The Optical Fiber

•Another interesting application of total internal reflection is the use of glass or transparent plastic rods to “pipe” light from one place to another. As indicated in Figure,

•If a bundle of parallel fibers is used to construct an optical transmission line, images can be transferred from one point to another. This technique is used in a sizable industry known as fiber optics.

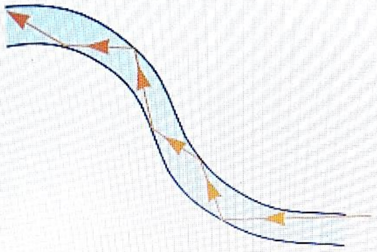


Figure Light travels in a curved transparent rod by multiple internal reflections.

Example:

a biological solution is found to have a refractive index of 1.34. what is the velocity of light in the solution? If a ray of light strikes the surface of the solution of an angle of incidence of 30°. What is the resulting angle of refraction?

Solution:

$$n = \frac{C}{v}$$

$$v = \frac{C}{n} = \frac{3 * 10^8}{1.34} = 2.24 * 10^8 m/s$$

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

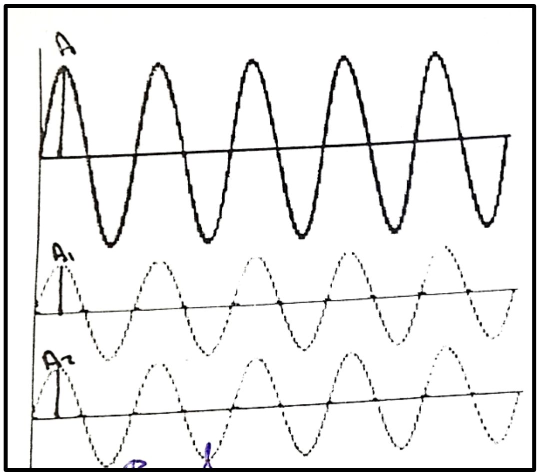
$$\sin \theta_2 = \frac{n_1 \sin \theta_1}{n_2} = \frac{\sin(30)}{1.34} = 0.373$$

$$\theta_2 = \sin^{-1}(0.373) = 21.2°$$

Interference

Interference is the addition of two or more waves that result in a new wave.

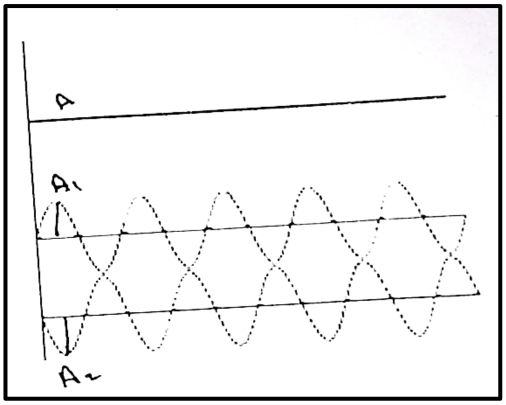
In order to observe interference in light waves, the following conditions must be met:



- The sources must be coherent—that is, they must maintain a constant phase with respect to each other.

- The sources should be monochromatic—that is, of a single wavelength. Consider two waves that are in phase, sharing the same frequency and with amplitude A_1 and A_2. Their troughs and peaks line up and the resultant wave will have amplitude $A = A_1 + A_2$ this is known as constructive interference.

If the two waves are π radians, or 180°, out of phase, the one waves crests will coincide with another waves troughs and so will tend to cancel it out. The resultant amplitude is $A = |A_1 - A_2|$.if $A_1 = A_2$ the resultant amplitude will be zero. this is known as destructive interference.



Polarization

- Light waves can vibrate in more than one direction are called un polarized light.

- The vibrating in one direction (in a single plane such as up and down) are called polarized light.

- The ways for produce polarized light from un polarized by:

(1) polaroid: Figure represents an un polarized light beam incident on a first polarizing sheet, called the polarizer. Because the transmission axis is oriented vertically in the figure, the light transmitted through this sheet is polarized vertically. A second polarizing sheet, called the analyzer, intercepts the beam. In Figure, the analyzer transmission axis is set at an angle θ to the polarizer axis. we conclude that the intensity of the (polarized) beam transmitted through the analyzer varies as:

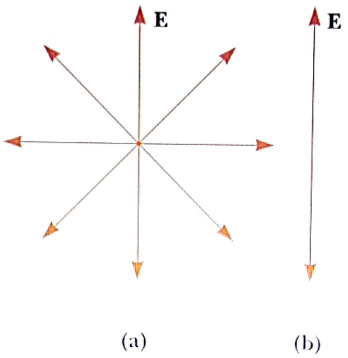
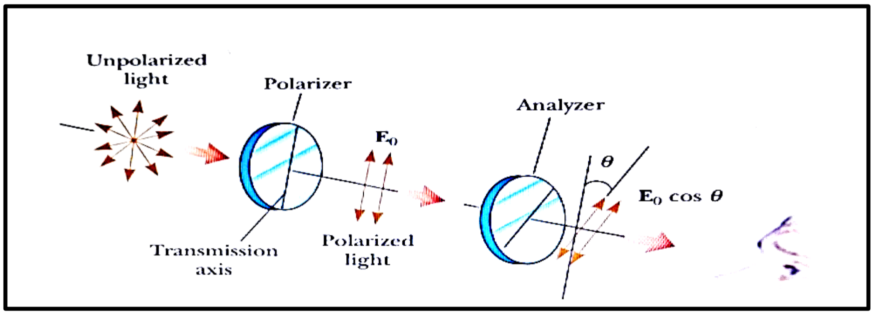


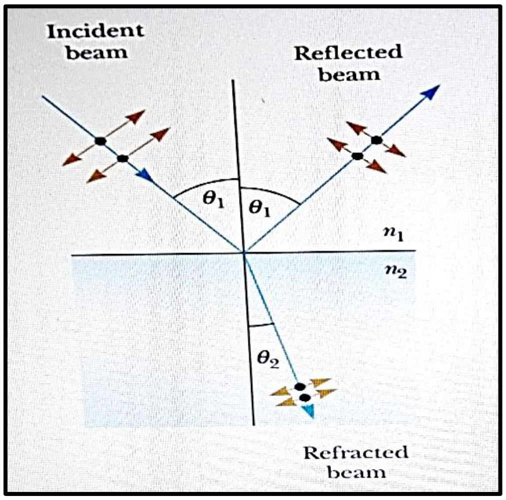
Figure 38.29 (a) A representation of an unpolarized light beam viewed along the direction of propagation (perpendicular to the page). The transverse electric field can vibrate in any direction in the plane of the page with equal probability. (b) A linearly polarized light beam with the electric field vibrating in the vertical direction.

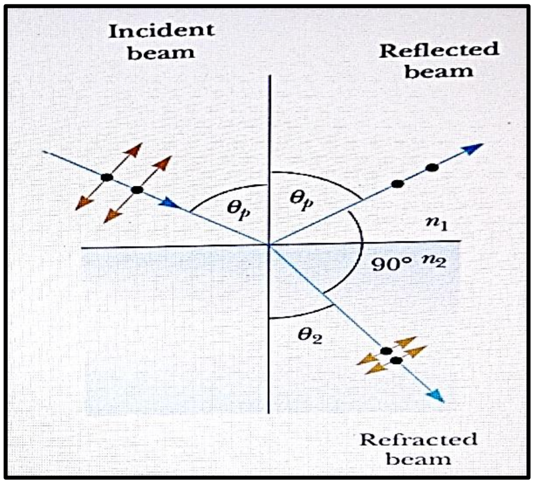
$$I = I_{max} cos^2\theta$$



(2) By reflection:

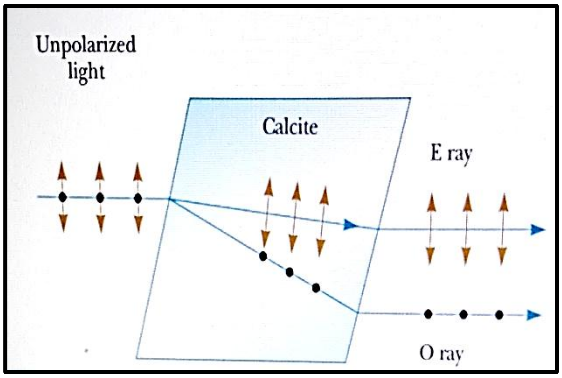
When un polarized light is incident on a reflecting surface, the reflected and refracted beams are partially polarized.The reflected beam is completely polarized when the angle of incidence equals the polarizing angle θ_p , which satisfies the equation $n = \tan\theta_p$. At this incident angle, the reflected and refracted rays are perpendicular to each other.





(3) By double refraction:

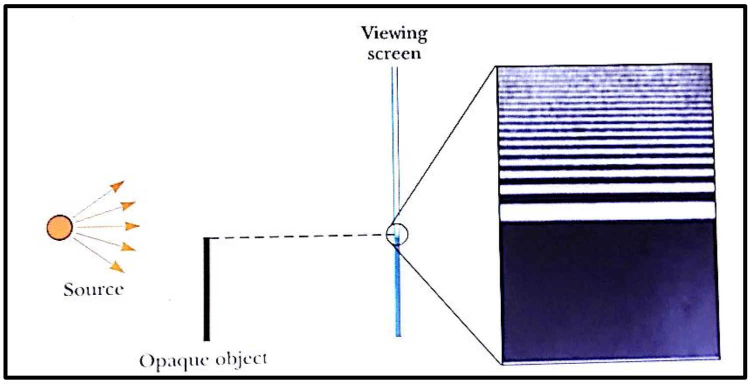
Un polarized light incident on a calcite crystal splits into an ordinary (O) ray and an extraordinary (E) ray. These two rays are polarized in mutually perpendicular directions.



(Drawing not to scale).

Diffraction

Light from a small source passes by the edge of an opaque object and continues on to a screen. A diffraction pattern consisting of bright and dark fringes appears on the screen in the region above the edge of the object.



The diffraction grating depends on diffraction in the same way as the double slit spreading the light so that light from different slits can interfere. It would be more correct to call it an interference grating, but diffraction grating is the name in use. Figure show a diffraction grating. The slit separation is d, and the path difference between adjacent slits is $d\sin\theta$.

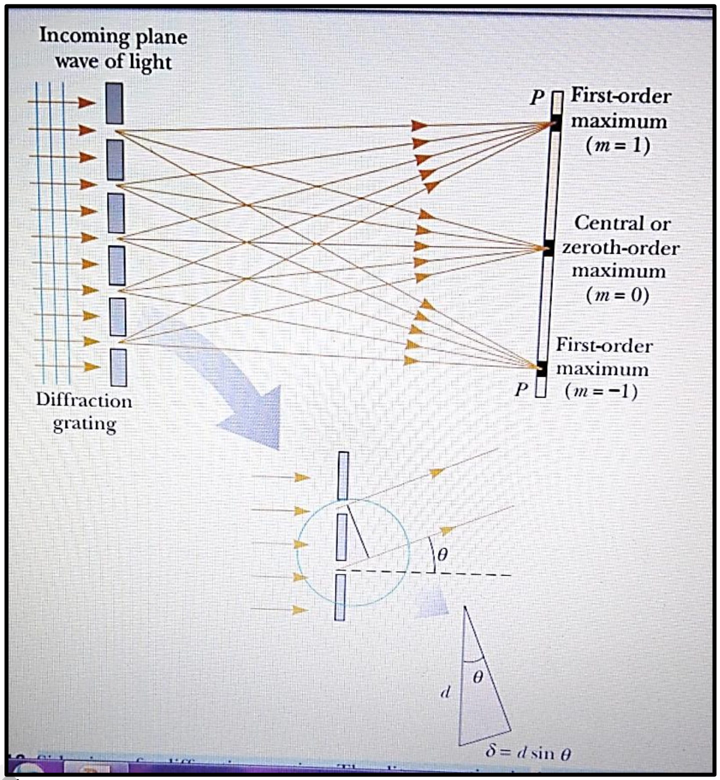


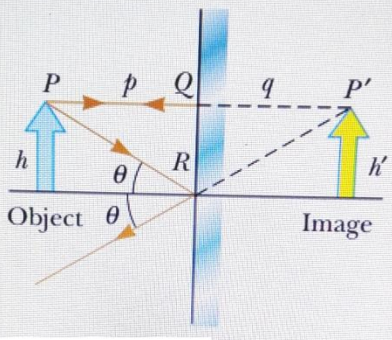
Image Formation

1)Plane Mirror

•Images are classified as real or virtual. A real image is formed when light rays pass through and diverge from the image point; a virtual image is formed when the light rays do not pass through the image point but only appear to diverge from that point.

• The image is as far behind the mirror as the object is in front.

• The image is unmagnified, virtual, and upright. (By upright we mean that, if the object arrow points upward as in Figure, so does the image arrow.)



A geometric construction that is used to locate the image of an object placed in front of a flat mirror. Because the triangles PQR and $P'QR$ are congruent, $|p| = |q|$ and $h = h'$.

• The image has front–back reversal.

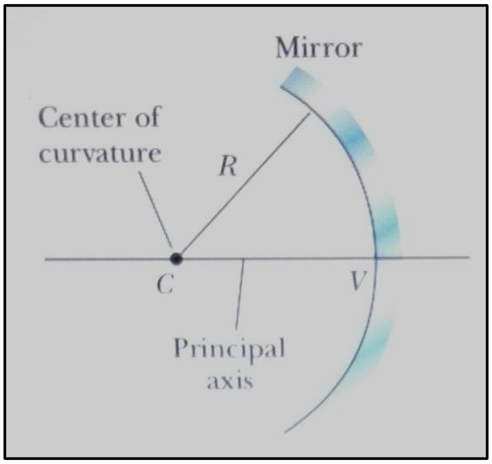
•Geometry also reveals that the object height h equals the image height h'. Let us define lateral magnification M of an image as follows:

$$M = \frac{image\ height}{object\ height} = \frac{h'}{h}$$

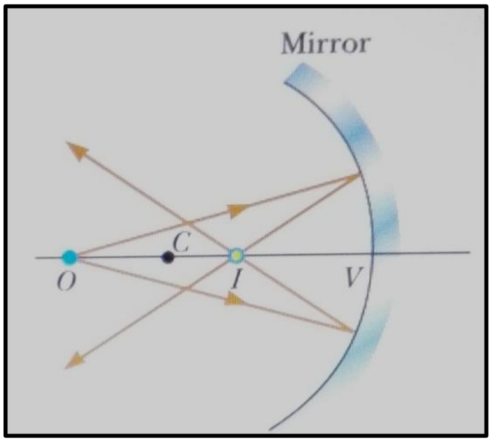
2)Spherical Mirror:

A) Concave Mirror

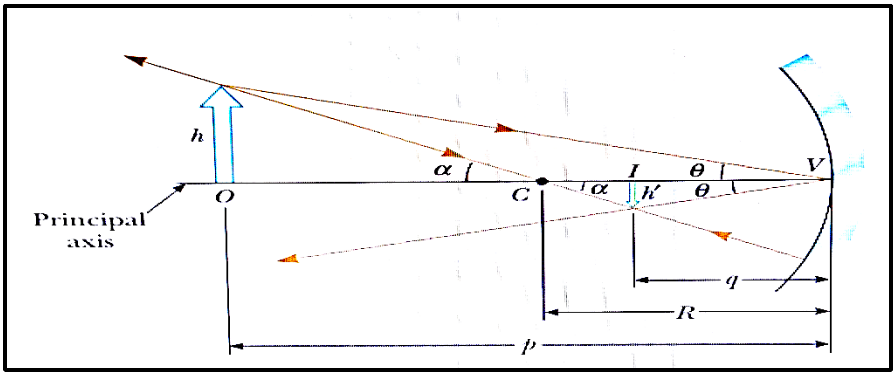
- in which light is reflected from the inner, concave surface.
- The mirror has a radius of curvature R, and its center of curvature is point C. Point V is the center of the spherical section, and a line through C and V is called the principal axis of the mirror.



- Now consider a point source of light placed at point O in Figure, where O is any point on the principal axis to the left of C. Two diverging rays that originate at O are shown. After reflecting from the mirror, these rays converge and cross at the image point I. They then continue to diverge from I as if an object were there. As a result, at point I we have a real image of the light source at O.



- We can use Figure to calculate the image distance q from a knowledge of the object distance p and radius of curvature R. By convention, these distances are measured from point V.
- Figure shows two rays leaving the tip of the object. One of these rays passes through the center of curvature C of the mirror, hitting the mirror perpendicular to the mirror surface and reflecting back on itself. The second ray strikes the mirror at its center (point V) and reflects as shown, obeying the law of reflection.
- The image of the tip of the arrow is



located at the point where these two rays intersect. From the gold right triangle in Figure, we see that $\tan\theta = \frac{h}{p}$, and from the blue right triangle we see that $\tan\theta = \frac{-h'}{q}$. The negative sign is introduced because the image is inverted, so h' is taken to be negative.

- Thus, we find that the magnification of the image is:

$$M = \frac{h'}{h} = \frac{-q}{p} \quad \ldots\ldots(1)$$

$$\tan\alpha = \frac{h}{p-R} \qquad \text{and} \qquad \tan\alpha = \frac{-h'}{R-q} \qquad \ldots\ldots(2)$$

$$\frac{h'}{h} = -\frac{R-q}{p-R} \qquad \ldots\ldots\ldots\ldots\ldots..(3)$$

If we compare Equations (1) and (3), we see that:

$$\frac{R-q}{p-R} = \frac{q}{p}$$

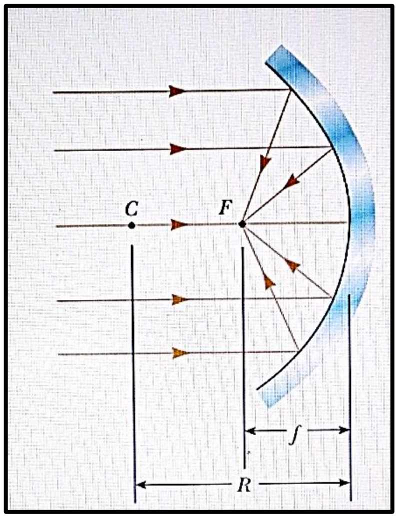
Simple algebra reduces this to:

$$\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$$

This expression is called the mirror equation.

We call the image point in this special case the focal point F and the image distance the focal length f, where:

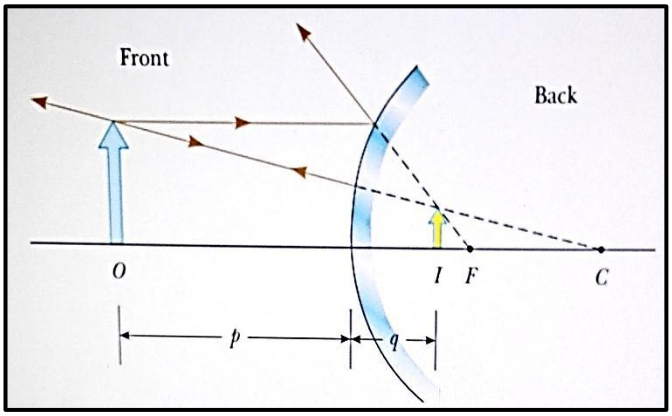
$$f = \frac{R}{2}$$



Focal length is a parameter particular to a given mirror and therefore can be used to compare one mirror with another. The mirror equation can be expressed in terms of the focal length:

$$\frac{1}{P} + \frac{1}{q} = \frac{1}{f} = \frac{2}{R}$$

B) Convex Mirror



in which light is reflected from the outer, convex surface.

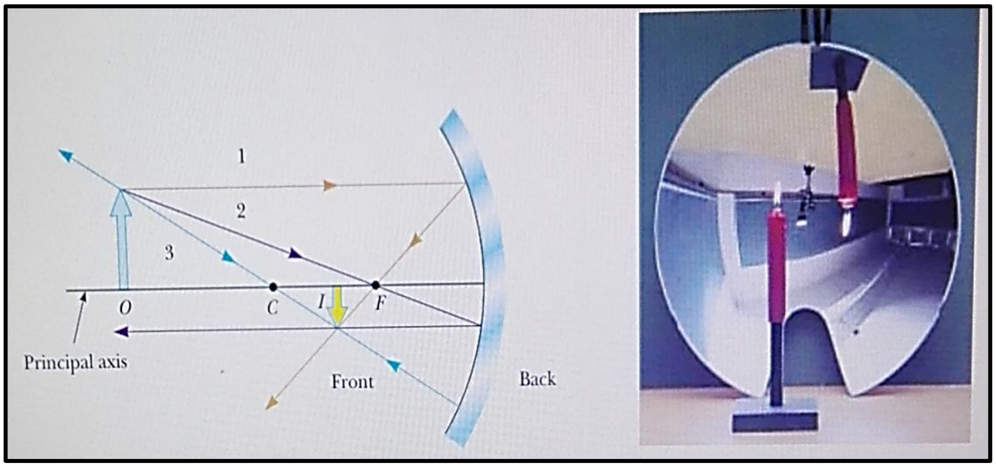
• This is sometimes called a diverging mirror because the rays from any point on an object diverge after reflection as though they were coming from some point behind the mirror.

• The image in Figure is virtual because the reflected rays only appear to originate at the image point, as indicated by the dashed lines.

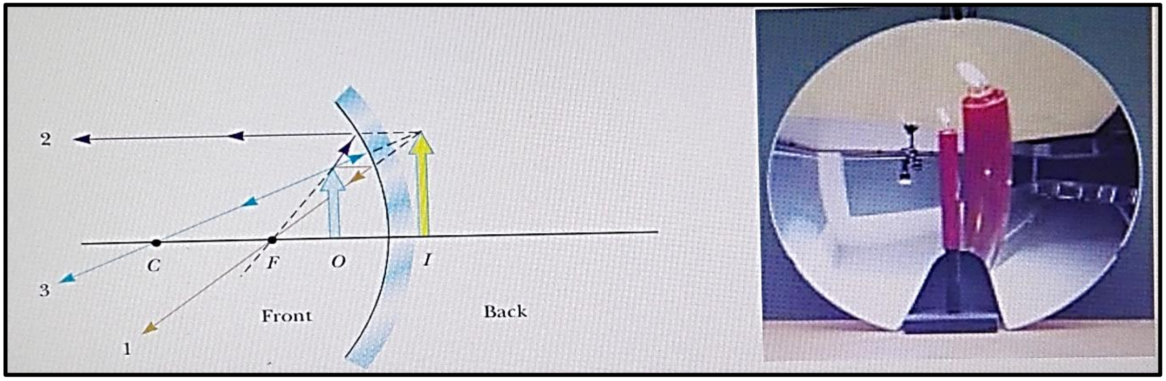
• the image is always upright and smaller than the object.

Ray Diagrams for Mirrors

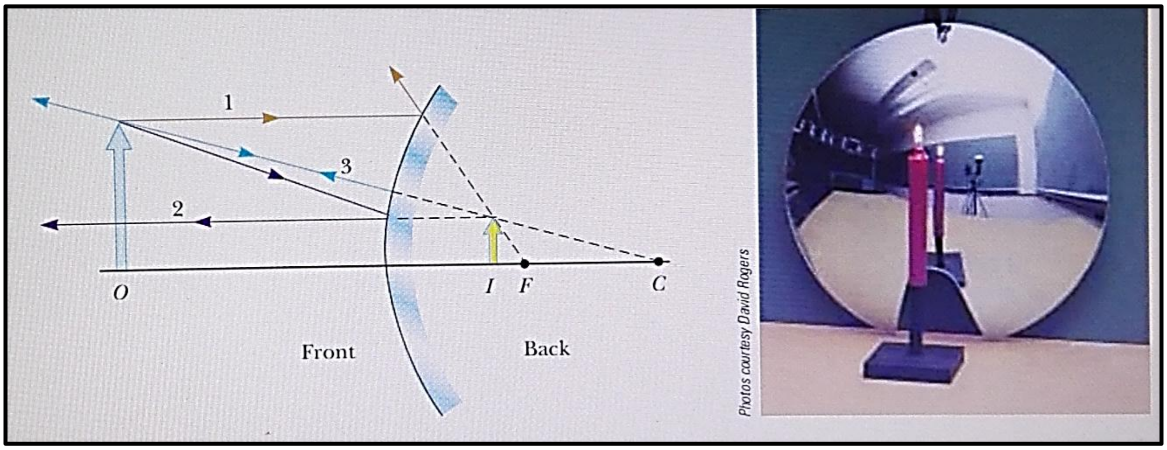
•When the object is located so that the center of curvature lies between the object and a concave mirror surface, the image is real, inverted, and reduced in size.



- When the object is located between the focal point and a concave mirror surface, the image is virtual, upright, and enlarged.



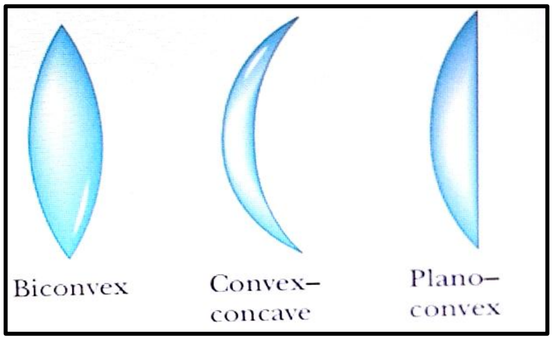
• When the object is in front of a convex mirror, the image is virtual, upright, and reduced in size.



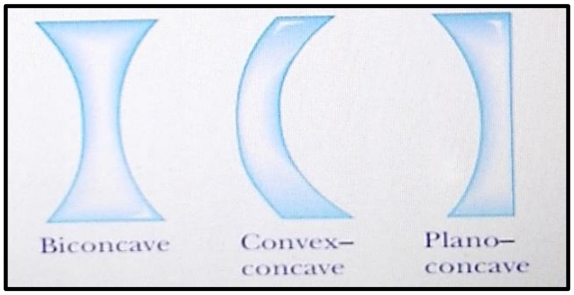
Photos courtesy David Rogers

Thin Lenses

•converging lenses:



• Diverging lenses

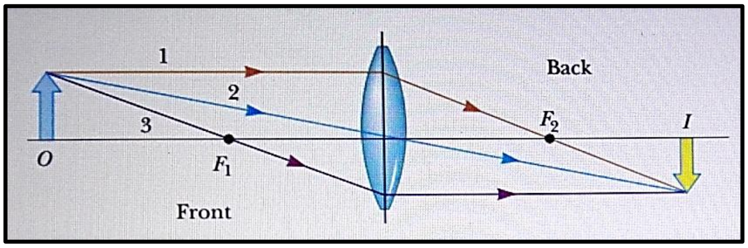


$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f} \qquad \text{(thin lens equation)}$$

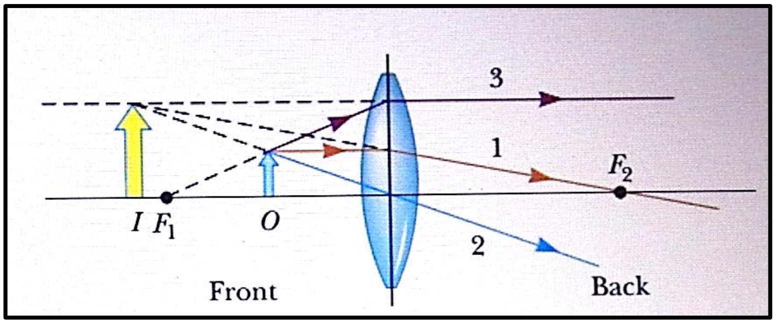
$$M=\frac{h'}{h}=-\frac{q}{p} \qquad \text{(magnification of image)}$$

From this expression, it follows that when M is positive, the image is upright and on the same side of the lens as the object. When M is negative, the image is inverted and on the side of the lens opposite the object.

- When the object is in front of and outside the focal point of a converging lens, the image is real, inverted, and on the back side of the lens.



- When the object is between the focal point and a converging lens, the image is virtual, upright, larger than the object, and on the front side of the lens.



- When an object is anywhere in front of a diverging lens, the image is virtual, upright, smaller than the object, and on the front side of the lens.