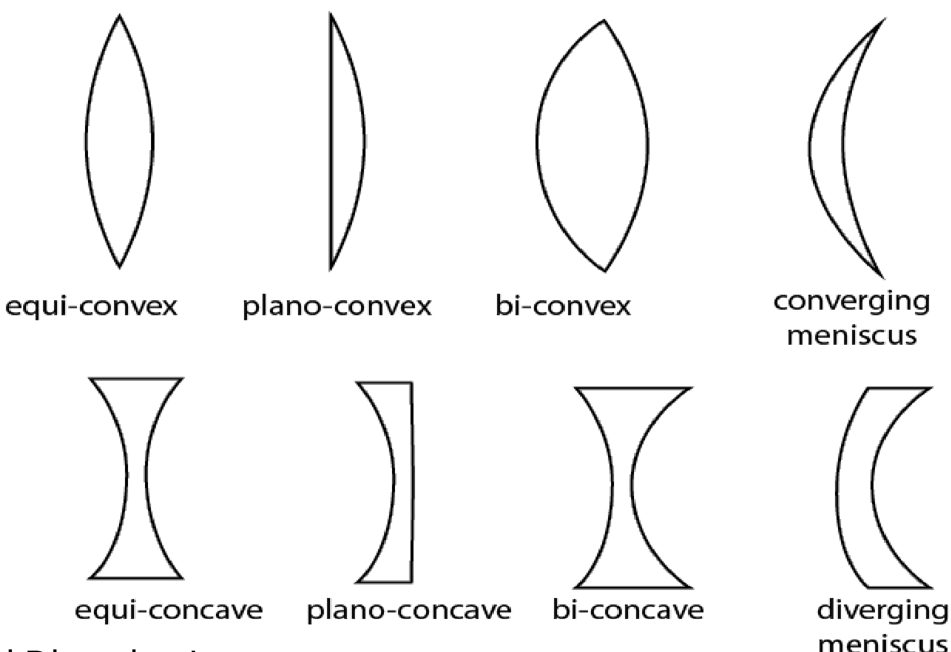
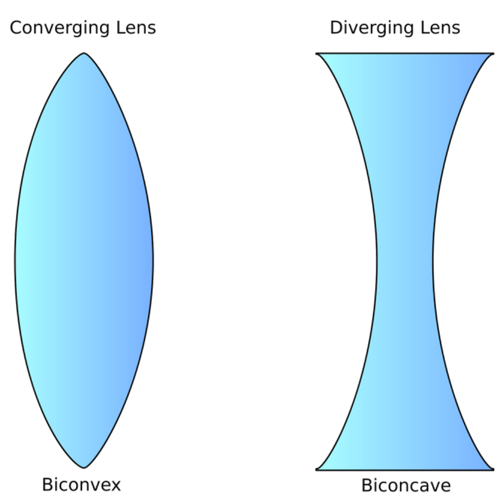
Refraction of Light at Curved Surfaces

Sign convention
Sign convention is a set of rules to set signs for image distance, object distance, focal length, etc for mathematical analysis of image formation. According to it:
Object is always placed to the left of lens.
All distances are measured from the optical centre of the mirror.
Distances measured in the direction of the incident ray are positive and the distances measured in the direction opposite to that of the incident rays are negative.
Distances measured along y-axis above the principal axis are positive and that measured along y-axis below the principal axis are negative.
Note: Sign convention can be reversed and will still give the correct results.
Convex lens has positive focal length and concave lens has negative focal length.

Types of lenses



Converging and Diverging Lens



Converging lens is convex lens whereas diverging lens is a concave lens. Converging lens converge and focus the light ray to meet at a single point whereas diverging lens, diverge the light falling on its surface and not meet at a single point.
Converging and diverging lens are shown in the figure.

Difference between concave and a convex lens

Concave Lens

Concave lens is thinner at the middle and thicker at the edges. middle and thinner at the
It is a diverging lens.
It is used as spy holes in doors, in optical instruments(telescope).

Convex Lens

Convex lens is thicker in the middle and thinner at the edges.
It is a converging lens.
It is used in compound microscope as eye piece, projectors and magnifying glass etc.

Convex lenses converge parallel rays going in and convex lenses diverge rays.
A convex lens is useful as a magnifying glass as it will produce a virtual enlarged image if the object is brought within the focal length. If the object is outside of the focal length, it will produce a real image that can be focused.With a convex lens, a virtual image is always produc
A concave lens is useful for people who are near-sighted. Your eye is a convex lens and near sighted people focus the light to much. A concave lens is put in place to spread the light out before entering the eye, thereby getting the light to focus further back.
Definition
Terms related to lenses
Centre of curvature (C): The centre of sphere of which lens is a part.
Radius of curvature (R): The radius of sphere of which lens is a part.
Principal axis: Line joining the centre of curvatures of two lenses.
Optical centre (O): The point on the principal axis of a thin lens through which a ray of light passes undeviated.
First focal point (F1): It is a point on the principal axis of the lens such that the rays of light starting from it (convex lens) or appearing to meet at the point (concave lens) after refraction from the two surfaces of the lens become parallel to the principal axis of the lens.
Second focal point (F2): It is a point on the principal axis of the lens such that the rays of light parallel to the principal axis of the lens after refraction from both the surfaces of the lens pass through this point (convex lens) or appear to be coming from this point.
Focal plane: Plane passing through focus and perpendicular to the principal axis.

Ray diagram of conventional rays used for image formation in spherical lenses

A ray emanating from the object parallel to the principal axis of the lens after refraction passes through the second principal focus F (in a convex lens) or appears to diverge (in a concave lens) from the first principal focus F.
A ray of light, passing through the optical centre of the lens, emerges without any deviation after refraction.
A ray of light passing through the first principal focus (for a convex lens) or appearing to meet at it (for a concave lens) emerges parallel to the principal axis after refraction.
Definition
Real and virtual images
Real image is formed by the actual intersection of light rays. It can be obtained on a screen. Hence, projectors form real images.
Virtual image is formed when the light rays appear to be originating from a point but does not actually meet. It can be seen by human eyes. Simple microscope forms virtual images.
Note: Concave lens always form virtual images. Convex lens may or may not form virtual image
Example
Effect of image formation when a part of lens is covered or removed
A thin lens has focal length f, and its aperture has diameter d. If the central part of the aperture, of diameter d/2 is blocked by an opaque paper, the focal length of the lens and the intesity of image will become:
Intensity of image will depend on the amount of light, which will depend on the area allowing light to enter.
If diameter d/2 is blocked then π×(d/2)2/π×d2=1/4× area gets blocked.
So intensity reduces to 3I/4 as I/4 intensity is blocked. The focal length is not affected as the curvature of the lens surfaces are not influenced.

Experimental determination of focal length of lenses

To determine the focal length of convex lens:
Refer the diagram (Figure 1):
The lens is set up in a suitable holder with a plane mirror behind it so that light passing through the lens is reflected back again.
The object used is a hole and cross-wire in a white screen illuminated by a pearl electric lamp.
The position of the lens holder is adjusted until a sharp image of the object is formed on the screen alongside the object itself.
The object will now be situated in the focal plane of the lens, i.e., a plane through the principal focus at right angles to the principal axis
Under these conditions, rays from any point on the object will emerge from the lens as a parallel beam.
They are therefore reflected back through the lens and brought to a focus in the same plane as the object.
The distance between lens and screen now gives the focal length of the convex lens.

To determine the focal length of concave lens (out of contact method):