The Science of Optics.

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In Fig. 13 x, the converging power of the convex being counteracted by the di·erging of the concave lens, parallel rays

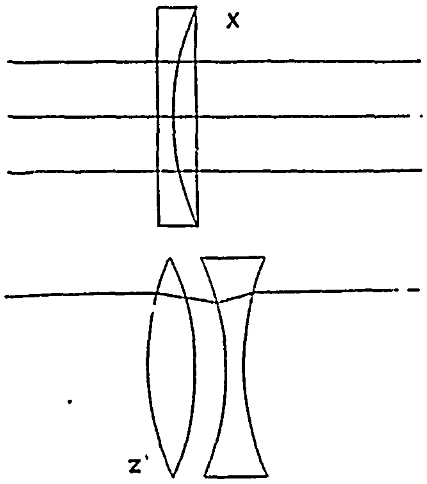

FIG. 13.

of light are parallel after passing through them, the two lenses having the same radius of curvature. In *Z* is shown the passage of a ray refracted by a convex and a concave lens.

Parallel rays passing through a lens formed of two segments of a sphere of 10-inch radius are refracted so that they come to a real or positive focus 10 inches behind the lens; this is the focal distance. The lense is numbered according to its focal length, and the focus made 10 inches behind it is called the principal focus.

The image formed at the real or positive focus is a real image; it is smaller than the object, and inverted (see Fig. 14), as the rays from the various points of the object after refraction cross each other before forming the picture. The shorter the focal length of the lens, the smaller, sharper, and clearer is the picture.

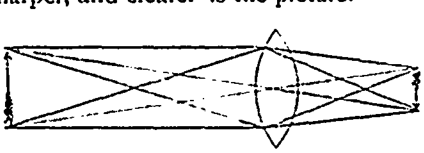

FIG. 14.

Then rays from a distance of 20 feet or more, that is, parallel rays, are brought to a focus at 10 inches behind a 10-inch lens; but if they come from points situated nearer than 20 feet, being then divergent rays, some of the refractive power of the lens is expended in making them parallel before it can converge them, so that the focus of divergent rays refracted by a convex lens is further behind it than its principal focus. If the rays diverge from a distance double the focal distance in front of a convex lens, the focus will be the same distance behind it.

The nearer the object is to the lens, the more divergent are the rays, and the further back behind the lens is the focus. The point at which divergent rays from a point are focussed as a point (see Fig. 15) is termed a conjugate focus, as the

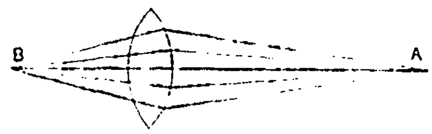

FIG. 15.

two points are interchangeable. In Fig. 15 the divergent rays from *A* are brought to a focus at *B*, divergent rays from *B* are focussed at *A*.

If the rays are divergent from a point situated just so far in front of the lens as the focal distance, say, they are from 10 inches in front of a 10-inch lens, then the refractive power is just sufficient to render them parallel when they emerge from the lens after refraction. In Fig. 16

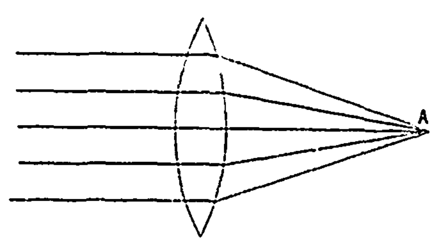

FIG. 16.

the rays from *A* at a distance equal to the focal length of the lens are rendered parallel, just as parallel rays would be refracted to *A*.

If the rays are very divergent from a point nearer than the focal distance, say, they are from an object situated 9 inches in front of a 10-inch lens, then the refractive power of the lens will not be sufficient to render them even parallel. After refraction the rays will emerge from the lens divergent, although much less so than when incident. If the eye be behind the lens the rays can be projected backwards, making what is called a virtual image of the object. In Fig. 17 the rays

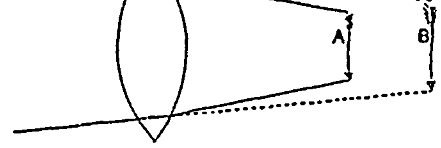

FIG. 17.

from *A*, placed 9 inches in front of a 10-inch convex lens, are refracted, and the virtual image *B* is formed on the same side of the lens as *A*. This image is upright, apparently larger and farther away than the object *A*. This explains why a convex lens magnifies an object brought within its focal length, such object being seen under a greater angle.

Note that any convex lens does exactly the same amount of refracting whether the incident rays be parallel, divergent, or very divergent.

A concave lense refracts rays outwards, and, therefore, can have no real focus; it has, however, a virtual or negative focus on the same side of the lens as the object, formed by projecting backward the rays in the direction they took after refraction by the lens. The image formed is virtual; it is upright, and apparently smaller and nearer than the object. In Fig. 18 the rays from *A*, the object, are bent outwards by the lens, and the image *B*, being seen under a smaller angle, is

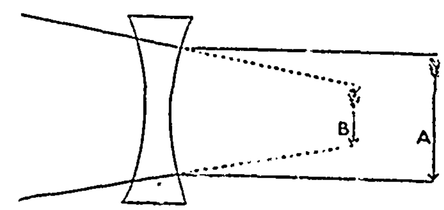

FIG. 18.

diminished in size, and apparently nearer than *A*. *This is equally true if the rays* refracted by a concave lens be parallel or divergent before refraction; but if the latter, the image is smaller than if the rays were parallel.

The optical centre of a lens is that point through which rays pass without being refracted, so that they emerge from *the lens in the same direction as they* entered it. The optical centre lies on the principal axis at a point that divides the axis in the ratio of the radii of curvature. *All rays that do not pass through* the optical centre are bent from their previous course to an extent dependent upon their distance from that centre; the farther away, *the more they are bent.*

The ray passing through the centre of the lens from the centre of the object is the axial ray; it suffers no refraction, and it is on *this, the principal axis, that the principal* focus of the lens is made. As, however, rays from luminous points are incident to the lens at every part of its anterior surface, *some one ray must be incident in* a direction perpendicular to the surface at every point on the surface of the lens. Such rays are the secondary axes, and the

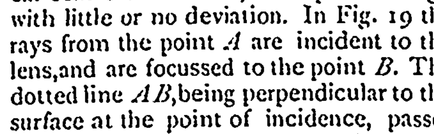

FIG. 19.

foci formed on them are secondary foci. They cross the principal axis at the optical centre of the lens, and pass through with little or no deviation. In Fig. 19 the rays from the point *A* are incident to the lens, and are focussed to the point *B*. The dotted line *AB*, being perpendicular to the surface at the point of incidence, passes through *O*, the optical centre, and emerges from the lens without any, or with very