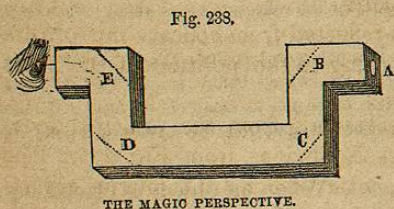


620. The Kaleidoscope consists of two narrow strips of glass running lengthwise through a tube, and forming with each other an angle of 60 or 45 degrees. One end of the tube, to which the eye is to be applied, is covered with clear glass. The other end terminates in a cell formed by two parallel pieces of glass an eighth of an inch apart, the outer one of which is ground to prevent external objects from marring the effect. This cell contains beads or small pieces of glass of different colors, free to move among themselves. On applying an eye to the tube, we see the objects in the cell multiplied by repeated reflections from the mirrors, and symmetrically arranged, with their images, around a common centre. By shaking the tube, we bring the objects into new relative positions, and have new combinations presented.

621. *The Magic Perspective.*—By arranging four plane mirrors as represented in Fig. 238, a person is enabled to see an object by looking directly towards it, though an opaque screen is interposed.



A rectangular box is bent four times at right angles; and in each of these angles is placed a piece of looking-glass, B, C, D, E, at such an inclination that the incident ray may strike it at an angle of 45 degrees. Any object opposite the aperture A is visible to an eye applied at the other extremity, though an opaque screen be placed between the arms of the instrument. The rays from the object first strike B at an angle of 45 degrees, and are reflected at the same angle to C, thence to D, thence to E, and finally to the observer's eye. The inventor of this instrument recommended its use in time of war, for discovering an enemy's movements without any exposure of the observer's person. It is more commonly used, however, by itinerant showmen, who for a penny allow the curious to read through a brick.

622. REFLECTION FROM CONCAVE MIRRORS.—In general, the effect of concave mirrors is to make incident rays more convergent or less divergent. In most cases, the images they produce appear in front of them.

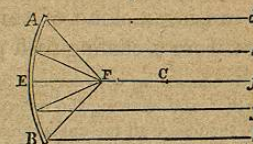
623. Parallel rays striking a concave mirror are made to converge to a point called the Principal Focus. This

to each other? How many, when they form an angle of 60 degrees? Of 45 degrees? In what is this principle applied? 620. Describe the Kaleidoscope. 621. How is a person enabled to see an object by looking towards it, though an opaque screen is interposed? Describe the Magic Perspective. By whom is it commonly used? 622. What is the general effect of concave mirrors? What is said of the images they

point is half way between the surface of the mirror and the centre of the sphere which the mirror would form if it were extended with uniform curvature.

In Fig. 239, let AEB be a concave mirror, forming part of the surface of a sphere, of which C is the centre. The parallel rays *d, e, f, g, h*, are reflected to the principal focus F, midway between the surface and the centre C.

Fig. 239.



Not only is light concentrated at the focus, but also heat, as we had occasion to note in § 476. Tinder, wood, or any other combustible material, is readily ignited, and with a combination of such mirrors the most intense heat can be produced. Hence concave mirrors are sometimes called Burning Glasses.

624. Converging rays reflected from a concave mirror are made to converge more.

625. Diverging rays reflected from concave mirrors are differently affected according to the position of the point from which they diverge.

626. Diverging rays starting from the principal focus are made parallel. This is obvious from Fig. 239. The rays diverging from F, after striking the mirror, are reflected in parallel lines to *d, e, f, g, h*.

This principle is turned to account in light-houses. The light is placed in the focus of a concave mirror, and its rays are reflected in parallel lines from every point of the mirror's surface. No image of the light is produced, but the whole surface of the mirror appears illuminated.

627. Diverging rays coming from a point between the principal focus and the mirror, become less divergent after reflection. An object in such a position forms an image larger than itself, which seems to be situated behind the mirror.

628. Diverging rays coming from a point between the

produce? 623. What effect has a concave mirror on parallel rays that strike it? How is the principal focus situated? Illustrate this effect with Fig. 239. What are concave mirrors sometimes called, and why? 624. What is the effect of concave mirrors on converging rays? 626. What is the effect of concave mirrors on diverging rays starting from the principal focus? How is this principle turned to account? 627. What effect have concave mirrors on diverging rays coming from a point between the principal focus and the mirror? What kind of an image is formed? 628. What effect have concave mirrors on rays diverging from a point between the



principal focus and the centre, converge, after reflection, to a focus on the other side of the centre. An inverted image will there be visible, suspended in the air. This image is made more distinct, and its effect greatly increased, by causing a cloud of thin bluish smoke to rise about the spot from a chafing-dish placed beneath.

By concealing with screens the mirror, the object, and the light that illumines it, and allowing the reflected rays to pass through an aperture, we may give the image all the appearance of reality. The observer beholds delicious fruit hanging in the air without any visible support, and can hardly convince himself that it is a delusion, even when he tries to grasp it without success. He sees a pail full of water standing bottom upward without spilling its contents, and men with every semblance of life walking on their heads. It was with apparatus of this kind that the pretended magicians of the Middle Ages wrought many of their miracles, terrifying the uninitiated with sudden apparitions of skulls, drawn swords, skeletons, ghosts, &c.

629. Diverging rays coming from the centre are reflected by a concave mirror back to the same point. Here, as in all other cases, the angle of reflection is equal to the angle of incidence. Striking the surface at right angles, they are reflected at right angles back to the centre.

630. Diverging rays coming from a point beyond the centre, after reflection by a concave mirror, converge to a point on the other side of the centre. In this case, the image is inverted and smaller than the object.

631. REFLECTION BY CONVEX MIRRORS.—In general, the effect of convex mirrors is to make incident rays more divergent or less convergent. The images they produce, like those of plane mirrors, seem to stand behind them, and are generally smaller than the objects they represent.

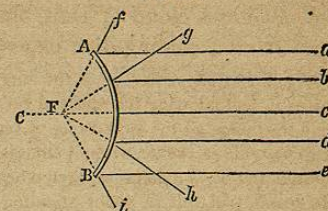
632. Parallel rays striking a convex mirror are made to diverge, as if they proceeded from a point on the opposite side of the mirror, called the Virtual Focus. This point is

principal focus and the centre? What sort of an image is formed? How is the image made more distinct? How may wonderful effects be produced with this mirror? By whom was apparatus of this kind employed? 629. What is the effect of concave mirrors on diverging rays coming from the centre? 630. What is their effect on diverging rays coming from a point beyond the centre? In this case, what kind of an image is produced? 631. What is the general effect of convex mirrors? What is said of the images they produce? 632. What is the effect of a convex mirror on parallel

half way between the mirror and the centre of the sphere which the mirror would form, if it were extended with uniform curvature.

In Fig. 240, let  $AB$  represent a convex mirror forming part of the surface of a sphere, of which  $C$  is the centre. The parallel rays  $a, b, c, d, e$ , diverge after reflection to  $f, g, h, i$ , as if they had come from the virtual focus  $F$  on the other side of the mirror.  $F$  is half way between the mirror and its centre  $C$ .

Fig. 240.



633. Diverging rays falling on a convex mirror are made more divergent by reflection. Converging rays are made less convergent, in some cases even becoming parallel.

### Refraction of Light.

634. When light strikes a transparent body, some of it is reflected and makes the body visible. The rest enters the body, and is partly absorbed and partly transmitted through it. According to the undulatory theory, we should say that some of the undulations that strike the transparent body are reproduced in the same medium with a change of direction, while others are brought to rest within the body, and others again are transmitted through it with certain modifications.

We have treated of that portion of the light which is reflected; we must now look at that which enters the transparent body.

635. When a boy rowing a boat brings his oar into the water, it no longer looks straight, but broken at the point where it enters. The same appearance is presented when he plunges a spoon or cane obliquely in a pail of water. On taking out the oar, the spoon, and the cane, they look perfectly straight again. It is evident, therefore, that the rays coming from the parts

rays? Where does the virtual focus lie? Illustrate the effect of convex mirrors on parallel rays, with Fig. 240. 633. What is the effect of convex mirrors on diverging rays? On converging rays? 634. When light strikes a transparent body, what becomes of it? Express this according to the Undulatory Theory. 635. Give some familiar examples which prove that rays are bent on passing from one medium to an-



immersed are turned from their course on entering the air, so that the points from which they come appear to lie where they do not really lie. Rays thus turned from their course are said to be *refracted*.

636. Refraction is that change of direction which a ray of light experiences on passing obliquely from one medium to another.

For an example, see the ray A in Fig. 241. If there were no water in the vessel, it would go on in a straight line to B; when the vessel is filled, it is refracted to C.

637. That branch of Optics which treats of the laws and principles of refracted light, is called Dioptrics.

638. REFRACTIVE POWER OF DIFFERENT MEDIA.—All media do not have the same refractive power. Rays of light falling from the air on water, alcohol, glass, and ice, are turned from their course in different degrees by each.

A medium that has great refractive power is said to be *dense*; one that has but little, is called *rare*. The terms *dense* and *rare*, therefore, applied to media in Optics, have a different meaning from that which they convey in other departments of Natural Philosophy.

As a general rule, those media are the densest that have the greatest specific gravity; and, of media having about the same specific gravity, the most inflammable is the densest. The following substances are arranged according to their refractive power, chromate of lead, a transparent solid, being the densest:—Chromate of lead, diamond, phosphorus, sulphur, mother-of-pearl, quartz, amber, plate-glass, olive oil, alcohol, water, ice, air, oxygen, hydrogen.

639. LAWS OF REFRACTED LIGHT.—1. *In a uniform medium, there is no refraction. It is only on passing from one medium (or stratum of a medium) to another, that a ray is turned from its course.*

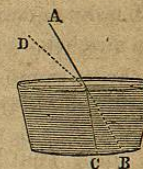
2. *Only such rays as enter a medium obliquely are refracted,—not such as enter at right angles.*

3. *When a ray passes obliquely from a rarer to a denser*

other. What term is applied to such rays? 636. What is Refraction? Illustrate this definition with Fig. 241. 637. What is Dioptrics? 638. What is said of the refractive power of different media? What is a Dense Medium? What is a Rare Medium? What is said of the meaning of the terms *dense* and *rare* in Optics? As a general rule, what media are the densest? Mention some substances in the order of their refractive power? 639. What is the first law of refracted light? The second? The

medium, it is refracted towards a line perpendicular to the surface. In Fig. 241, let the ray A pass from air, a rarer medium, into water, a denser medium, and instead of going on in a straight line to B, it will be refracted to C, nearer the perpendicular.

Fig. 241.



4. *When a ray passes from a denser medium into a rarer, it is refracted from the perpendicular.* In Fig. 241, let the ray B pass obliquely from water into air, and instead of going on in a straight line to A, it will be refracted to D, farther from the perpendicular.

640. An interesting experiment which every pupil may perform for himself, admirably illustrates refraction, and proves the last law to be true. Place a coin on the bottom of an empty vessel (see

Fig. 242.



Fig. 242), and fix the eye in such a position that it just misses seeing it on account of the vessel's side coming between. Keep the eye there, and let water be poured in; the coin will then become visible, the rays from its surface being refracted so as to meet the eye. The coin will appear to lie at N, some distance above the bottom of the vessel; because the rays from it that last meet the eye, if continued in straight lines, would go on to that point.

The change caused by refraction in the apparent position of an object often misleads persons standing on the bank of a sheet of water as to its depth. Objects on the bottom seem to be several feet nearer the surface than they are, and bathers, deceived by the appearance, venture beyond their depth and are drowned.

641. ATMOSPHERIC REFRACTION.—Rays from the heavenly bodies, on entering our atmosphere obliquely from a rarer medium, are refracted towards the perpendicular. Hence we never see these bodies in their real position, except when they are directly over head.

The sun is visible to us some time before he really rises above the horizon, and remains visible at night after he has sunk below it. We owe our twilight to successive reflections and refractions of his rays by atmospheric strata of different densities, after he has disappeared.

third? The fourth? Illustrate the third and the fourth law with Fig. 241. 640. What interesting experiment illustrates refraction? How are persons standing on the bank of a sheet of water often deceived? 641. When do we see the heavenly bodies in their real position? Why, at other times, do we not see them in their real position?



642. *Mirage*.—Different strata of the atmosphere differ in their refractive power. Accordingly, rays from an object below the horizon (that is, concealed from us by the roundness of the earth) may, under peculiar circumstances, by successive refractions through different strata, be made to describe a curve to our eyes, and will in that case appear to come from a distant point in the air lying in the direction of the line described by the ray as it entered the eye. Such is the origin of the phenomenon called *Mirage* [*me-rahzh*].

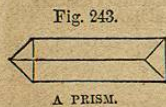
Mirage is the appearance in the air of an erect or inverted image of some distant object which is itself invisible. It is most frequently seen on the water, but has also appeared to persons travelling through deserts, with such vividness as to make them believe that they saw trees and springs before them in the distance.

Mirage is sometimes remarkably distinct at sea. Captain Scoresby, on one occasion, in a whaling-ship, recognized his father's vessel, when distant from him more than 20 miles (and consequently below the horizon), by its inverted image in the air, though he did not previously know that it was cruising in that part of the ocean. Another notable case occurred on the coast of Sussex, England. Cliffs were distinctly seen in the air; and the sailors, crowding to the beach, recognized different parts of the French shore, distant from 40 to 50 miles. These phenomena are comparatively frequent in the Strait of Messina, and as there exhibited have been called *Fata Morgana* [*fah'-tah mor-gah'-nah*].

643. REFRACTION BY PRISMS AND LENSES.—Prisms and lenses are much used in experimenting on light and in the construction of optical instruments.

Fig. 243. 644. *Prisms*.—A Prism (see Fig. 243) is a solid piece of glass, having for its sides three plane surfaces and for its ends two equal and parallel triangles.

645. A ray of light falling on a prism must pass through two of its surfaces. If it strike both of them obliquely, it

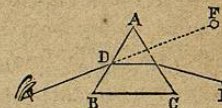


To what do we owe our twilight? 642. Explain how an object below the horizon is rendered visible. What phenomenon is thus produced? What is *Mirage*? Where is it seen? What case of mirage is recorded by Captain Scoresby? What other notable case is mentioned? Where are these phenomena frequent? 643. What are much used in experimenting on light? 644. What is a Prism? 645. What is the effect of

will be twice refracted; if it strike one surface perpendicularly and the other obliquely, it will be refracted but once. In either case, the object from which it comes will appear to lie in a position more or less removed from its real one.

Fig. 244 shows the refractive effect of a prism. A ray from E, entering the prism ABC, from air, a rarer medium, is refracted to D, and on passing back into the rarer medium, at that point is refracted to the eye. The object from which it comes appears to lie at F, in the direction from which the ray entered the eye. Had there been but one refraction, it would still have appeared elevated above its real position, but not so much.

Fig. 244.



646. *Lenses*.—A lens is a transparent body which has two polished surfaces, either both curved or one curved and the other plane. The general effect of lenses is to refract rays of light, and magnify or diminish objects seen through them. They are generally made of glass; but in spectacles rock crystal is sometimes used instead of glass, because it is harder and less easily scratched.

647. *Classes of Lenses*.—Lenses are divided into six classes according to their shape. Fig. 245 shows these six classes. The name of each is given on one side, and a description of it on the other.

Fig. 245.

DOUBLE CONVEX LENS.		Both sides convex.
PLANO-CONVEX LENS.		One side convex, the other plane.
MENISCUS.		{ One side convex, the other concave. Thickest in the middle.
DOUBLE CONCAVE LENS.		Both sides concave.
PLANO-CONCAVE LENS.		One side concave, the other plane.
CONCAVO-CONVEX LENS.		{ One side concave, the other convex. Of uniform thickness, or thickest at the ends.

a prism on a ray of light? Show this effect with Fig. 244. 646. What is a lens? What is the general effect of lenses? Of what are they made? 647. Into how many classes are lenses divided? Name them. Describe the Double Convex Lens. The Plano-convex. The Meniscus. The Double Concave Lens. The Plano-concave.



The first three of the above lenses, which are thickest in the middle, are called Convex Lenses, and their effect is to make rays passing through them incline more towards each other. The next two (the double concave and plano-concave) which are thinnest in the middle, are called Concave Lenses, and their effect is to make rays passing through them incline farther from each other.

The concavo-convex lens, when its two surfaces are parallel (as in the above Figure) does not change the direction of rays passing through it, for the convergent effect of the convex surface is nullified by the divergent effect of the concave surface. When the convex surface has a greater curvature than the concave, this lens becomes a meniscus. When the concave surface has the greater curvature, it becomes a concave lens, and participates in the properties of that class.

648. *Refraction by Convex Lenses.*—The general effect of convex lenses is threefold:—1. They make rays passing through them incline more towards each other than before. 2. They enable us to see objects which are invisible to the naked eye on account of their distance. 3. They magnify objects seen through them.

649. A double convex lens of glass, with sides equally convex, brings parallel rays passing through it to a focus at the centre of the sphere, of which the surface of the lens first struck by the rays forms a part. This is shown in Fig. 246. Converging rays would be brought to a focus between the centre and the lens; diverging rays, on the other side of the centre.

Fig. 246.

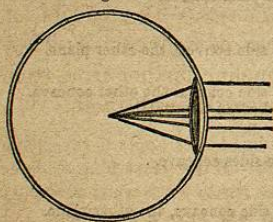
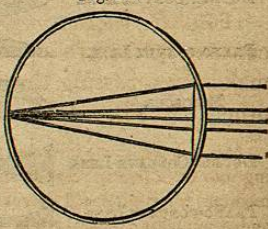


Fig. 247.



The Concavo-convex. What are the first three of these lenses called? What is their effect? What are the double concave and the plano-concave lens called? What is their effect? What is the effect of the concavo-convex lens, when its two surfaces are parallel? When the convex surface has a greater curvature than the concave? When the concave surface has a greater curvature than the convex? 648. What is the general effect of convex lenses? 649. What is the effect of a double convex glass lens on parallel rays passing through it? On converging rays? On diverging rays?

A plano-convex lens brings parallel rays to a focus at a distance from the lens about equal to the diameter of the sphere of which the convex surface of the lens forms a part. This is shown in Fig. 247.

650. Convex lenses collect heat as well as light at their focus. Hence they are sometimes called Burning Glasses. Hold an old person's eye-glass in the sun-shine a short distance from your hand. A bright spot of light marks the focus, and the heat at that point soon becomes too great to be borne. All the rays that fall on the surface of the lens being concentrated in this one point, *the heat at the focus is as many times greater than the heat of ordinary sun-light as the area of the lens is greater than the area of the focus.* If the area of the lens be 100 square inches, and that of the focus  $\frac{1}{4}$  of an inch, the ordinary heat of the sun will be increased 400 times.

651. The second effect of convex lenses follows from the first. Light, it will be remembered, diminishes in intensity according to the square of the distance from the luminous body; hence rays from exceedingly remote stars become so faint by the time they reach the eye as not to produce the sensation of vision. A convex glass concentrates a great number of these faint rays, and thus renders the distant object visible to an eye placed at its focus.

652. The third effect of convex lenses is to magnify objects seen through them. Hence they are sometimes called Magnifying Glasses. The glasses used by old persons, as well as by engravers and others who have to deal with minute objects, are convex lenses.

653. *Refraction by Concave Lenses.*—The effects of concave lenses are opposite to those of convex. 1. They make rays passing through them incline farther from each other. 2. They diminish objects seen through them.

654. All the above laws relating to prisms and lenses apply to rays passing into them from a rarer medium, such as air. If they come from a denser medium, the results will be reversed,—convex lenses will have a diverging and diminishing effect, while concave lenses will have a converging and magnifying effect.

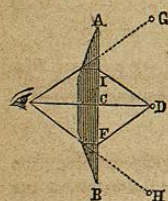
What is the effect of a plano-convex lens on parallel rays? 650. What are convex lenses sometimes called, and why? How may their concentration of heat be shown? How does the heat at the focus compare with that of ordinary sun-light? 651. Show how a convex lens enables us to see distant heavenly bodies that would otherwise be invisible. 652. What is the third effect of convex lenses? What are they sometimes



655. *Glasses with Parallel Surfaces.*—When rays pass through a refracting medium having parallel surfaces, they leave it, not exactly in the same line, but in a direction parallel to that in which they entered it. The last refraction nullifies the change of direction produced by the first. Hence we see objects through a pane of window-glass very nearly in their real position. Irregularities in the glass cause objects seen through it to look distorted.

656. *The Multiplying Glass.*—If a plano-convex lens have its convex surface ground into several flat surfaces, an object seen through it will be multiplied as many times as there are flat surfaces.

Fig. 248.



THE MULTIPLYING GLASS.

In Fig. 248, A B represents a multiplying glass, and D an object viewed through it. The ray D C, striking both surfaces perpendicularly, reaches the eye without refraction; but D I and D F, falling obliquely, suffer two refractions, which bring them also to the eye at the focus. As objects are always seen in the direction in which their rays enter the eye, three objects like D will be visible: one at D, in its real position; the others, in the direction of the dotted lines, at G and H.

657. **DOUBLE REFRACTION.**—Certain substances (chiefly minerals) have the property of causing rays which pass through them to take two distinct paths, and thus produce two images. This phenomenon is called Double Refraction.

Fig. 249.



A crystal of carbonate of lime, commonly called Iceland Spar, is one of the best substances for exhibiting double refraction. Let it be placed over a piece of paper containing lines, and each line will be seen double, as shown in Fig. 249.

Keeping the same side on the paper, and turning the crystal round on its axis, we find that the double lines continue parallel, but that the distance between them varies,—diminishing till they coincide, then increasing; then diminishing till they coincide again, and then once more increasing in consequence? 658. What are the general effects of concave lenses? 654. In what case do the above laws relating to prisms and lenses apply? Suppose the rays pass into them from a denser medium, what will be the result? 655. What effect has a refracting medium with parallel surfaces on incident rays? How do we see objects through a pane of window-glass? 656. How is the multiplying glass formed? How many times is an object seen through it multiplied? Show this with Fig. 248. 657. What is Double Refraction? How is it exhibited with Iceland spar? What phe-

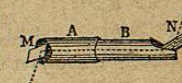
ing. During each revolution of the crystal, the lines will coincide twice. A single pencil of rays is thus refracted into two distinct pencils, one of which, following the usual law of refraction, is called the Ordinary Pencil, while the other, deviating from that law, is called the Extraordinary Pencil.

### Polarization of Light.

658. Light is said to be *polarized*, when, on being reflected or refracted by a surface which it strikes at a certain angle, it is absorbed by a similar surface perpendicular to the former one, though it is reflected or transmitted by one forming any other angle with it.

Let A and B (Fig. 250) be two tubes open at both ends, and so adjusted to each other that B turns stiffly within A. In each tube fix a piece of polished glass, M, N, roughened and blackened on the back, so as to form an angle of 33 degrees with the axis of the tubes. Bring the instrument into such a position that the light from a luminous body, falling on M, may be reflected along the axis and strike N. Now, keeping the tube A stationary, turn within it the tube B, carrying the reflector N. The reflection from N, if observed, will be seen to keep varying in intensity. In the two positions in which N is parallel to M, the reflection will be brightest; at the points midway between these,—that is, when N is perpendicular to M,—there is no reflection at all. We express this by saying that the light reflected from M is *polarized*.

Fig. 250.



659. The polarizing angle,—that is, the angle which the incident ray must make with a perpendicular to the first reflecting surface, in order to be polarized,—is different in the case of different substances. For glass, it is about 57 degrees.

660. If a polarized ray be received on a crystal of Iceland spar, there will be but a single refraction.

661. Light is polarized by reflection at a certain angle, as we have just seen; by transmission through substances that have the property of double refraction,—through some imperfectly crystallized substances, such as agate, mother-of-pearl, &c.,—and also through a sufficient number of uncrystallized plates. However produced, polarized light always has the same properties. Its phenomena are striking, and seem to prove the truth of the undulatory

nomena are presented as the crystal is turned around? What are the two pencils presented to the eye called? 658. When is light said to be polarized? Illustrate the polarization of light with Fig. 250. 659. What is meant by the polarizing angle? What is this angle in the case of glass? 660. If a polarized ray is received on a crystal of Iceland spar, what follows? 661. Mention the different ways in which light is polarized. What is said of the properties and phenomena of polarized light, how-

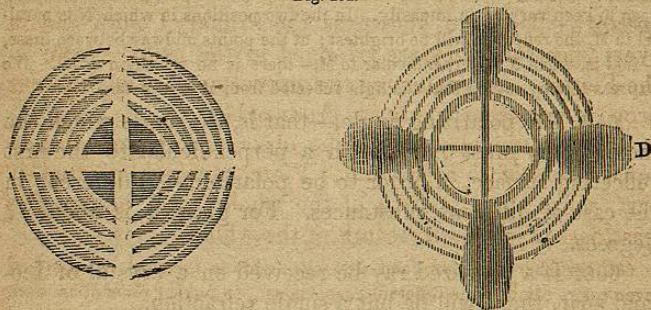


theory. It is thought that the undulations of ether ordinarily take place in planes perpendicular to the direction in which they are propagated; but that, when light is polarized, they take place in planes parallel to this direction. At certain angles, the undulations, thus changed from their usual direction, are reproduced or transmitted by the second reflecting or refracting surface, and reach the eye; but, when the two surfaces form an angle of 90 degrees, they are stopped, and the sensation of vision is not produced.

662. The mineral called Tourmaline [*toor'-ma-leen*] possesses the property of polarizing light in a high degree. It is cut into plates one-twentieth of an inch thick, which are fixed between plates of glass for convenience of use. If we look at the sun through such a plate, we shall find that most of the light is transmitted. Place a second plate behind the first and parallel to it, and the light will still be transmitted; but turn the second plate so as to bring it at right angles to the first, and no light will pass through.

663. Some crystals viewed by polarized light, exhibit systems of beautiful rings, like those shown in Fig. 251. Plates of the mineral called Selenite,

Fig. 251.



bearing different designs, placed so as to be seen by polarized light, display the most gorgeous coloring, and may be made to undergo remarkable and beautiful changes by causing one of the reflecting surfaces to revolve.

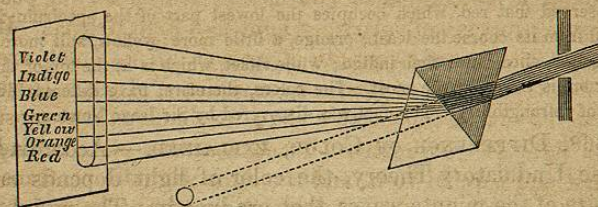
#### Chromatics.

664. Chromatics is that branch of Optics which treats of colors.

ever it is produced? Explain the polarization of light according to the undulatory theory. 662. What mineral possesses the property of polarizing light in a high degree? How is tourmaline prepared? What experiment may be performed with tourmaline plates? 663. What phenomena are seen when certain crystals are viewed

665. THE SOLAR SPECTRUM.—If a ray from the sun be admitted into a dark room through a small aperture, it will form a circular spot of white light on the surface receiving it. But if, after entering the room, it be received on a prism, as shown in Fig. 252, it will be decomposed into

Fig. 252.



THE SOLAR SPECTRUM.

seven different colors. When made to fall on a white surface, these seven colors are distinctly seen, covering an oblong space, which is called the Solar Spectrum (plural, *spectra*). They are known as the Primary Colors, and in every spectrum they are arranged in the order shown in the Figure. By combining the primary colors in different proportions, other colors are produced.

The seven colors, it will be observed, do not occupy equal spaces of the spectrum. Violet covers the greatest part, more than one-fifth of the whole; and orange the least, less than one-thirteenth of the whole.

666. Ordinary sun-light (and all white light) is therefore composed of seven colors combined in different proportions. In further proof of this, we may re-unite the seven primary colors of the spectrum, and we shall have simply a small circular spot of white light. To re-unite the colors, we may receive the spectrum on a concave mirror or double convex lens, which brings together at its focus the parts of the decomposed ray. Or, we may receive the spectrum on another prism placed in contact with the first, as shown in Fig. 252. In either case, we have the same circular spot of white light that would have been formed if the ray had not been decomposed at all.

by polarized light? When plates of selenite are viewed by polarized light? 664. What is Chromatics? 665. Describe the solar spectrum, and the way in which it is formed. Name the seven primary colors in order. How are the other colors produced? Which color occupies most of the spectrum, and which the least? 666. Of what, then, is all white light composed? What further proof have we