SCIENTIFIC AMERICAN

[Entered at the Post Office of New York, N. Y., as Second Class Matter.]

A WEEKLY JOURNAL OF PRACTICAL INFORMATION, ART, SCIENCE, MECHANICS, CHEMISTRY, AND MANUFACTURES.

Vol. LV.—No. 1. [NEW SERIES.] NEW YORK, JULY 3, 1886. [Price 10 Cents. $3.00 per Year.

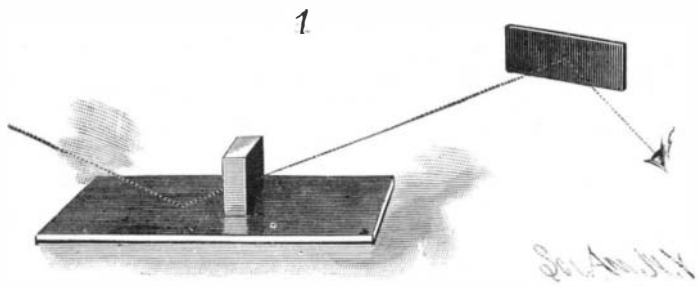
SIMPLE EXPERIMENTS IN POLARIZED LIGHT.

BY GEO. M. HOPKINS.

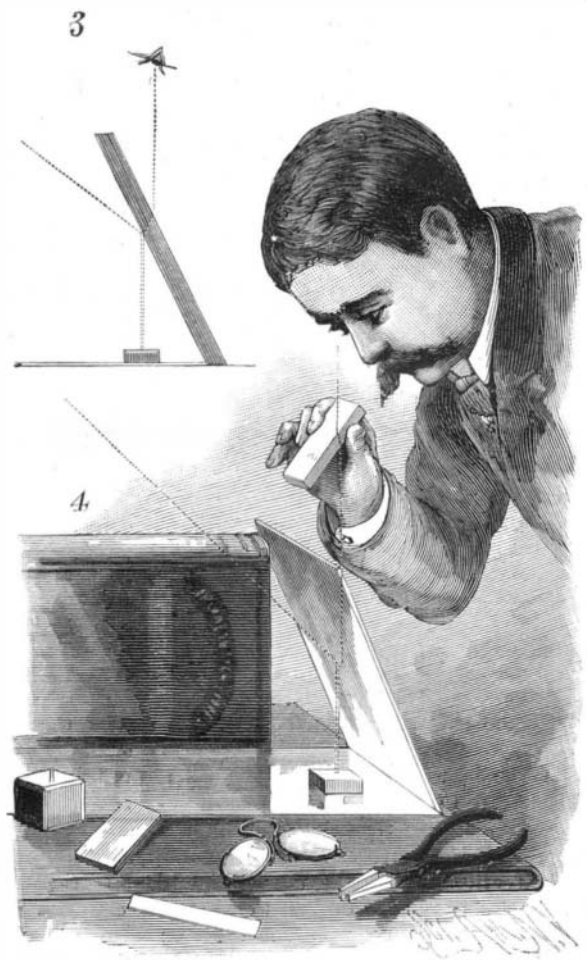
I.

It is ever a source of pleasure to the student of science to be able to explore an unfamiliar realm by means of commonplace and readily accessible things, which, if not already possessed, may be had almost for the asking.

There is scarcely a branch of scientific research more prolific in the development of expensive apparatus than that of light, yet there is nothing in the domain of physics capable of being better illustrated by apparatus of the most simple and inexpensive character. The subject of polarized light, as intricate and difficult as it may at first appear, may be illustrated by apparatus costing less than a dime, in a manner that can but excite the wonder and admiration of one inexperienced in this direction.



POLARIZATION BY REFLECTION FROM BLACKENED GLASS.



SIMPLE FORM OF NORREMBERG DOUBLER.

A small piece of window glass and a black covered book constitute the apparatus for beginning the study of this interesting subject, and with a glass bottle stopper, a glass paper weight, or a piece of mica, the effects of polarized light may at once be shown.

The book is placed horizontally near a source of light, such as a window or a lamp, so that a broad beam of light will fall obliquely on it, and upon the book is placed the object to be examined, which may be either of those named.

Now, by viewing the reflected image of the object in the piece of window glass, with the glass arranged at the proper angle, it is probable that colors will be seen in the object. If no colors appear, it is due to one of three causes: either the object is incapable of depolarizing the light polarized by reflection from the book cover, or it is too thick or too thin to produce interference phenomena, or the eye of the observer and the glass employed for the analyzer are not in a correct position relative to the object and the polarizer (the book cover).

The glass, if thoroughly annealed, will produce no effect on the polarized beam, but most thick pieces of glass, such as paper weights, ink stands, heavy glass bottle stoppers, and the like, are either unannealed or only partly annealed, and are thus under permanent strain, which is readily indicated by their action on polarized light. A plate of mica of suitable thickness exhibits bright colors when examined by polarized light, particularly when the plate is either bowed or inclined.

To render the polariscope thus described more efficient, a plate of glass may be placed on the book, when the superior reflecting surface will at once make itself manifest in the increased brightness of the colors and improved definition of the object. A still greater improvement may be made by blacking one side of each glass with asphaltum varnish or any other convenient black varnish or paint, using in the experiments the unblackened surfaces, as shown in Fig. 1.

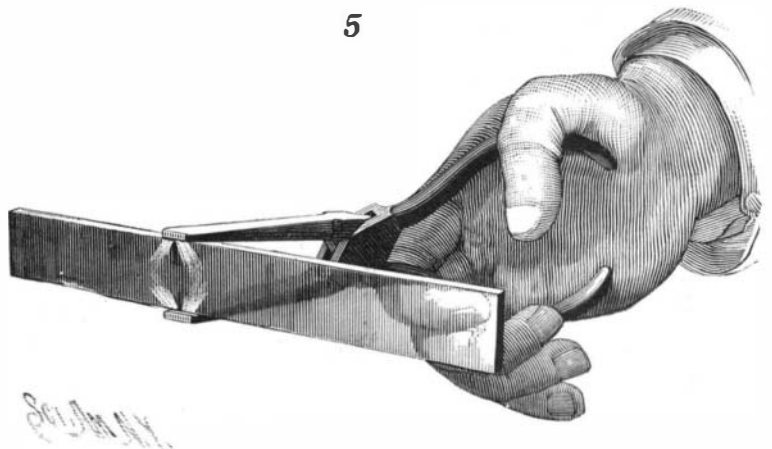
The angle which the incident light beam should make with the polarizer or horizontal blackened plate is 35° 25′, and the polarized beam should strike the analyzing plate at the same angle, to secure the maximum effects; but it is unnecessary to measure the angles, as they may be easily determined by the appearance of the object.

With the two plates of blackened glass much may be learned with regard to the properties of polarized light. Plates of mica of various thicknesses and forms, inclined at various angles, bowed and turned in their own planes, pieces of quartz, bodies of glass such as those already mentioned, and odd-shaped pieces of unannealed glass such as may be picked up at glass works, are easily secured objects. Brazilian pebble spectacle lenses often show gorgeous colors when turned at different angles in the beam of polarized light.

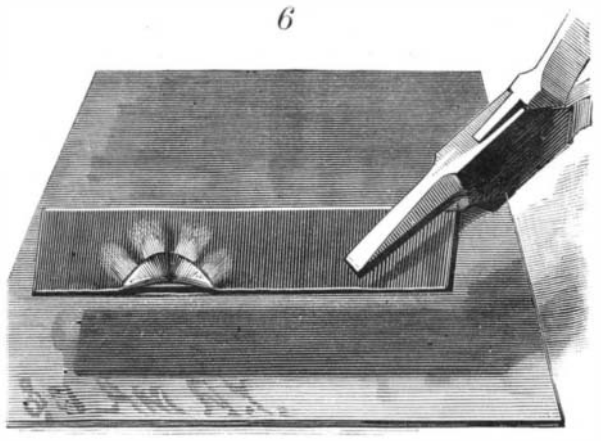
The writer well remembers the smiles provoked among the storekeepers when he visited various stationery and fancy goods establishments, armed with a Nicol prism, in quest of objects for the polariscope. As one article after another was placed upon a dark covered book, and examined with the prism, the writer imagined he could vaguely hear such words as Ward's Island, asylum, etc., and at this stage, as a matter of policy, the purchases were generally made, for sanity was at once established when the dealer examined the articles for himself with the Nicol, and the price of certain glass objects immediately advanced.

Seeing their own wares by polarized light, for some of the dealers, at least, was a new experience.

The best position for the polarizing plate is near a window, with the broad light of the clear sky shining upon it.



GLASS STRAINED BY PRESSURE.

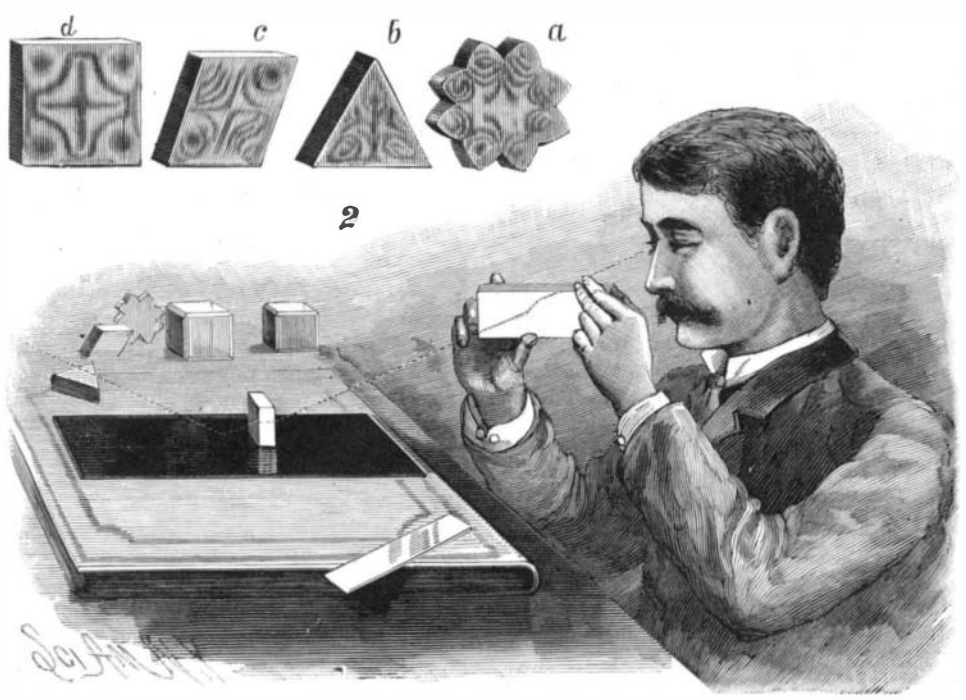


GLASS STRAINED BY HEAT.

By turning the analyzing plate on the axis of the light beam, some curious effects may be observed. When the plates are at right angles with each other, the polarized beam will be nearly quenched,* and when they are parallel with each other the reflection of the sky will be quite bright.

The employment of a blackened glass reflector for an analyzer is attended with some difficulty, on account of the necessity of changing the position of the eye for each new position of the analyzer. A bundle of six or eight plates of ordinary glass is more convenient, but not quite as efficient. These plates will be used as shown in Fig. 2, the light passing through them to the eye instead of being reflected. The plates may be turned at any angle without changing the position of the eye.

(*Continued on page 6.*)



ANALYZATION BY BUNDLE OF GLASS PLATES AND VERRE TREMPE.

* With black glass reflectors employed as polarizer and analyzer, the extinction of the light is not quite complete, even when they are arranged accurately at the polarizing angle. See paper on "Polarized Light" in SUPPLEMENT 538.

SIMPLE EXPERIMENTS IN POLARIZED LIGHT.

(*Continued from first page.*)

The most perfect analyzer, however, is the Nicol prism.* A very small one will answer perfectly for this class of experiments, and is not expensive. But to return to our experiments; when the analyzer and polarizer are crossed and the field is dark, if a few pieces of mica of various thicknesses and shapes are held between the analyzer and the black glass plate, and bowed and inclined at different angles, a great variety of tints will be observed, and if held in one position while the analyzer is turned, another effect will be noticed.

Among the objects which may be examined in this way are the paper weights, stoppers, and other thick, partly annealed pieces of glass, a piece of glass held edgewise in a hand vise or pair of pliers and put under compression, as shown in Fig. 5. A piece of glass held edgewise for a moment in a small gas or candle flame, and then placed in the polarized beam, shows the strain by a light figure, like that represented in Fig. 6, or it may assume other forms, according to circumstances. As the glass cools, the figure fades away.

Small glass squares and triangular and diamond-shaped plates, about three-quarter inch across, suspended by a fine wire in the flame of a Bunsen burner or alcohol lamp until their corners begin to fuse, and then cooled in air, become permanently strained, and exhibit symmetrical figures formed of dark and light

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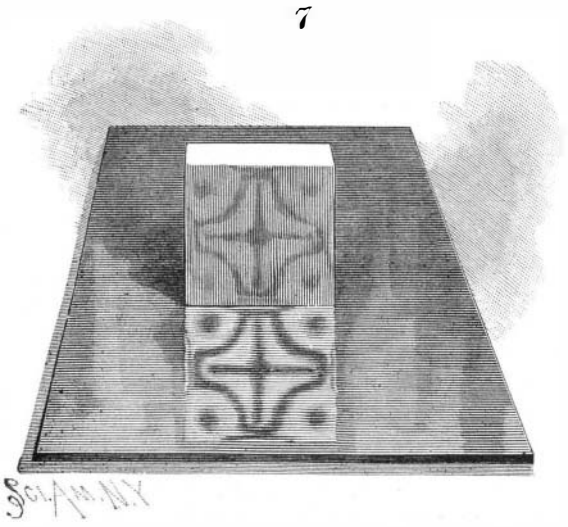

DOUBLE POLARIZATION WITH SINGLE GLASS PLATE.

spaces, but show little color on account of their thinness. By superposing several such plates, color effects may be seen.

The beautiful *verre trempe*, or strained glass blocks, a few examples of which are represented at *a*, *b*, *c*, *d*, in Fig. 2, are similar in character to what has just been described. They vary in thickness from one-fourth inch to one-half inch, and even thicker. They are expensive objects, but exceedingly beautiful and interesting.

In Fig. 3 is shown a method of polarizing and analyzing with a single bundle of plates. It is, in principle, a Norremberg doubler. The light strikes the under surface bundle of plates at the polarizing angle, and is reflected downward in a polarized state, passing through the object which rests upon the horizontal silvered mirror. It is then reflected back through the object, and passes through the bundle of plates to the eye of the observer; the plates, as before stated, serving to analyze the polarized beam.

A Norremberg doubler, which answers a good purpose, may be made by leaning a clear plate of glass upon the edge of a book, over a piece of ordinary looking glass, and employing a bundle of glass plates as an analyzer, as shown in Fig. 4. Here the polarization is effected by the single plate of glass, and the analyzation by the bundle of plates held in the fingers. Equipped with this instrument, the student of polarized light may proceed a long way with his investigations.

In this intrument the objects to be examined are laid upon the horizontal mirror, and the inclined plate is arranged with reference to the light so that it will reflect the broad light of the sky downward. The position of the single plate and bundle of plates may be varied to secure the best effects.

In Fig. 7 is shown an arrangement by which the object and the blackened glass both act simultaneously as polarizer and analyzer. By placing a specimen of *verre trempe* edgewise on the blackened glass, as shown in the engraving, the light, striking the strained glass at about the polarizing angle, is reflected from the back surface of the glass and partly polarized. The beam thus polarized is reflected downward obliquely, and at the same time depolarized by the strained body of the glass; it is reflected upward to the eye and analyzed by the blackened glass mirror, thus producing an image which is apparently below the surface of the mirror. The image seen in the *verre trempe* itself is produced by the reverse of what has just been described. The light is polarized and reflected by the black glass mirror, and passes through to the back surface of the *verre trempe*, which reflects it back through the body of the glass; the glass then acts as both object and analyzer.

When the polarizer, analyzer, and object are each movable, different effects will be produced by rotating any of them. As a means of exhibiting complementary colors, nothing can excel the polariscope, as the colors produced in the successive changes resulting from turning the analyzer or polarizer are exactly complementary to each other. Little has been said about theories. The writer's object is to interest the reader in polarized light sufficiently to induce him to study the literature of the subject.

* For description see SUPPLEMENT 538.

House Bill 4458.

The Patent Bar Association of Chicago have sent to Congress the following petition, which very ably sets forth the serious objections to the above bill, to which we have heretofore called the attention of our readers:

Whereas, It is the sense of the "Patent Bar Association," of Chicago, Ill., composed of patent lawyers representing varied and diverse interests dependent upon letters patents for inventions, that the "Townsend" bill (No. 4458), now pending in the House of Representatives, is unconstitutional, inherently and radically wrong in principle, and calculated, if it becomes a law, to work great hardship and injustice to meritorious inventors, in the following particulars, to wit:

First.—In that, by not excepting from the operation of the bill patents heretofore granted, it directly interferes with and takes away rights already vested under said patents.

Second.—In that it deprives inventors of the exclusive rights to their discoveries or inventions, contrary to the provisions of Section 8 of Article 1 of the Constitution of the United States.

Third.—In that its provisions are so vague and ambiguous that it will enormously multiply litigation, and will for several years render it impossible to determine what are the legal rights and remedies of the owners of letters patent.

Fourth.—In that it is "class" legislation as against the products of the brains of inventors, while the exclusive rights of authors are fully protected by the laws of Congress.

Fifth.—In that it takes away the jurisdiction of the Circuit and District Courts of the U. S., in suits for infringement of patents involving less than $200, without designating any tribunal for the hearing and adjudicating thereof, thereby depriving patentees having small claims of any remedy, legal or equitable.

Sixth.—In that its provisions are a direct temptation and incitement to fraud as to knowledge or notice of the grant of letters patent for invention, and in permitting an infringing purchaser for use, whose wrong is begun innocently, to continue the same deliberately, after notice during the life of the patent; and,

Seventh.—In that it extends to infringing manufacturers, who are supposed to engage in business deliberately and with their eyes open, the same privileges and exemptions as are extended to innocent purchasers buying in open market; therefore, be it

Resolved, That this Association respectfully and earnestly petitions Congress not to pass said bill—H. R. 4458.

Resolved, That our Senators and Representatives in Congress are respectfully requested to oppose the passage of said bill. J. M. THACHER, *President.*

E. S. EVARTS, *Secretary.*

The Making of Rubber Stamps.

The wording of the desired rubber stamp having been correctly set up in ordinary type, the same is locked up and placed upon a level support. Around it is put an iron frame, which will determine the shape and size of the matrix.

By means of a soft brush, the type as well as all surrounding parts, that are to be covered by the plaster of Paris, are well oiled.

For the purpose of making the cast, finely ground fresh plaster of Paris is needed; if of long standing, the same will lose its desirable properties. This plaster of Paris, of which a sufficient quantity should at one time be mixed to the consistency of pap, using clear water, is poured over the frame containing the type in a thin layer, so as to barely cover it. With a stout brush the mixture is driven into all spaces and interstices, until all details are thoroughly covered. After this the remaining pap of plaster of Paris is added until the frame is filled to overflowing. The surface is smoothed down, after the plaster has settled somewhat, and in a short while the matrix in the frame may be removed from the type.

After this it becomes necessary to bake the matrix in an oven for a period of from four to six hours. When thoroughly baked, the matrix should be well brushed with a thin solution of shellac to impart a smooth surface, and at the same time greater strength.

The matrix, at this stage, represents a yellowish-white block, in which the lettering appears indented, but in proper place. The indentation corresponds to the height of the letter upon the piece of type or the marks upon a cut, while the remaining parts should be perfectly smooth and free from holes. This matrix, obtained by a coating from the type or cut, will serve as the mould for the final rubber stamp.

Pieces of caoutchouc are cut to the required size and laid upon the matrix. If pressure is now exerted, the soft mass will adjust itself to fill all the spaces and reproduce the mould inverted. Indentations become raised matter, and the whole will show as did primarily the type.

But as the caoutchouc has a tendency to return to its previous shape, it becomes necessary to apply the process called vulcanizing. The object is to impart hardness to the rubber, and to prevent its losing the form into which it has been pressed.

To accomplish this, the caoutchouc must be heated to a temperature of from 120 to 130 deg. C. As the substance is ordinarily softened by heat, it is necessary to take some means to prevent it from sticking to the mould. For the purpose soapstone will answer, and the mould, as well as the piece of caoutchouc, should be well brushed or dusted with this substance.

The duration of the heating varies with the thickness of the rubber sheet. As a general thing, from 20 to 30 minutes ought to be sufficient. It may be mentioned here that special apparatus has been constructed for pressing and vulcanizing. The proper vulcanization is of the greatest importance in determining the durability of the stamp.

All that remains to complete the stamps is the mounting of the rubber plate upon a suitable base or handle. This is best done either with zinc or with a solution of caoutchouc in benzine. The surface of the handle, as well as the back part of the stamps, having been covered with such a solution and well pressed together, after drying the entire stamp will be ready for use.—*Amer. Lith. and Printer.*

Compensating Pendulums.

At a recent meeting of the Royal Astronomical Society, London, Dr. Leonard Waldo, of Yale College, described an escapement for clocks of precision, with which he had been making experiments. He said there are several obscure sources of error in the rate of clocks, which have not been properly investigated. It is ordinarily assumed that the pendulum swings in a plane; but this is never actually the case. There is always some deviation from the plane, as maybe shown by fixing a reflector on to the pendulum rod, and observing a reflected light on the cross wires of a telescope as the pendulum swings. Then there is always some mobility about the support, which, if the pendulum is heavy, may be a serious cause of error. Then the coefficient of elasticity of the suspension spring is always changing with the temperature. I have found the best results with a very firm and specially built stone arch between two piers, like the piers of a transit instrument, from which to suspend the pendulum. I have had to discard the use of a glass rod and glass jar for mercury, on account of the difficulty of getting a straight uniform rod or an accurate cylinder to contain the mercury; and we have fallen back on the use of a steel jar and steel rod, which, though they are subject to greater expansion, can be accurately turned. I have had to reject altogether zinc and steel gridiron pendulums, on account of their tendency to warp. There is an uncertainty about such pendulums which is totally unexplained. I use a weight of from 45 to 60 pounds of mercury, properly freed from oxide, which is another source of change of rate. The escapement I have used is a modified form of the Denison gravity escapement, which does not want any great amount of power to drive it.

Mr. Buckney said: I should like to make a few remarks on what Dr. Waldo has said, for his experience does not agree with mine. First, as to the mercurial pendulum being better than the zinc and steel compensating pendulum. I much prefer the zinc and steel, especially for large pendulums, for a change of temperature does not act immediately; and with the mercurial pendulum, the rod takes up the new temperature, while only the outside of the mercurial jar is heated, and until the whole of the mercury in the jar is heated the clock will lose. I have made some experiments as to this, and found that a mercurial jar of 2 in. in diameter, which is the ordinary size used, when exposed to a change of temperature of 30°, takes a whole day to steady itself. A jar of 3 in. in diameter took between two and three days to compensate itself. I do not understand why; but the increase of temperature took about double the time to show its effect that the cooling did. With a zinc and steel pendulum the bob can be suspended from its center so as to eliminate all errors due to the expansion of the bob itself, so that the expansion of a large mass need not be considered.

Mr. Inwards: There seems to me to be another objection to the mercurial pendulum which has not been referred to—the mercury, being liquid, always flops about to a certain extent, which must be equivalent to so much friction.