :-

When an object is placed on one side or the other of a converging lens and beyond the focal plane, an image is formed on the opposite side .

- The object is moved closer to the primary focal plane; the image will be formed farther away from the secondary focal plane and will be larger, magnified.
- If the object is moved farther away from F, the image will be formed closer to and will be smaller.

The lens formula :-

A lens formula may be defined as the formula which gives the relationship between the distance of object(s), distance of image(s′), and the focal length (f) of the lens of negligible thickness, in air. General formulas of thin lens for point object as shown in figure.



To find the image forming from first surface

$$\frac{n'}{s_1} + \frac{n}{s_1'} = \frac{n-n'}{R_1} \quad \ldots\ldots\ldots\ldots(1)$$

Suppose that M' is a virtual object for second surface and its image M''

$$\frac{n}{-s_2} + \frac{n''}{s_2'} = \frac{n''-n}{-R_2} \ldots\ldots\ldots\ldots(2)$$

The sum of two equations (1) and (2)

$$\frac{n'}{s_1} + \frac{n}{s_1'} - \frac{n}{s_2} + \frac{n''}{s_2'} = \frac{n-n'}{R_1} + \frac{n''-n}{-R_2}$$

When thin lens used

($s_1' = s_2$) and $n' = n''$ (the lens is located in the same medium)

$s = s_1$ (Object distance from center of lens)

$s' = s_2'$ (Image distance from center of lens)

$$\frac{n'}{s} + \frac{n'}{s'} = (n - n')\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

When the medium is air

$$\frac{1}{s} + \frac{1}{s'} = (n - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

s: Object distance from lens

s′: Image distance from lens

R_1 : Radius for first surface of lens

R_2 : Radius for second surface of lens

Derivation of the lens Maker's formula :

An object is placed in the primary focal point f = s , the image position was in the infinity s′=∞, substitute in the general formula:

$$\frac{1}{f} + \frac{1}{\infty} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$ lens Maker's formula

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$ thin lens formula

- An object is placed at a distance ($s > f$) from a positive lens (convex lens) of focal length f , an image distance s' according to this formula is formed on a screen that is placed on the opposite side of the lens. This sort of image a real image (This is the principle working of the camera, and of the human eye).
  a virtual image results when the object distance is smaller the focal length ($s < f$) , the lens thus being used as a magnifying glass,
- Using a negative lens (concave) with a real (positive sign of object distance) can only produce a virtual image (negative sign of image distance), according to the above formula. It is also possible for the object distance to be negative; in this case the lens treats a so-called virtual object.

$$m = -\frac{s'}{s}$$ **(Lateral Magnification of Lenses)**

$$p = \frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$$ **(The Power of thin lens) (m^{-1}) called the diopter**

$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'} - \frac{t}{f_1 f_2}$ (البعد البؤري المركب)

$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$ (When the distance between two lenses are zero t = 0)

S → + (if the object is real)

S → - (if the object is a virtual)

s′ → + (if the image is real)

s′ → - (if the image is a virtual)

m → + (for an image that is upright with respect to the object)

m → -(for an image that is inverted with respect to the object)

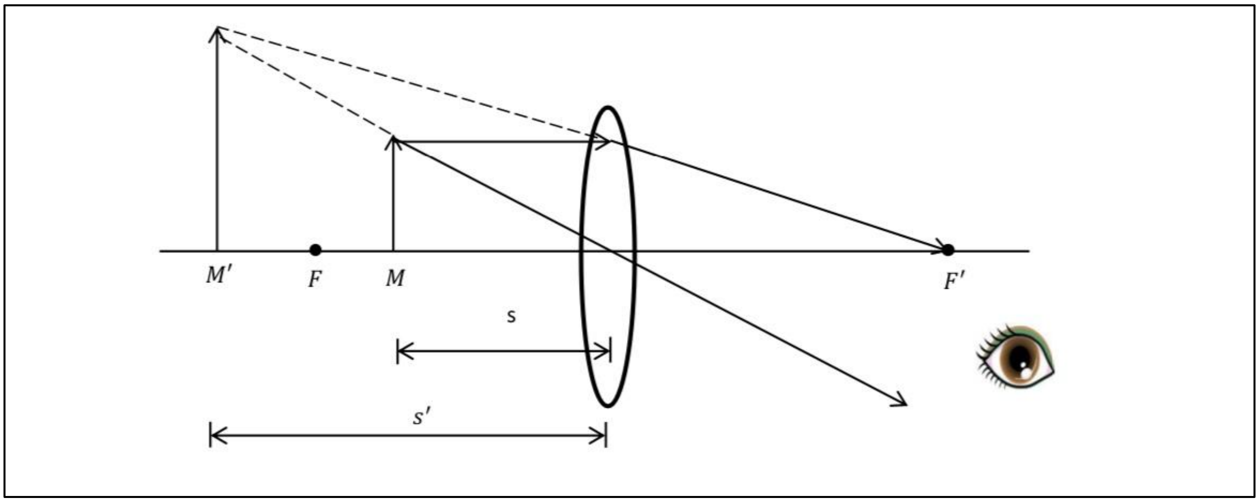
Example-1- An object is located 6.0 cm in front of a positive lens of focal length + 4.0 cm. Find the image distance.

$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$$

$$\frac{1}{4} = \frac{1}{6} + \frac{1}{s'} \longrightarrow \frac{1}{s'} = \frac{1}{4} - \frac{1}{6} = \frac{6-4}{24} = \frac{2}{24} = 0.083$$

s′ = +12 cm

Example-2- If an object is located 6.0 cm in front of a lens of focal length + 10.0 cm, where will the image be formed?



$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$$

$$\frac{1}{10} = \frac{1}{6} + \frac{1}{s'} \longrightarrow \frac{1}{s'} = \frac{1}{10} - \frac{1}{6} = \frac{6-10}{60} = \frac{-4}{60} = -0.066$$

$s' = -15$ cm

The magnification is obtained by

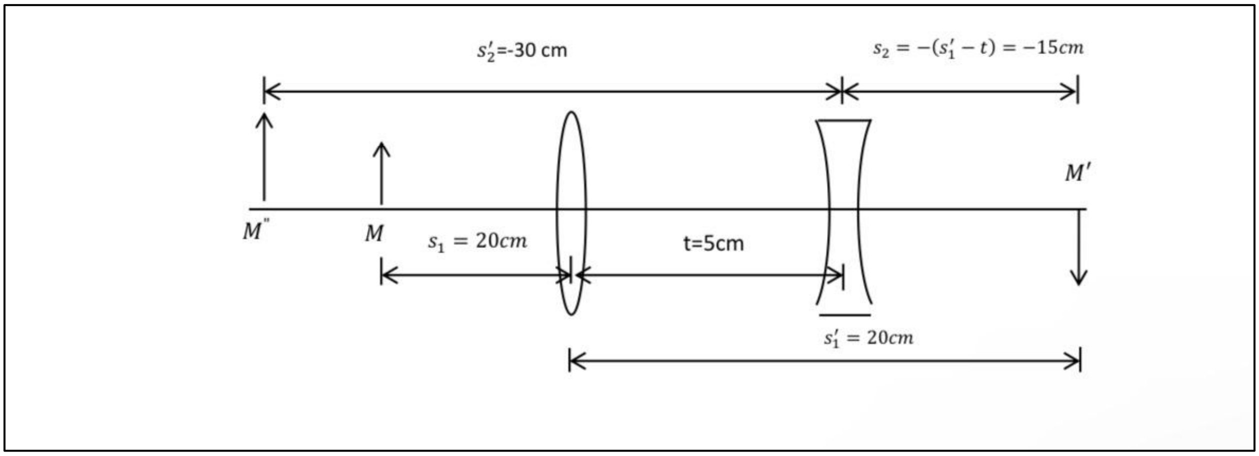
$m = -\frac{s'}{s} = -(\frac{-15}{6}) = +2.5$ (الصورة معتدلة)

Example-3 - The radii of both surfaces of an equiconvex lens of index 1.60 are equal to 8.0 cm. Find its power.

$$P = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \longrightarrow (1.6-1)\left(\frac{1}{0.080} - \frac{1}{0.08}\right) = 0.60\left(\frac{2}{0.08}\right) =$$

+15 D

Example-4- Two thin lenses the focal length for both lenses are 10 cm the distance between them is 5 cm as shown in figure find the final image characteristic when an object is placed 20 cm from converging lens?



$$\frac{1}{f_1} = \frac{1}{s_1} + \frac{1}{s'_1} \longrightarrow \frac{1}{10} = \frac{1}{20} + \frac{1}{s'_1}$$

$$\frac{1}{s'_1} = \frac{1}{10} - \frac{1}{20} \longrightarrow \frac{1}{s'_1} = \frac{2-1}{20} = \frac{1}{20} = 0.05$$

$$s'_1 = +20 \text{ cm}$$

$$s_2 = -(s'_1 - t) = -(20-5) = -15$$

$$\frac{1}{f_2} = \frac{1}{s_2} + \frac{1}{s'_2} \longrightarrow \frac{1}{-10} = \frac{1}{-15} + \frac{1}{s'_2}$$

$\frac{1}{s'_2} = \frac{1}{-10} + \frac{1}{15} = \frac{-15+10}{150} = \frac{-5}{150}$ = - 0.033

s'_2 = -30 cm

$m = m_1 * m_2$

$m = (-\frac{s_1'}{s_1})(-\frac{s_2'}{s_2}) = (-\frac{20}{20})(-\frac{-30}{-15})$ = (-1)(-2) = +2

(الصورة افتراضية و معتدلة و مكبرة)