PRACTICAL EXPERIMENTS IN MAGNETISM, WITH SPECIAL REFERENCE TO THE DEMAGNETIZATION OF WATCHES.—No. 2.

BY ALFRED M. MAYER.

Experiments which show Something about the Nature of a Magnet.—Take the piece of steel wire, six inches long and one sixteenth of an inch in diameter, mentioned among the articles required in our experiments; score this piece of wire at short distances apart, by filing it around with a sharp file. Now heat the wire to a cherry red, and then plunge it vertically into water. It will now be quite hard, and may be readily made into a magnet by drawing it over the pole of your rat tail file magnet. Paste a small piece of paper around one of the ends of the steel wire before you magnetize it, and then, if you draw the wire over the N. pole of the magnet, from the papered end to the unpapered end, the papered end of the wire will have north polarity, as may be shown by applying the wire to the magnetometer. The magnetic condition of the wire having been found out, we begin by snapping the wire into small pieces, which is readily done, for the scores on the wire determine where it will break. Place each piece on the table as it is separated from the wire, and with its ends pointing in the same direction which they had when it formed part of the wire. Examine each of these pieces in succession. They will be found to be perfect magnets, with N. poles turned all one way, their south poles turned in the other direction. This examination may be made by means of the magnetometer. The fact that each piece is a magnet may also be readily shown by rolling it in iron filings, when it will be found that the filings adhere to the ends of the piece of wire just as they did to the large magnet. See Fig. 11.

23.

Fig. 23 gives a view of the pieces of wire placed end to end just in the position they had when they formed parts of the steel wire. We see that each piece is a perfect magnet, and that the north poles of these pieces all point to the right and their south poles all to the left. But each of these little fragments may be broken into two, and so on; and as far as the subdivision may be carried, it has been found that each minute fragment is a perfect magnet, with one of its ends a south, and the other a north magnetic pole. In imagination we may conceive of this subdivision carried so far that one of the particles thus reached may be invisible to the unaided eye. Indeed, nothing prevents us from logically assuming that even if a molecule of the steel should be reached it would be found to be a perfect magnet.

An Experiment with a Magnet formed of Steel Filings Packed in a Paper Cylinder, is interesting when studied in connection with the experiments just made, and will serve to give us further information as to the nature of a magnet.

Take a piece of letter paper, and having wrapped it several times around a lead pencil, paste the free edge of the paper on to that wrapped around the pencil. After the paste has dried you may draw out the lead pencil, and you will then have a tube made of paper. Cork one end of this tube, or you may close it by doubling over the paper at its end and gluing. Fill this tube with steel filings, and then close the other end of the tube. This tube, filled with steel particles, may be formed into a magnet by drawing it over the pole of your rat-tail file magnet. After you have performed this operation several times, present the tube to the magnetometer, and you will find one of its ends is a north, while the other is a south pole. Having thus satisfied yourself that it is really a magnet, shake the tube so that the positions of the particles of steel filings are changed. On testing the tube at the magnetometer it will be found that much, probably all, of its magnetism has gone from it. If it has not all disappeared it can be made to do so by repeated shaking of the tube. This experiment shows that not only must each particle or even molecule of a steel bar be a perfect magnet, but it also shows that these magnetized particles must be arranged in a definite order, that is, with all their N. poles pointing in one direction and their south poles in the opposite direction, so that the body, as a whole, may obtain and retain its magnetic polarity. Before the year 1600, when William Gilbert, the physician to Queen Elizabeth, made the celebrated experiment of breaking a magnet into many parts and testing the polarity of each piece, it had been thought that all of the north polar magnetism was contained in one end of the magnet, while the other end of the magnet held the south polar magnetism.

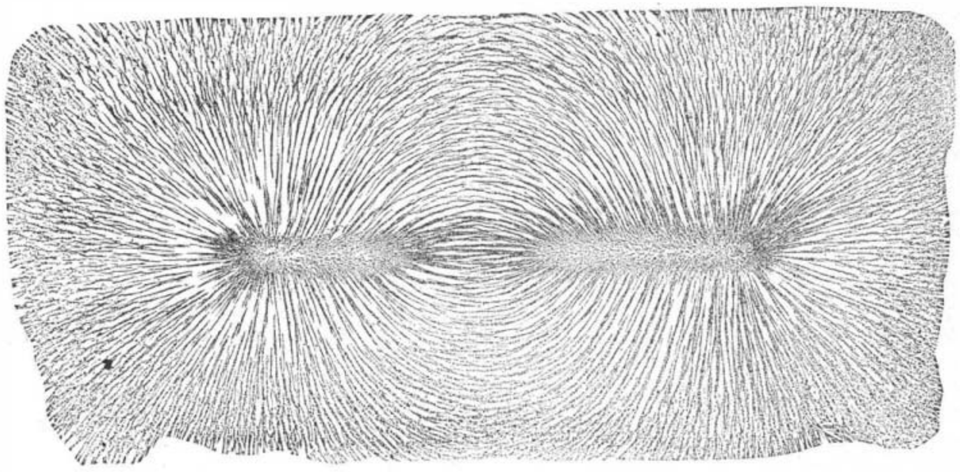


FIG. 24.—MAGNETIC CURVES AS SHOWN BY IRON FILINGS.

Interesting Experiments may be made with magnets acting inductively on a great number of iron grains spread on a surface placed over the magnet. We may thus form an idea of how this magnetic influence extends itself into space.

Take a piece of cardboard about one foot long and six inches broad. Support this at its corners on blocks of wood a little thicker than the diameter of your rat-tail file magnet. Place the latter under the cardboard. Now lift the cardboard off its supports and place it to one side on the table. Through a fine sieve sift soft iron filings evenly, and not too thickly, over the cardboard. Lift it up carefully and place it over the magnet. A slight bristling of the filings is all that you will observe of the action of the magnet; but on vibrating the cardboard, by letting fall vertically on it a piece of copper wire, or by tapping it gently with a lead pencil, you will observe curious motions among the grains of filings. They will finally arrange themselves over the magnet in the curves shown in Fig. 24.

Fig. 25 shows the arrangement taken by the iron filings when they are placed on a card and vibrated over the end of a round magnet, the magnet being held in a vertical position under the cardboard.

Fig. 26 are the lines formed over the end of a magnet. Figs. 27 and 28 respectively show the actions of magnets with their unlike and like poles opposite each other.

Fig. 29 is interesting, showing the arrangement of the lines of filings produced on a surface when under it a magnet, 216 millimeters long and 12 millimeters in diameter, is acting inductively on a cylinder of soft iron, 32 millimeters long and 10 millimeters in diameter. In April, 1871, I published in the *American Journal of Science* a method I had invented for permanently fixing these lines of iron filings (or *magnetic spectra*, as they are often called) on plates of glass. When thus permanently attached these plates were used as negatives from which a series of photographs were printed, exactly as a photographer prints from an ordinary photographic negative. The admirable engravings of magnetic spectra given in this article were made by a photo-engraving process directly from the glass plates made by me in 1871. These glass plates carrying the magnetic spectra I have also used for several years as slides in the lantern, in order to exhibit them before large audiences and college classes.

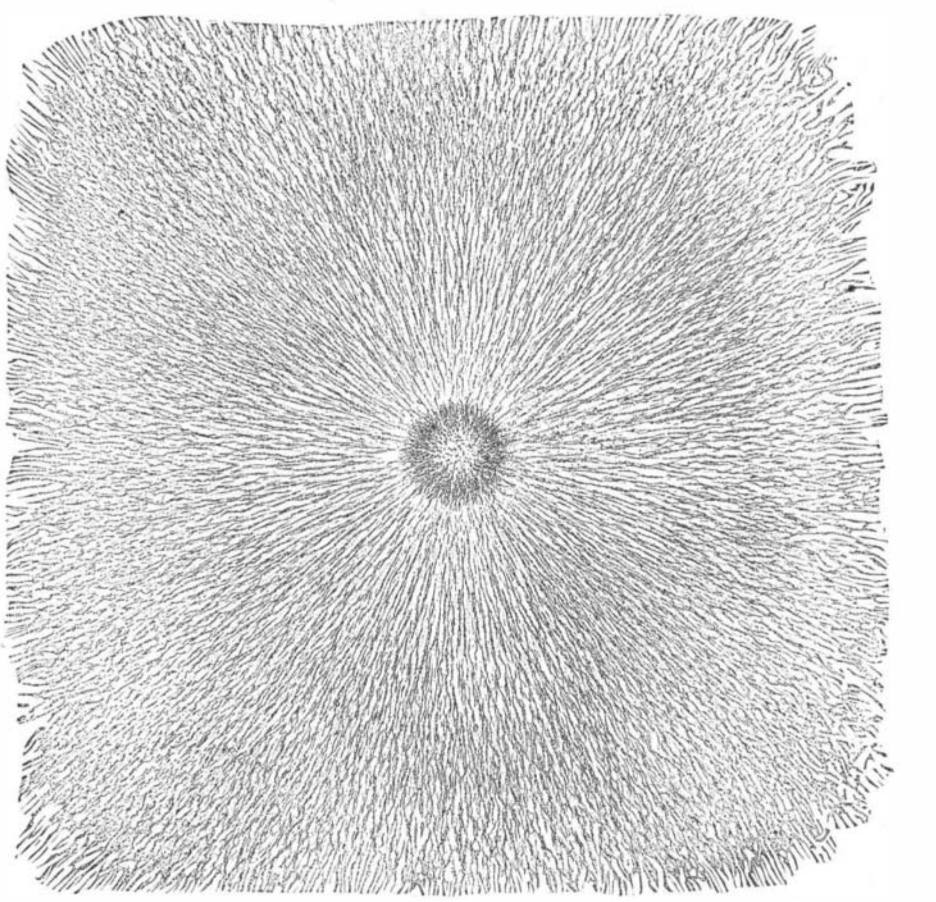


FIG. 25.—ARRANGEMENT OF FILINGS OVER THE END OF A ROUND MAGNET.

The following is the method of permanently attaching these magnetic figures to glass. A clean plate of thin glass is coated with a film of hard varnish by flowing over it the spirit varnish used by photographers in coating their negatives. If this is not handy, then a solution of shellac in alcohol will do nearly as well, only the latter requires more heating to cause the iron filings to adhere to it. The varnish is poured on one end of the plate, and then caused to cover the entire plate with an even film, by tilting and draining the plate just as a photographer does when he coats his plate with collodion. After the varnish has dried to a hard film the plate is placed, varnished side up, over the magnet or magnets, with its ends resting on slips of wood, so that the under surface of the plate just touches the magnet. Fine iron filings obtained from Norway iron, which has been repeatedly annealed, are now sifted uniformly over the plate, and then the magnetic curves are developed by letting fall on the plate vertically at different points a piece of copper wire. The vibrations of the plate momentarily detach the filings from its surface, and at these moments the magnet arranges them in obedience to its inductive action on them. The plate is now lifted from the magnet, being careful to hold it always in a horizontal position, and either placed with its ends resting on bricks over a hot stove, or it is heated over a gas stove. The film of varnish is thus melted, and the filings sinking into it are permanently fixed there after the varnish has cooled. If any filings should remain unattached, they are removed from the plate by letting its edge fall squarely on the table.

The lines forming these magnetic spectra were called "lines of magnetic force" by Faraday. He also devised the term "magnetic field." *A magnetic field* may be defined as any space at every point of which exists a finite magnetic force; while *a line of magnetic force* is a line drawn through a magnetic field in the direction of the force at each point through which it passes. Before the time of Faraday natural philosophers were satisfied with the mere statement that magnets acted at a distance, and followed generally the same law as ruled in the action

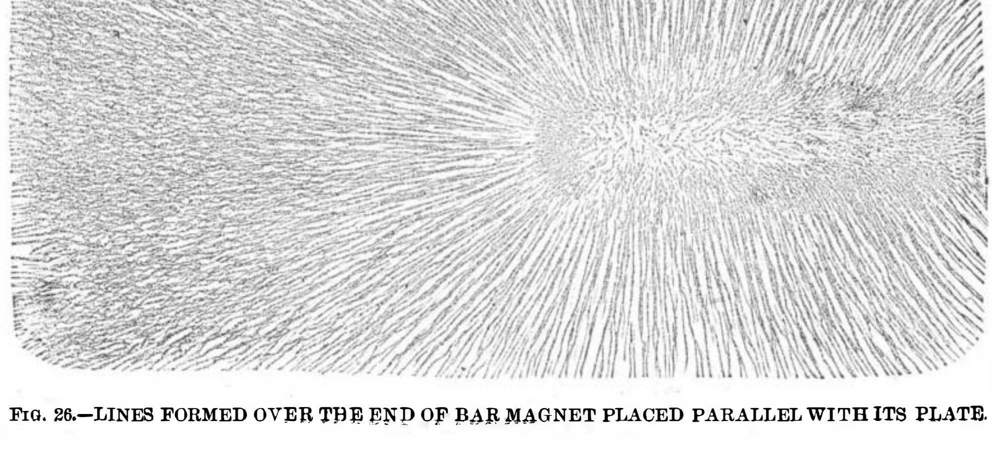


FIG. 26.—LINES FORMED OVER THE END OF BAR MAGNET PLACED PARALLEL WITH ITS PLATE.

of gravitation throughout the celestial spaces, that is to say, that the intensity of the magnetic action decreased inversely as the squares of the distances from the pole of the magnet; but Faraday, in the words of Professor Maxwell, "in his mind's eye saw lines of force traversing all space where the mathematicians saw centers of force attracting at a distance; Faraday saw a medium when they saw nothing but distance; Faraday sought the seat of the phenomena in real actions going on in the medium; they were satisfied that they had found it in a power of action at a distance impressed on the electric fluids." Faraday discovered the general laws which rule the behavior of bodies in the magnetic field. When the magnetic field is uniform—that is, when the lines of magnetic force are parallel—magnetic bodies place themselves in the direction of the lines of force; but when the magnetic field is not uniform, magnetic bodies (like iron, nickel, cobalt, etc.) tend to go from weaker to stronger places of magnetic action, while diamagnetic bodies (like bismuth, borate of lead, etc.) tend to go from stronger to weaker places in the magnetic field.

The conception of the lines of force and the magnetic field, and the statement of the laws ruling the action of bodies in field of a magnet, ' formed," says Sir William Thomson, "one of the most brilliant steps made in philosophical exposition of which any instance exists in the history of science. . . . Mathematicians were content to investigate the general expression of the resultant force experienced by a globe of soft iron in all such cases; but Faraday, without mathematics, divined the result of the mathematical investigation, and, what has proved of infinite value to the mathematicians themselves, he has given them an articulate language in which to express their results. Indeed, the whole language of the magnetic field and lines of force is Faraday's. It must be said for the mathematicians that they greedily accepted it, and have ever since been most zealous in using it to the best advantage. Indeed, much of the scientific work of Thomson, and nearly all of Maxwell's celebrated 'Treatise on Electricity and Magnetism,' may be regarded as translations of Faraday's conceptions into the language of mathematical analysis."

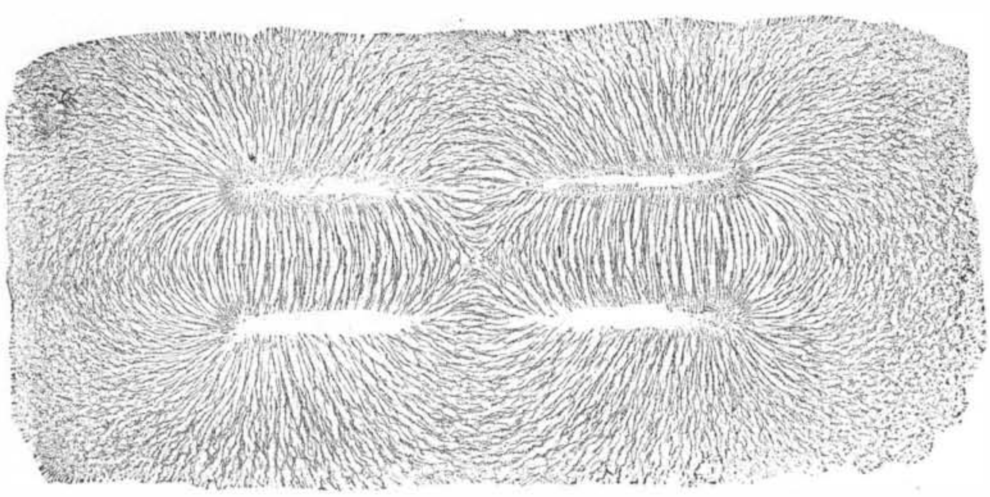


FIG. 27.—MAGNETIC CURVES UNLIKE MAGNETIC POLES OPPOSITE EACH OTHER.

Let us now make a few experiments on these lines of magnetic force. We will thus be led to some remarkable results. Form a small magnet of a piece of sewing needle about one quarter of an inch long. Suspend this with a filament of the floss silk. Having formed a magnetic spectrum, and with the magnet remaining undisturbed under the cardboard or glass, bring the little magnet over one of the lines traced out by the filings. Move the suspended magnet over this line, and you will observe that the length of the needle always lies in the direction of the line, no matter where the needle may be placed over this line. Faraday, from this fact indeed, gave his definition of a line of magnetic force as "that line which is described by a very small magnetic needle, when it is so moved in either direction correspondent to its length, that the needle is constantly a tangent to the line of motion."

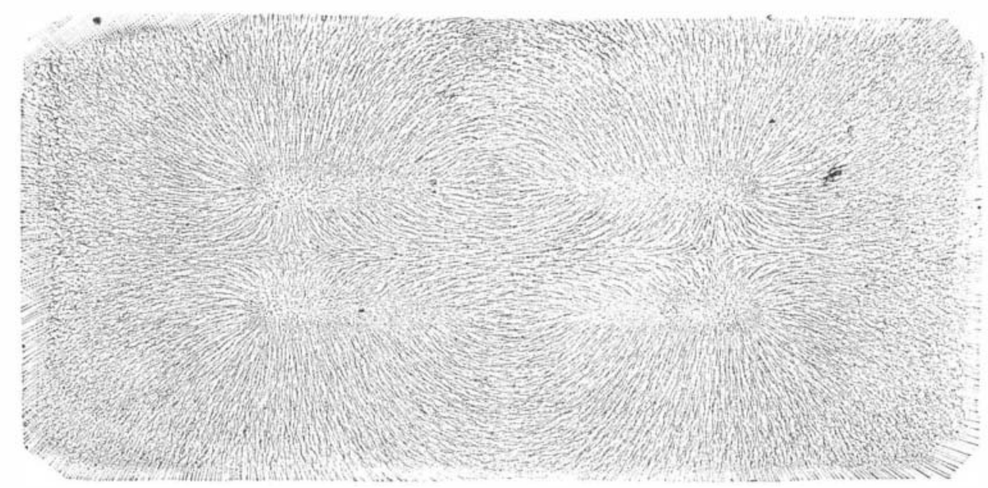


FIG. 28.—MAGNETIC CURVES LIKE POLES OPPOSITE EACH OTHER.

"The Earth itself is a Great Magnet." These are the words which may be said to form the text on which the illustrious William Gilbert wrote his work "De Magneto," or "On the Magnet," in 1600; and he certainly gave proofs of the truth of his statement, which, when viewed in the light of the knowledge which he himself discovered, forms an era in the history of the experimental sciences. If the earth be a great magnet, then it also must have its lines of force surrounding it and stretching out into space. At first sight it would seem difficult to prove this, for its proof seems to require the existence of some immensely extended, light, movable and luminous matter surrounding the earth, on which its magnetism can act, and by this action render manifest the direction of its lines of force. Now it so happens that such evidence is not wanting. All of our readers, I imagine, have seen those luminous and movable columns which form the aurora borealis. They appear to start from some level above the northern horizon, and stretching upward appear to converge at some point high up in the heavens. Sometimes this point is higher, sometimes it appears lower, according to the latitude of the observer.

Now we have seen that the magnetic needle always places itself in the direction of, or, more correctly speaking, at a tangent to a line of magnetic force, and it has been often observed that a magnetic needle, when suspended so that it can place itself in any position, either up, down, to the right or to the left, always places itself parallel to those luminous columns. This observation has been repeatedly made in various latitudes, and its general truth is established. The vast luminous rods, which are often 500 miles and over in length, actually trace out in space the earth's lines of magnetic force.

That the earth is a great magnet, you may at any time show to yourself and your friends by a few simple but very charming experiments.

Take the piece of iron, one foot long and three eighths of an inch in diameter (which I mentioned among the things required in our experiments), and heat it to a dull red heat in the fire, and then allow it slowly to cool in the hot ashes. In cooling the rod it should be placed with its length in an east and west direction. After the rod is cold paste a piece of paper around one of its ends. Take it carefully in the hand and avoid letting it fall or giving it a blow. Bring the papered end of the rod up to the needle of the magnetometer, and point it at right angles to the length of its needle and directly toward its center. You will observe that the needle remains stationary as long as the iron rod points *in a horizontal direction* toward its center. This is so because the iron is devoid of magnetism, and hence attracts the north end of the needle with a force equal to that with which it attracts the south end of the needle.

Now observe what takes place when we slowly lift up the end of the rod furthest from the magnetometer. The south pole of the needle at once swings around toward the iron rod. This cannot be owing to the inclined position of the iron, because, even in this inclined position, it is symmetrically placed in reference to the needle, and should not on this account cause the latter to turn. Evidently the iron rod has become magnetic from this change of position. The mere tilting up of its end has made it a magnet. A temporary magnet, it is true, for on slowly lowering the iron into a horizontal position the needle slowly turns into the magnetic meridian, and is then apparently indifferent to the presence of the iron rod.

Now bring the unpapered end of the rod up to the magnetometer and repeat the above experiments. The needle again turns its south end toward the rod when the latter is tilted upward. This shows that the magnetism of the rod depends alone on its position, and that end which is down is always of north magnetic polarity. It has also been found—and you can prove it for yourself—that when the rod is held inclined in the meridian, with its upper end leaning away from the north, so that it is at an angle of about 76° with the horizon, it has the most powerful magnetism that can be given to it by this means.

All of the above curious facts are explained if we consider the earth itself as a great magnet, with its south magnetic pole situate somewhere near the north geographic pole, and with its north magnetic pole placed somewhere near the south geographic pole. If you carry your small suspended magnetic needle over the length of a magnet, you will observe that the north end of the needle will point down ward when it is over the south pole of the magnet, and that the south end of the needle will point downward when it is over the north pole of the magnet; while, when over the center of the magnetic bar, the needle takes up a horizontal position. In the same manner acts a freely suspended magnetic needle when carried over the surface of the earth along a meridian. In a far northerly latitude, on the western coast of Boothia, Sir James Ross, in 1831, found that the magnetic needle pointed directly down ward, with its north pole toward the center of the earth. He inferred that he then stood on the termination of a line drawn from the earth's center through its magnetic pole to his feet. Subsequently this bold mariner undertook another voyage of discovery in search of a similar point on the southern hemisphere, and in 1841 succeeded in reaching south latitude 76° 12′, on Victoria Land, when the south end of the needle pointed downward and made an angle of 88° 40′ with the horizon. He concluded from this and other observations that the position where the needle would be vertical was about 160 nautical miles distant. From these and other magnetic observations made in the Antarctic seas, it is supposed that the magnetic pole of the southern hemisphere must be somewhere about south latitude 70° and near the meridian of 125° east of Greenwich. This would bring the position of the magnetic pole somewhere on the territory discovered by our countryman Wilkes. The exact position of this point, however, is not known, for no explorer has ever reached it. Also, it has been well ascertained that along an irregular line, situated on the equatorial belt of the earth, the needle has a horizontal position, just as it has when placed midway between the poles of an artificial bar magnet. This irregular equatorial line is called the earth's magnetic equator.

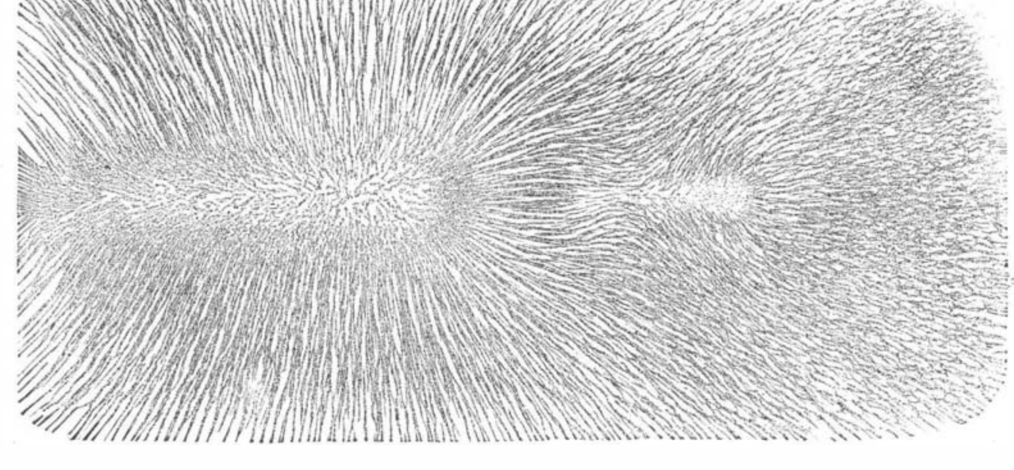


FIG. 29.—CURVES SHOWN BY A MAGNET ACTING INDUCTIVELY ON A CYLINDER OF SOFT IRON.

These facts are all explained by conceiving the earth as a huge magnet, and if the earth be a magnet, it also follows that the soft iron rod, when held upright in the southern hemisphere, will have its lower end of south magnetism; while the same end in the northern hemisphere, we have ourselves found, is always of north magnetic polarity. We cannot travel over the earth and test this conclusion for ourselves, but I once found in the Transactions of the Royal Society of London a paper headed "*On the tendency of the Needle to a piece of Iron held perpendicular, in several climates. By a master of a ship, crossing the Equinoctial Line. Anno* 1684." Let the mariner give his own account of his experiments, and we will see that his statements show that when you cross the magnetic equator the lower end of the upright iron rod changes from north to south magnetic polarity: "All the way from England to 10° north latitude, the north end of the needle tended to the upper end of the iron, and the south point to the lower end, very strongly. . . . In latitude 8° 17′ south, and meridian distance from the Lizard 17° 35′ west, the north point of the needle would not respect the upper end of the iron; but the south point would still somewhat respect the lower end. . . . In latitude 29° 25′ south and 13° 10′ west, from the meridian of the Lizard, the south point of the needle respected the upper end of the iron, and the north point the lower end strongly."

On the "Magnetic Neutral Line."—There has recently appeared much discussion about the existence of a position of neutrality near a magnet. That a region of that kind, where there appears a break in the continuity of the magnet's attractive and directive force, exists, I have no doubt; but I cannot agree with those who have declared for the existence of a line, or plane, of neutrality in the sense in which Mr. Gary and others have put it. Indeed one hundred and twenty years ago a neutral line was discovered by the celebrated John Robison, Professor of Natural Philosophy in the University of Edinburgh. He is the man of whom James Watt said, "He has the clearest head of any man I know." Having such good indorsement for clearness of head, I cannot do better than let him describe his own experiments:

"Amusing myself in the summer of 1758 with magnetic experiments, two large and strong magnets, A and B (Fig. 30), were placed with their dissimilar poles fronting each other and about three inches apart. A small needle, supported on a point, was placed between them at D, and it arranged itself in the same manner as the great magnets. Happening to set it off to a good distance on the table, as at F, I was surprised to see it immediately turn round on its pivot and arrange itself nearly in the opposite direction. Bringing it back to D restored it to its former position. Carrying it gradually out along D F, perpendicular to N S, I observed it to become sensibly more feeble, vibrating more slowly; and when in a certain point, E, it had no polarity whatever towards A and B, but retained any position that was given it. Carrying it further out, it again acquired polarity to A and B, but in the opposite direction, for it now arranged itself in a position that was parallel to N S, but its north pole was next to N and its south pole to S.

"This singular appearance naturally excited my attention. The line on which the magnets, A and B, were placed had been marked on the table, as also the line, D F, perpendicular to the former. The point, E, was now marked as an important one. The experiments were interrupted by a friend coming in, to whom such things were no entertainment. Next day, wishing to repeat them to some friends, the magnets, A and B, were again laid on the line on which they had been placed the day before, and the needle was placed at E, expecting it to be neutral. But it was found to have a considerable verticity, turning its north pole toward the magnet, B, and it required to be taken further out, toward F, before it became neutral. While standing there something chanced to joggle the magnets, A and B, and they instantly rushed together. At the same instant the little magnet, or needle, turned itself briskly, and arranged itself, as it had done the day before, at F, quivering very briskly, and thus showing great verticity. This naturally surprised the beholders; and we now found that by gradually withdrawing the magnets, A and B, from each other, the needle became weaker, then became neutral, and then turned round on its pivot and took the contrary position. It was very amusing to observe how the simply separating the magnets, A and B, or bringing them together, made the needle assume such a variety of positions and degrees of vivacity in each.

"The needle was now put in various situations, in respect to the two great magnets; namely, off at a side, and not in the perpendicular, D F. In these situations it took an inconceivable variety of positions which could not be reduced to any rule; and in most of them, it required only a motion of one of the great magnets for an inch or two, to make the needle turn briskly round on its pivot, and assume a position nearly opposite to what it had before.

"But all this was very puzzling, and it was not till after several months that the writer of this article, having conceived the notion of the magnetic curves, was in a condition to explain the phenomena. With this assistance, however, they are very clear and very instructive.

"Nothing hinders us from supposing the magnets, A and B, perfectly equal in every respect. Let N H M, N E L, be two magnetic curves belonging to A; that is, such that the needle arranges itself along the tangent of the curve. Then the magnet, B, has two curves, S G K, S E Q, perfectly equal and similar to the other two. Let the curves, N H M and S G K, intersect in C and F. Let the curves, N E L and S E Q, touch each other in E.

"The needle being placed at C would arrange itself in the tangent of the curve, K G S, by the action of B alone, having its north pole turned toward the south pole, S of B. But by the action of A alone it would be a tangent to the curve, N H M, having its north pole turned away from N. Therefore, by the combined actions of both magnets, it will take neither of these positions, but an intermediate one, nearly bisecting the angle formed by the two curves, having its north pole turned toward B.

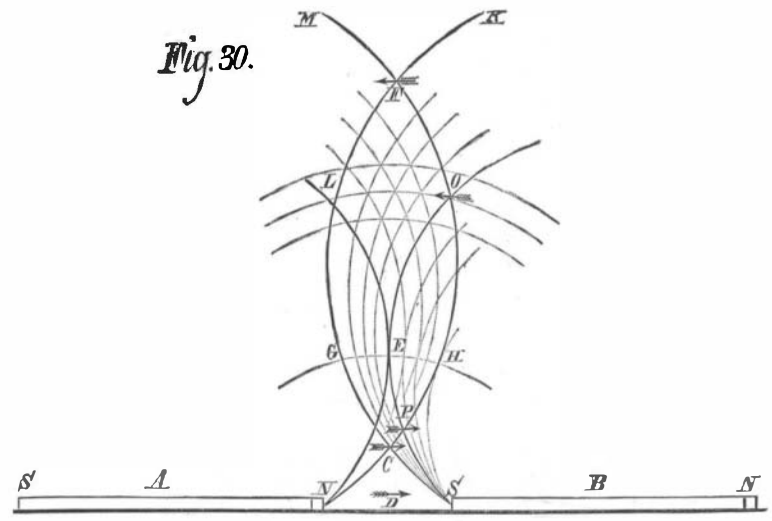
"But remove the needle to F. Then, by the action of the magnet, A, it would be tangent to the curve, F M, having its north pole toward M. By the action of B, it would be a tangent to the curve, K F G, having its north pole in the angle, M F G, or turned toward A. By this joint action, it takes a position nearly bisecting the angle, G F M, with its north pole toward A.

"Let the needle be placed in E. Then, by the action of the magnet, A, it would be a tangent to the curve, N E L, with its north pole pointing to F. But, by the action of B, it will be a tangent to S E Q, with its north pole pointing to D. These actions being supposed equal and opposite, it will have no verticity, or will be neutral, and retain any position that is given to it.

"The curve, S E Q, intersects the curve, N H M, in P and Q. The same reasoning shows that when the needle is placed at P, it will arrange itself with its north pole in the angle, S P H; but, when taken to Q, it will stand with its north pole in the angle, E Q M.

"From these facts and reasonings we must infer that, for every distance of the magnets, A and B, there will be a series of curves, to which the indefinitely short needle will always be a tangent. They will rise from the adjoining poles on both sides, crossing diagonally the lozenges formed by the *primary or simple* curves, as shown in Fig. 30. These may be called *compound or secondary* magnetic curves. Moreover, these secondary curves will be of two kinds, according as they pass through the first or second intersections of the primary curves, and the needle will have opposite positions when placed on them. These two sets of curves will be separated by a curve, G E H, in the circumference of which the needle will be neutral. This curve passes through the points where the primary curves touch each other. We may call this *the line of neutrality* or inactivity.

Fig. 30.



LINES OF MAGNETIC FORCE.

"We now see distinctly the effect of bringing the magnets, A and B, nearer together, or separating them farther from each other. By bringing them nearer to each other, the point, E, which is now a point of neutrality, may be found in the *second* intersection (such as F) of two magnetic curves, and the needle will take a subcontrary position. By drawing them farther from each other, E may be in the *first* intersection of two magnetic curves, and the needle will take a position similar to that of C.

"If the magnets, A and B, are not placed so as to form a straight line with their four poles, but have their axes making an angle with each other, the contacts and intersections of their attending curves may be very different from those now represented; and the positions of the needle will differ accordingly. But it is plain, from what has been said, that if we knew the law of action, and consequently the form of the primary curves, we should always be able to say what will be the position of the needle. Indeed, the consideration of the simple curves, although it was the means of suggesting to the writer of this article the explanation of those more complicated phenomena, is by no means necessary for this purpose. Having the law of magnetic action, we must know each of the eight forces by which the needle is affected, both in respect of direction and intensity, and therefore able to ascertain the single force arising from their composition.

"When the similar poles of A and B are opposed to each other, it is easy to see that the position of the needle must be extremely different from what we have been describing. When placed anywhere in the line, D F, between two magnets whose north poles front each other in N and S, its north pole will always point away from the middle point, D. There will be no neutral point, E. If the needle be placed at P or Q, its north pole will be within the angle, E P H, or F Q I. This position of the magnets gives another set of secondary curves, which also cross the primary curves, passing diagonally through the lozenges formed by their intersection. But it is the other diagonal of each lozenge which is a chord to those secondary curves. They will, therefore, have a form totally different from the former species.

"The consideration of this compounded magnetism is important in the science, both for explaining complex phenomena, and for advancing our knowledge of the great desideratum, the law of magnetic action.

(*To be continued.*)

THE force of the Light-house Board of the Treasury Department has been reduced by the dismissal of eleven clerks.

Electricity as a Motive Power.

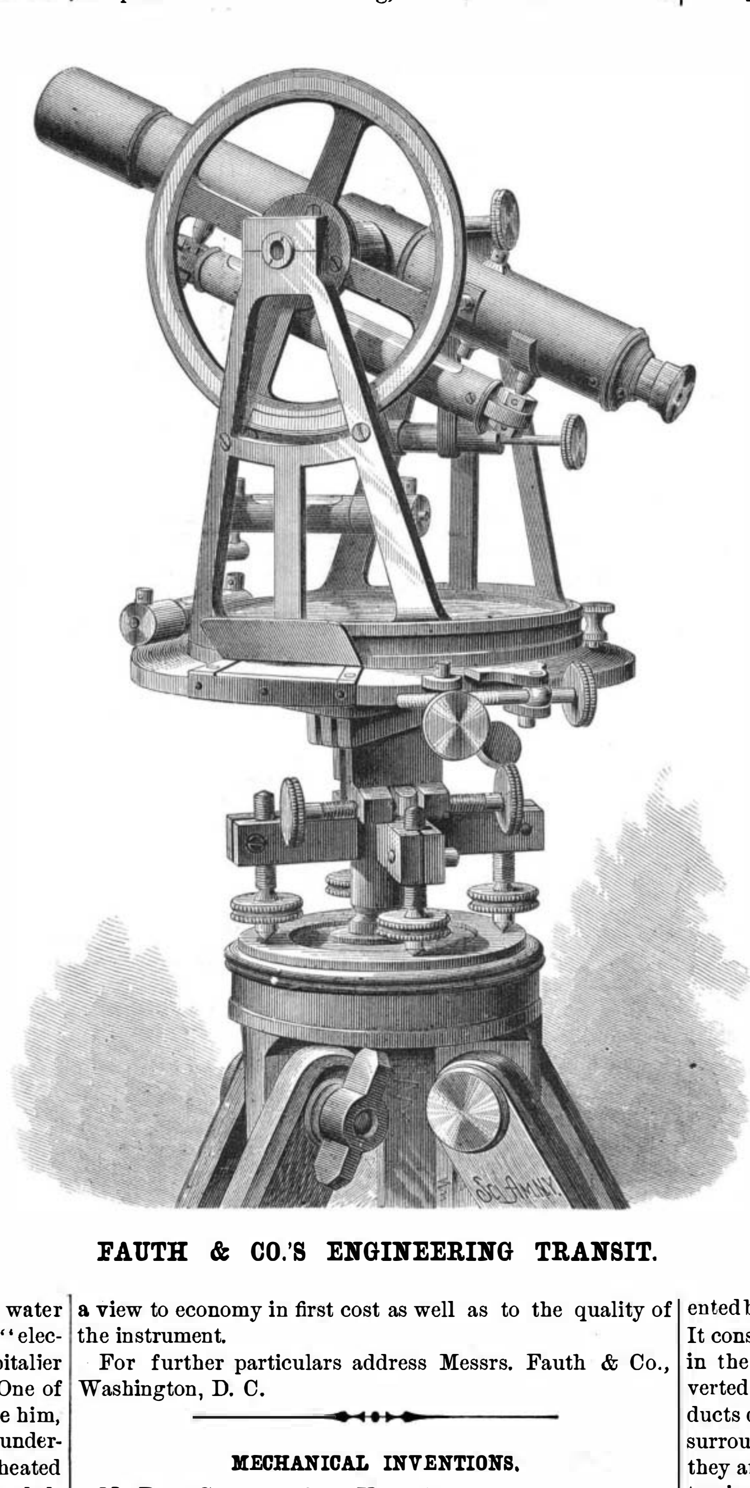
At a recent meeting of the British Association, Professor W. E. Ayrton delivered a lecture on "Electricity as a Motive Power," and interesting illustrations were given, including machinery in motion, driven by power derived from a distance.

The lecturer stated that in any generation of electricity there was a certain property called the electro-motive force, which meant its tendency to send a current, and which was analogous with the head of water in a reservoir, inasmuch as the product of the quantity of electricity flowing per second, multiplied by this electro-motive force, measured the amount of energy furnished by the generator per second, and which could be reproduced as motive power elsewhere if there were no friction. The loss of energy due to electrical friction in the wires was equal to the square of the current flowing per second multiplied by what was called the resistance of the wire—a number depending on the length, the diameter of the wire, the material of which it was made, and the temperature. The most efficient way to transfer energy electrically was to use a generator producing a high electro-motive force, and a motor producing a return high electro-motive force, and by so doing the waste of power in the transmission ought, he considered, to be able to be diminished with the best existing dynamo-electric machines to about 30 per cent. It would be impossible to increase indefinitely the speed of revolution of the cylinder of an induction machine, since, apart from mere mechanical friction, the iron constituting the core of the revolving part had to be magnetized and demagnetized very rapidly as it revolved. Now, there was a physical limit to the speed with which this could be done, and, in addition, this rapid change of magnetism heated the iron very much. But experiment showed that at the ordinary speed of revolution of dynamo-electro-machines—700 turns per minute—the electro-motive force was proportional to the speed. They were, therefore, very far yet from the limit of speed. Consequently it would be well for the transmission of power to attempt first, a considerable increase of speed in the generator combined with so light a load on the motor, that its speed would be also very high. When this began to fail as larger and larger amounts of power were transmitted, then they might begin increasing the amount of wire on the revolving coils of each; but this, of course, had the objection that the loss of power from a given current would then become somewhat larger. As they had seen that by the use of electricity properly employed, the waste of power in transmission could be reduced for any distance to about thirty per cent of the whole power absorbed at the generator, it followed that the employment of steam engines of vast size at points outside Sheffield would be by far the most economical mode of extracting the energy out of coal. For it was at least four times as expensive to produce power with a small steam engine as with a large one; therefore, including the waste of power in electric transmission, the cost of production of power in small workshops would be little more than one third as dear as if small steam engines were used, and similarly the waste of power in any large mill or factory in its transmission from the large steam engine at its base to all the floors and machines on each floor would be very much diminished. But they would say that in advocating the employment of electricity he was advocating a total change in our mode of producing and transmitting power. Was the probable gain worth the expense of the necessary change? To answer this question they must consider what would be the probable minimum annual gain by the proposed change in Sheffield alone. In making this calculation they must remember that not only could electricity produce motive power, but also heat and light, and electric heating and lighting had this great advantage that no chimneys were required. For example, with the electric current sent to that hall from Messrs. Walker & Hall's works, he could heat a long coil of iron wire white hot, so that when put into a vessel of water, the water in a short time would begin to boil. Various calculations had been made as to the relative cost of lighting by burning coal to produce gas, or by burning coal to work dynamo machines for producing electric currents, and it seemed to be pretty certain that if a large amount of light be required in one place, the electric light was at least twenty times as cheap as coal. Sir William Thomson, the eminent electrician, went so far as to say that it might be made 133 times as cheap. And certainly that there was a great saving in expense in electric lighting was seen from the actual result obtained at the Albert Hall, London, which was an example, and perhaps the only example, in connection with electric lighting, where the science of putting a brilliant light high up had been allowed to ride over the precedent of putting a number of feeble glimmers all over a building. The actual cost, including labor of men, allowance for wear and tear of machinery, etc., was only one-third of that of the former inferior gas lights, and thus a saving of about 30s. an hour had been effected. Lighting streets by electricity had not been so successful economically, for the simple reason that instead of giving a large bright light, at a considerable height, reflected downwards, as in the Albert Hall, London, English conservatism had prevented the authorities from grasping the possibility of using for street illumination anything differing from an ordinary iron lamp post. But there could be little doubt that if a few large electric lights, high up, were used for street illumination, the same sort of result as has been obtained at the Albert Hall would be arrived at. The cost of using gas in Sheffield for lighting large halls, such as the one they were now in, factories, and the streets, could be halved if electric currents, generated by water engines, worked by hill streams, as well as by very large steam engines, were substituted for gas. It was not necessary for him to tell them how he proposed to employ the electric light to illuminate private rooms, if only he could get people to throw away the notion that to light a room they must have something with a globe on it, like an oil lamp; nor was it necessary for him to remind them that by whitewashing the walls—yes, by whitewashing even the very machines themselves—in some of the Paris factories, the supposed strong shadows cast by the electric light had been less than the strong shadows cast by another bright light, one that we not only put up with, but one that from the force of habit we were tolerably contented with, namely, the sun. At present he was concerned with the pounds, shillings, and pence question, which had more than usual weight in these days of slack trade. Assuming that the cost of gas for lighting the large buildings, factories, and the streets of Sheffield could be halved, also that where it was used for heating purposes the expense could also be halved, by substituting electric currents generated by very large steam engines at certain points, and by turbines driven by falling water out of the town; then they would save per year about £45,000. Supposing, also, that the cost of producing motive power could in the same way also be halved, this represented an annual saving of something like £60,000. In reality, he believed this last economy would be larger, since not only could power be produced so much more economically than by small steam engines or even by a large engine, when a large proportion of its power was, as now, wasted in driving the shafting alone in their factories; but, in addition, much hand work could be economically replaced by machine work. And, lastly, supposing the consumption of coal in Sheffield for heating their metals and for heating their houses could also be halved, then there was another saving of about £300,000 a year; or, altogether, the annual saving that might be produced in this town alone, by substituting electricity for coal, would be something like the large sum of £400,000.

Last year, two French engineers, MM. Chretien and Felix, at Sermaize (Marne), actually plowed fields by electricity, the electric current being produced by two dynamo-electric machines of a form invented by M. Gramme. These machines were usually worked with a steam engine at some convenient place three or four hundred yards away in an adjoining road, and the electro-motors were also two Gramme machines, one on each side of the field, with their coils revolving of course backwards. Through one of these the electric current was sent alternately, so that motion was given to one or other of two large windlasses, one on each of the wagons containing the electro-motors. In this way the plow, which could be used going in either direction, was first pulled across the field, making a furrow, and then back again, making another parallel furrow. If electricity were produced in large quantities at certain centers, then one difficulty that would of course be met with would be that of distributing it properly, since, just as in the case of water or gas, if a large branch pipe in a main be suddenly opened then the supply going on to the other branch pipes in the same main would be diminished, a result causing serious inconvenience in the case of electric lighting. But just as automatic governors had been devised for water and gas, to keep the supply constant, so automatic "electric current regulators" had been devised by M. Hospitalier and by Dr. Siemens, to keep the current constant. One of those invented by Dr. Siemens was on the table before him, and the general principle of its construction was easily understood. As the current passed through the regulator it heated a very thin ribbon of steel, which consequently expanded. The effect of this expansion was to introduce coils of wire into the circuit, the extra resistance of which diminished the strength of the current. Consequently the stronger the current the more was it automatically resisted, and the weaker it became the less was it resisted, and so it remained practically constant at any desired strength for which the regulator was previously adjusted. In conclusion the lecturer said there was a time when "not only in the villages around old Sheffield," so said the historian of Hallamshire, "were the file makers' shops or the smithy to be seen, with the apprentices at work; but even on the hillside in the open country, at the end of the barn, would be the cutler's shed, while in the valley below, by the river, was the grinding stone ready to sharpen the tools that had been manufactured." And why not now? Why should not that mountain air that had given the workmen of Hallamshire in past times their sinew, their independence, blow over their grindstone now? Why should not division of labor be carried to its end, and power brought to them instead of them to the power? Let them hope, then, that in the next century electricity might undo whatever harm steam during the last century might have done, and that the future workman of Sheffield would, instead of breathing the necessarily impure air of crowded factories, find himself again at the hill side, but with electric energy laid on at his command.

IMPROVED ENGINEER'S TRANSIT.

The two instruments shown in previous numbers, made by Fauth & Co., were purely astronomical ones. We now illustrate an instrument familiar to most of our readers—an improved engineering transit. This is the standard instrument as furnished by Messrs. Fauth & Co. to the government department that are using this class of apparatus, and it is rapidly gaining favor with railroad engineers and surveyors. The instrument is constructed so as to give great strength with little metal. Instruments of this construction have not sustained serious injury by heavy falls. The telescope standards, which in the old form are merely held on the plate by means of screws, are in this instrument cast on a common base and radiate out from the center, giving the superstructure a firmness which cannot be secured by any other method. A glance at the engraving will give a clear idea of the construction and arrangement of the various parts, and we will only add that the graduations are on silver; the telescope is powerful, and has an achromatic objective. The compass needle is 5 inches long, and the whole is made with a view to economy in first cost as well as to the quality of the instrument.



FAUTH & CO.'S ENGINEERING TRANSIT.

For further particulars address Messrs. Fauth & Co., Washington, D. C.

MECHANICAL INVENTIONS.

Mr. Peter Cooper, of New York city, has recently patented an improvement in propulsion of railway cars, which consists in a combination of well known mechanical powers, by which trains of cars can be propelled at any desired speed by means of an endless chain or wire rope. The endless chain or rope is to be borne up in its entire length by being fastened firmly to the outside and in the center of as many sets of cars as there are stopping places on the whole line of the road. The stopping places are to be all of equal distances apart, and there will be bearing trucks between the different sets of passenger cars to prevent the chain from dragging or rubbing against anything in its passage around the circuit. The endless chain or rope, with the attached cars, is made to pass around a large drum wheel placed at each end of the line, which is to be of sufficient strength and operated by sufficient power to move the whole line of cars. By having stopping places at equal distances apart the rails can be so elevated as to use up the momentum of the cars in their ascent of the elevation at each stopping place. The elevation will be sufficient to bring the cars to rest and hold the power ready to be given out at once by all the cars going over the ascent at the same time. This will give back all the power consumed by forcing the cars up the ascent, and will reduce the necessary propelling power to that required on a dead level.

Mr. William H. Ellis, of Brooklyn, N. Y., has patented an improved umbrella drip cup, which consists of two conical cups connected together at the base, the outer one joined at its smaller end to a tube, into which the lower end of the umbrella stick is entered and secured so that the cup is just under the umbrella; by this means, when the umbrella is folded up, the water runs down and is caught and retained in the chamber between the two cups, from which it slowly runs out through the perforations in the connected base of the cones when the umbrella is again lifted or reversed.

Charles E. Fox, of Mount Pleasant, Mich., has invented an improved washing machine, which consists of one or more rollers arranged transversely in relation to the corrugated face of the wash board, and having a crank and gear attachment, the parts being mounted in a suitable frame, which is attached to the wash board, and adapted to yield so that the rubbing rollers act on both small and large fabrics.

Mr. David L. Towslee, of West Salem, O., has invented an improved drag sawing machine, so constructed that it may be worked by the operator with both hands and feet, or with either his hands or his feet. It is simple in construction, easily operated, and apparently effective in operation.

Mr. Martin Williams, of St. Johnsville, N. Y., has invented an improved thrashing machine, that runs steadily and easily and effects a thorough separation of the grain from the straw.

An improved device for lighting a fire automatically, at any given time, has been patented by Mr. Eibe H. Doescher, of Homestead, Ia. The invention consists in the combination of devices that cannot be readily described without an engraving.

A simple and effective device for automatically regulating the height of water in a steam boiler, has been patented by Mr. John Bridges, of Leon, Iowa. The invention consists of a novel construction and arrangement, in connection with a boiler, of a float, valve, and pipes, and their connections, with a feed pump.

Thaddeus C. Histed, of Junction City, Kan., has invented an improvement in that class of washing machines in which beaters are employed in connection with a rotated tub; and consists in the peculiar construction and arrangement of mechanism by which the work is thoroughly done.

Mr. Sylvanus A. Fisher, of Geneseo, Ill., has invented an improved wire stretcher, which consists in a lever fitted with a cam-acting holding jaw, by which the wire is securely held and from which it may be readily released.

An improved washing machine has been patented by Mr. Melvin A. Tinker, of Fairfield, Ill. The invention is an improvement in the class of washing machines composed of rolls held in yielding contact by means of springs, the bed rollers being arranged in the arc of a circle and inclosed or covered by an endless apron.

Mr. Soren Andersen, of Stronach, Mich., has patented an improved saw grinder for grinding saws down to as thin a gauge as they will work at, thereby rendering the waste in sawing as small as possible. It saves power; and by means of this combined grinder and gummer, saws can be used until they are actually worn out or worn down too small for use.

An improvement in smoke stacks has been patented by William F. Cosgrove, of Jersey City Heights, N. J. It consists in providing the stack with an inclosing jacket, in the double conical head of which is supported an inverted perforated cone and a screen for deflecting the products downward, where they fall upon an inclined collar surrounding the stack which leads them to a spout, whence they are conveyed by a pipe to a chamber formed in an extension of the boiler shell.

Messrs. George Coombs and Charles S. Blakeslee, of Chariton, Ia., have patented an improvement in car couplings. This is a simple and effective self coupler for cars, but it cannot be described without engravings.

Photographic Illustration of Mental Operations.

Professor Huxley illustrates his argument respecting complex impressions which are more or less different from each other by reference to composite portraiture, thus: "This mental operation may be rendered comprehensible by considering what takes place in the formation of compound photographs—when the images of the faces of six sitters, for example, are each received on the same photographic plate for one-sixth the time requisite to take one portrait. The final result is that all those points in which the six faces agree are brought out strongly, while all those in which they differ are left vague; and thus what may be termed a *generic* portrait of the six, in contradistinction to the specific portrait of any one, is produced."