having the highest rate capable of affecting the eye are perceived as violet, while those of the lowest rate are perceived as red. According to Ogden Rood's "Modern Chromatics," the rate of the former is 757 billions of waves per second,

Fig. 220.

Simple Apparatus for producing the Spectrum.

that of the latter is 395 billions of waves per second, and between these extremes are ranged waves of every possible rate, representing as many colors. When light waves of all periods are mingled, there is no color—the light is white.

Newton discovered a way of resolving white light into its constituent colors. He made exhaustive experiments with prisms, first producing the gorgeous array of colors known as the spectrum, then recombining the colored rays by means of another prism producing white light. He found that the colors of the spectrum were simple, *i. e.*, they could not be further decomposed, and he also demonstrated that the red rays were the least and the violet rays the most refrangible.

The solar spectrum is always a delight to the eyes of every person having normal eyesight, and it is a simple matter to produce it by means of a prism. When a prism is not available, it may be produced in the manner illustrated by Figs. 220 and 221. This method is inexpensive, and yields a large spectrum. The materials required are a piece of a plane mirror, five or six inches square, a dish of water, and a sheet of white paper or a white wall. The mirror is immersed in the water and arranged at an angle of about 60°; this angle, however, may be varied to suit the direction of the light. The incident beam received on the mirror is refracted on entering the water and dispersed. It is further dispersed upon emerging from the water. By causing the reflected beam to strike obliquely upon the white paper or wall, the spectrum thus produced may be made to cover a large surface.

Fig. 221.

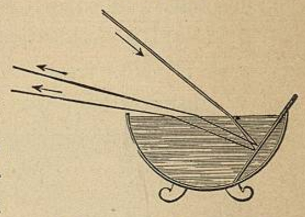


Diagram of Spectrum Apparatus.

Should the sun be too high or too low, the proper direction may be given to the incident beam by means of a second mirror held in the hand. The diagram, Fig. 221, shows the direction of the rays.

Some very interesting absorption experiments may be made in connection with this simple apparatus. For example, colored glass, or sheets of colored gelatine, may be placed in the reflected beam. If red be placed in the path of the beam, red light, with perhaps some yellow, will pass through, while the other colors will be absorbed, and will not, therefore, appear on the wall. With the other colors the same phenomenon is observed. Each colored glass or gelatine is transparent to its own color, but opaque to other colors. It will be observed that few bodies have simple colors.

In a similar manner a piece of red paper or ribbon placed in the red portion of the spectrum will reflect that color, but if placed in some other part of the spectrum it will appear dark, the other colors being absorbed or quenched by the colored surface. It is seen by these experiments that when light passes through a colored glass or film, it does not retain all its colors. It is simply a matter of straining out every color except that to which the glass or film is transparent. In reality only a small part of all the light striking the colored glass passes through it.

In the above experiment it is essential to avoid all jarring of the water, as ripples upon its surface defeat the experiment. If it is possible to so place the dish as to avoid jarring, the ripples may be prevented by suspending a transparent plane glass horizontally, so that its under side will just make contact with the surface of the water.

NEW CHROMATROPE.

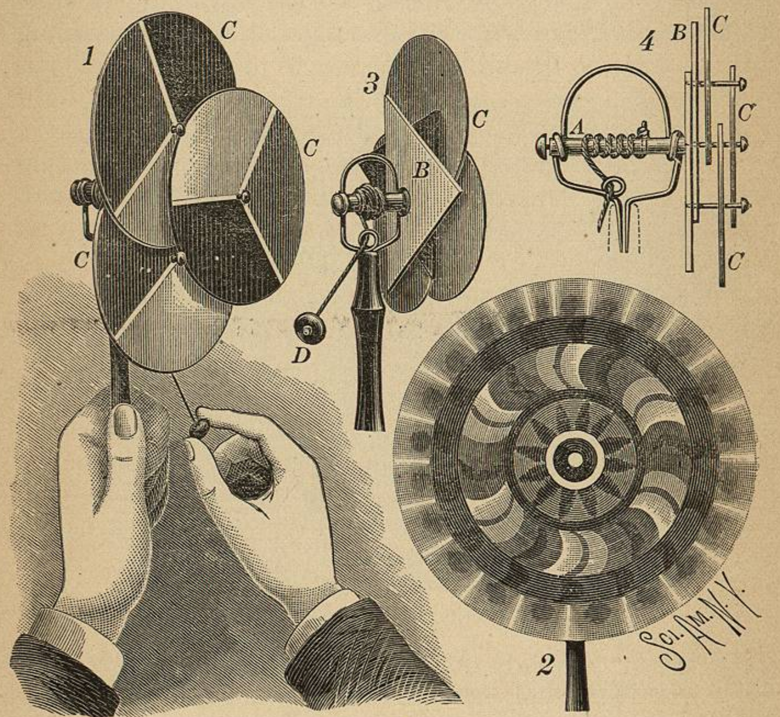
A novel toy which illustrates some of the phenomena of color is illustrated by Fig. 222. Upon the spindle, A, is secured a star, B, formed of two triangular pieces of pasteboard arranged so that their points alternate. One triangle is red, the other bluish green—complementary colors, which produce white when they are blended by the rotation of the star. In the angles of one of the stars are secured wire nails, which serve as pivots for the three disks, C, as shown at 1 and 4. Each disk is divided into three equal parts, which are colored respectively red, green, and violet. The disks overlap at the center of the star, B.

Around the spindle, A, is wound a cord which passes through the loop formed in the star frame in which the spindle is journaled, and is provided at its end with a button, D. By pulling the cord, the star, B, is whirled first in one direction and then in the other. As the series of disks, C, turn, the colors are blended in different ways, according to

the relative arrangement of the different sections. All the phenomena of the blending of surface colors are illustrated by this simple toy. At times the center will be a fine purple, while the outer part is green. At other times some portions of the color disk presented by the rotating disks are white, showing that a proper mixture of the three primary colors yields white light.

At the instant of the change of rotation from one direction to the other, the arrangement of the disks is such as to present beautiful symmetrical figures. All the changes of color in the toy in its normal condition are, of course, accidental.

FIG. 222.



Chromatrope.

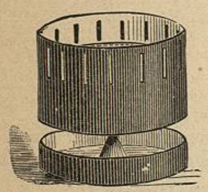
When it is desired to try the blending of any of the colors, when arranged in a particular way, the disks may be prevented from turning on their pivots by stretching over each disk a small rubber band.

The maker of this simple toy has succeeded in securing colors which produce remarkably good effects.

PERSISTENCE OF VISION.

The zoetrope, or wheel of life, is a common, but interesting, optical toy. It depends for its curious effects upon the persistence of vision. It consists of a cylindrical paper box mounted on a pivot, and having near its upper edge a series of narrow slits, which are parallel with its axis. Against the inner surface of the wall of the box is placed a paper slip, carrying a number of images of the same object arranged in as many different positions, each image differing slightly from the adjoining images, the successive positions of the several images being such as to complete one entire motion or series of motions.

FIG. 223.



Zoetrope.

When these pictures are viewed through the slits, as the box is turned, the eye glimpses the figures in succession, and retains the image of each during the time of eclipse by the paper between the slits and until the next figure appears. The images thus blend into each other, and give the figure the appearance of life and action.

Some very interesting studies for the zoetrope have been produced by the aid of instantaneous photography.

IRRADIATION.

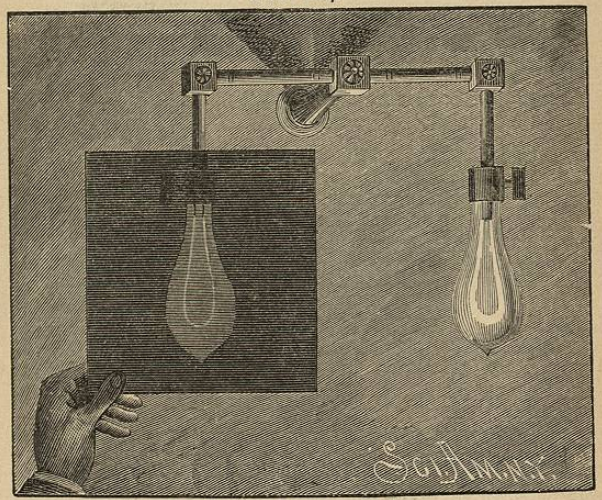
Brilliantly illuminated white surfaces and self-luminous bodies, when emitting white light, appear to the eye much larger than they really are. In nature examples of this phenomenon are presented by the sun, moon, and stars. The sun, viewed with the naked eye, appears very much larger than when the light is modified by a smoked glass. The crescent of the moon appears to project beyond the moon's periphery; and the stars, which are mere points of light even when viewed through the largest telescope, appear to the eye to have a disk of some size.

This phenomenon—known as irradiation—is due to the stimulation or sympathetic action of the nerves of the retina adjoining those which actually receive the image.

The ends of pieces of iron heated to incandescence by the blacksmith for welding seem to be unduly enlarged—an appearance due to irradiation.

Without doubt the most striking illustrations of irradiation are to be found in electric illumination. The electric arc, which is no larger than a pea, appears to the eye as large as a walnut; and the filament of an incandescent lamp, which is scarcely as large as a horsehair, appears as large as

FIG. 224.



An Example of Irradiation.

a small lead pencil. In viewing an ordinary incandescent lamp, it is difficult to believe that the delicate filament is not in some way immensely enlarged by the electric current or by the heat, but the experiment illustrated by the engraving shows that the size of the filament is unchanged, and proves that the effect is produced in the eye.

The experiment consists merely in holding a smoked or darkly colored glass between the eye and the lamp. The glass cuts off a large percentage of the light, and enables the eye to see the filament as it really is.