One of the simplest of toys illustrating the action of convex lenses is the water bulb magnifier.

Fig. 212.

Water Bulb Magnifier.

It is a small hollow sphere of glass filled with water and provided with a pointed wire arm for supporting the object to be examined. It is a Coddington lens lacking the central diapraghm. It answers very well as a microscope of low power, and illustrates refraction as exhibited by glass lenses. It receives the rays from the object placed within its focus, and refracts them, rendering them convergent upon the opposite side of the bulb; but all of the rays do not converge exactly at one point, so that the image, except at the center of the field, is distorted and indistinct. This effect is spherical aberration.

MIRRORS.

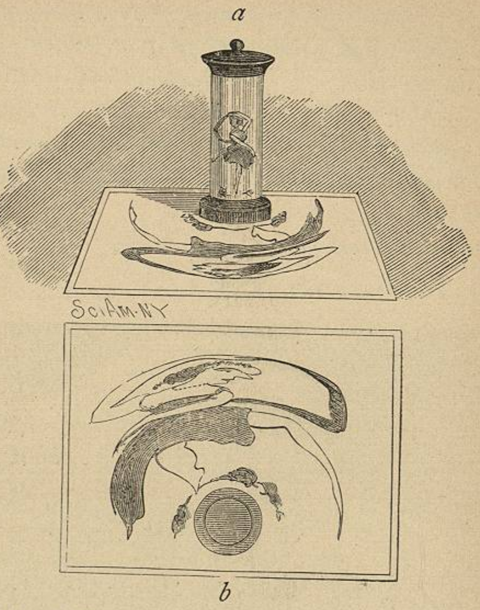
The convex cylinder mirror shows an ordinary object very much contracted in one direction.

The pictures accompanying these mirrors are distorted to such an extent as to render the object unrecognizable until viewed in the mirror, which corrects the image.

By tracing the incident ray from any point in the picture to a corresponding point in the image in the mirror, then tracing the reflected ray from the same point in the mirror to the eye, it will be found that in this, as in all other mirrors, the simple law of reflection applies; that is, that the angle of incidence and the angle of reflection are equal.

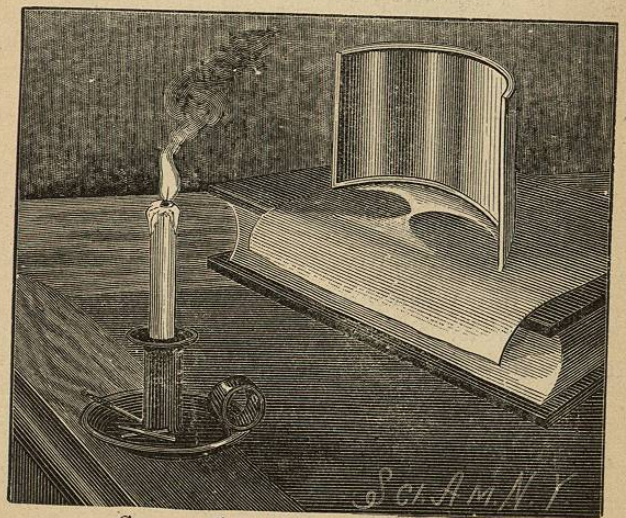
The concave cylindrical mirror (Fig. 214) is the reverse of the mirror just described. It produces a laterally expanded image of a narrow picture, and while the convex cylindrical mirror disperses the light from a distant source, the concave mirror renders it convergent; but, as in the case of the water bulb, the reflected rays do not focus at a single point, but cross each other, forming caustic curves. These curves may be exhibited by placing an ordinary cylindrical concave mirror edgewise on a white surface, and arranging a small light, such as a candle or lamp, a short

Fig. 213.



a, Convex Cylindrical Mirror. *b*, Distorted Picture to be viewed in Mirror

Fig. 214.



Concave Cylindrical Mirror, Caustics.

distance from the mirror, as shown in the engraving. The same phenomenon may be witnessed by observing a glass partly filled with milk, arranged in proper relation to the light. The inner surface of the glass serves as a mirror, and the surface of the milk serves the same purpose as the white paper. A cylindric napkin ring will show the curves under similar conditions. In fact, any bright concave cylindrical surface will do the same thing.

A convex spherical mirror distorts to a remarkable degree. A silvered glass globe held in the hand yields an image something like that shown in the engraving.

FIG. 215.

Spherical Mirror.

The size of the image depends upon the distance of the mirror, and is always less than that of the object. The farther the object is, the smaller is its image. This explains the distortion of the image, which appears to be behind the mirror.

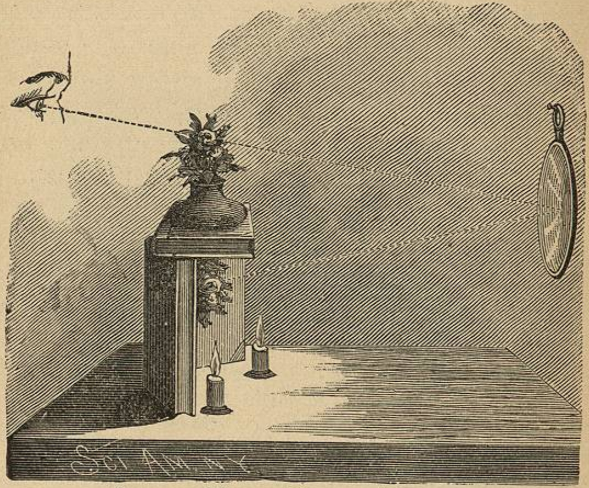
The spherical concave mirror produces effects which are the reverse of those just described if the object be nearer than the principal focus. In this case, as in the other, the virtual image appears behind the mirror, and is a magnified one. The image which appears in front of the concave mirror may be either larger or smaller than the object itself, depending upon the position of the object relative to the mirror and the observer.

It is inverted, and is formed in the air. A candle placed between the center of curvature of the mirror and the principal focus forms an inverted image in air, which is larger than itself.

PHANTOM BOUQUET.

The phantom bouquet, an interesting and very beautiful optical illusion, is produced by placing a bunch of flowers (either natural or artificial) in an inverted position, behind a shield of some sort, and projecting its image into the air by means of a concave mirror. A magnifying hand glass answers the purpose, if of the right focal length, and a few books may serve as a shield. Two black-covered books are placed upon one end and arranged at an angle with each other, and a third book is laid horizontally on the ends of the standing books. The bouquet is hung top downward in the angle of the books, and a vase is placed on the upper book, over the hanging bouquet.

FIG. 216.



Concave Mirror, Phantom Bouquet.

The concave mirror is arranged so that the prolongation of its axis will bisect the angle formed by lines drawn from the top of the vase and the upper part of the suspended bouquet, and it is removed from the bouquet and vase a distance about equal to its radius of curvature.

A little experiment will determine the correct position for the mirror. When the proper adjustment is reached, a wonderfully real image of the bouquet appears in the air over the vase. It is necessary that the spectator shall be in line with the vase and mirror. With a good mirror and careful adjustment, the illusion is very complete. The bouquet being inverted, its image is erect. A very effective way of illuminating the bouquet, which is due to Prof. W. Le Conte Stevens, of Brooklyn, is shown in the engraving. It consists in placing two candles near the bouquet and behind the shield, one candle upon either side of the bouquet. In addition to this, he places the entire apparatus on a pivoted board, so that it may be swung in a horizontal plane, allowing the phantom to be viewed by a number of spectators.

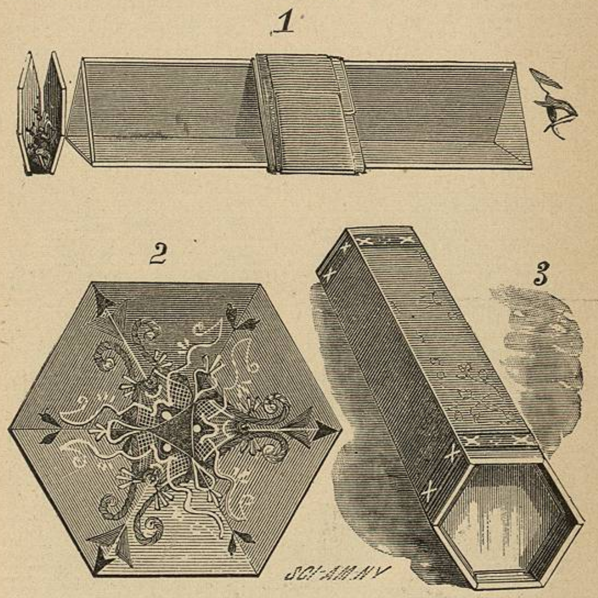
This simple experiment illustrates the principle of Herschel's reflecting telescope. In that instrument the image of the celestial object is projected in air by reflection and magnified by the lenses of the eyepiece.

MULTIPLE REFLECTION.

The kaleidoscope is one of the most beautiful and inexpensive of optical toys. It can be purchased in the ordinary form for five or ten cents. It is sometimes elaborately mounted on a stand and provided with specially prepared objects. It consists of a tube containing two long mirrors commonly formed of strips of ordinary glass, arranged at an angle of 60°, with a plain glass at the end of the mirrors, then a thin space and an outer ground glass, the space being partly filled with bits of broken glass, twisted glass, wire cloth, etc. The mirrors may be arranged at any angle which is an aliquot part of 360°. When the mirrors, *a b*, are inclined at an angle of 60°, as in the present case, the object, *c*, together with the five reflected images, will form a hexagonal figure of great beauty, which may be changed an infinite number of times by turning the instrument so as to cause the bits of glass, etc., to fall into new positions.

The images adjoining the object are formed by the first reflections of the object. The images in the second sectors are formed by second reflections, and two coincident images in the sector diametrically opposite the object are formed by third reflections.

Fig. 217.



1, Parts of Kaleidoscope. 2, The Figure. 3, Kaleidoscope.

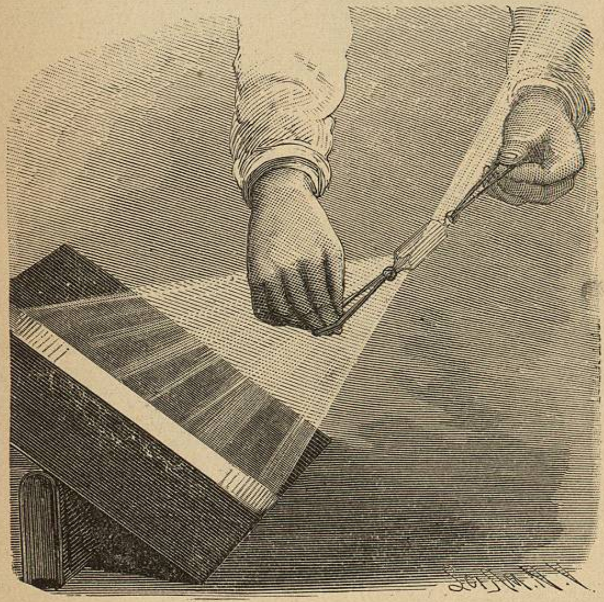
In most kaleidoscopes a third mirror is added, which multiplies the effects, and in the best instruments an eye lens of low power is provided.

ANALYSIS AND SYNTHESIS OF LIGHT.

An ordinary glass prism, such as may be purchased for fifty cents, is sufficient for the resolution of a beam of white sunlight into its constituent colors. By projecting the dispersed beam obliquely upon a smooth, white surface, the spectrum may be elongated so as to present a gorgeous appearance. It is not difficult to understand that whatever is exhibited in the spectrum must have existed in the light before it reached the prism, but the recombining of the colors of the spectrum so as to produce white light is of course conclusive.

The colors of the spectrum have been combined in several ways, all of which are well known. Newton's disk does it in an imperfect way by causing the blending, by persistence of vision, of surface colors presented by a rotating disk. Light from different portions of the spectrum has been reflected upon a single surface by a series of plane mirrors, thus uniting the colored rays forming white light. The colored rays emerging from the prism have been concentrated by a lens upon a small surface, the beam resulting from the combination being white. Besides these methods, the spectrum has been recombined by whirling or rocking a prism; the movement of the spectrum being so rapid as to be beyond the power of the eye to follow, the retina receiving the impression merely as a band of white light, the colors being united by the superposing of the rapidly succeeding impressions, which are retained for an appreciable length of time.

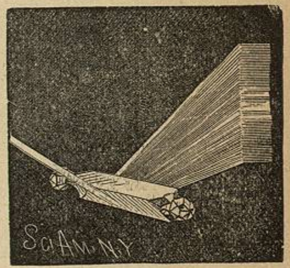
Fig. 218.



Simple Rocking Prism.

The engravings show a device to be used in place of the ordinary rocking prism. It is perfectly simple and involves no mechanism. It consists of an inexpensive prism, having attached to the knob on either end a rubber band. In the present case the bands are attached by making in each a short slit and inserting the knobs of the prisms in the slits. The rubber bands are to be held by inserting two of the fingers in each and drawing them taut. The prism is held in a beam of sunlight, as shown in Fig. 218, and with one finger the prism is given an oscillating motion. The band of light thus elongated will have prismatic colors at opposite ends, but the entire central portion will be white. To show that the colors of the spectrum pass over every portion of the path of the light, as indicated by the band, the prism may be rocked very slowly.

Fig. 219.



The Spectrum.

An ordinary prism may be made to exhibit several Fraunhofer's lines by arranging it in front of a narrow slit, through which a beam of sunlight is admitted to a darkened room. One side of the prism in this experiment must be adjusted at a very small angle with the incident beam. The spectrum will contain a number of fine dark lines, known as Fraunhofer's lines.

These lines tell of the constitution of the sun. The principle illustrated by this experiment is the one upon which the spectroscope is based.*

SIMPLE METHOD OF PRODUCING THE SPECTRUM.

Color is a sensation due to the excitation of the retina by light waves having a certain rate of vibration. Those

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*For further information on this subject the reader is referred to "Studies in Spectrum Analysis," by J. Norman Lockyer.