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PREFACE

The ingenious experiments and recreations described by "Tom Tit" in his three volumes of *La Science Amusante* have long delighted the young people of France. To present some of these in English garb, so that our youth might find therein as great delight, is the aim of this volume.

The most characteristic parts of the Second and Third Series of these fascinating glimpses into scientific truth have been considerably rearranged, and to them have been added a few new experiments and descriptions.

In translating and paraphrasing the contents of Tom Tit's inimitable pages, I have tried to preserve the playful spirit of the original as well as its fidelity to the truths of science. One pleasing feature of the whole method is the continual appeal to the manipulative skill of the reader. There is always something to do or to construct, to test or to make to go. Let no one be content with mere reading.

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SCIENTIFIC AMUSEMENTS.

PART I.—PRACTICAL GEOMETRY.

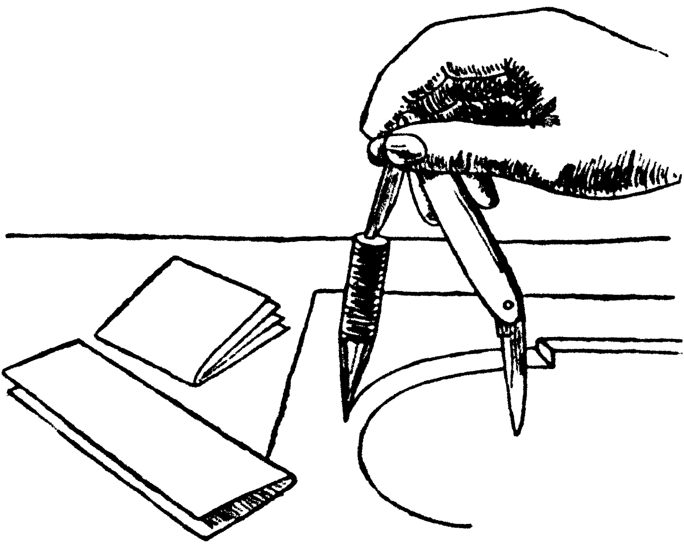
1. THE NECESSARY INSTRUMENTS.

DO we wish at a moment's notice to trace some geometrical figures, but have at hand neither compasses, nor straight-edge, nor square? We should probably be somewhat embarrassed.

We may, however, construct out of ordinary appliances a temporary set of instruments to serve our purpose.

Thus, a sheet of stiff paper once folded will give a straight-edge, straighter indeed than many a so-called ruler. This is a geometrical necessity, for two planes meet in a straight line. By double folding a rectangular sheet of paper, taking care to have the edges come together, we obtain a perfect right angle. The second fold must, of course, be at right angles to the first. By tracing the edges of this right angle on a piece of stiff cardboard, and cutting it carefully with a knife, we quickly construct a "set square." If equal lengths are marked off on the containing sides an isosceles or equal-sided triangle can easily be formed with the other angles each 45°.

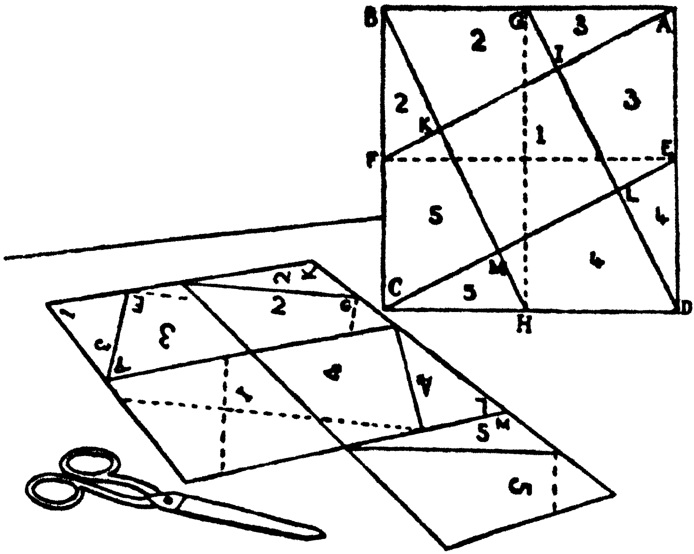
A pair of serviceable compasses may be made



out of a pocket knife with two blades in the way indicated in the figure. The point of the one blade serves as the pivot of the compasses. The point of the other blade is inserted into the end of a short pencil; and with this improvised instrument circular arcs and circles may be drawn.

We are now able to make a set square with 30° and 60° for the other angles. For that purpose we draw a semicircle on a chosen line as diameter. Then from either end of the diameter as centre describe an equal circle, cutting the first semicircle in a definite point. The triangle obtained by joining this point with the two ends of the diameter is a right-angled triangle with the right angle at the point, and the other angles are 60° and 30° respectively. The drawing should be made on stiff cardboard, out of which the figure of the triangle may then be cut; and the set square is complete.

With these simple instruments all the figures in Euclid's Geometry may be easily constructed.



2. TO DIVIDE A SQUARE INTO FIVE EQUAL SQUARES.

If you were asked to divide a square into four equal squares you would smile at the simplicity of the problem. You would say, "Fold it along one middle line and then along the other, and the thing is done."

But suppose you were asked to divide the square into five equal squares, how would you proceed? This problem is not immediately obvious; yet it can be effected in a very simple manner.

First fold the square ABCD into four quarters, as already described. Let FE and GH be these middle folds. Join AF, BH, CE, DG—that is, by pairs of parallel lines drawn from the middle points of the sides to the corners. These lines cut so as to portion off nine parts, of which the middle one is a perfect square, bounded by four exactly similar and equal figures each of four sides, while the remaining parts are equal triangles, any one of which with any one of the four-sided figures will make up a square exactly equal to the central square. By cutting the paper along these lines we obtain nine fragments which can be readily pieced together to form five squares.

The construction may be assumed to verify the truth of the proposition; but mathematicians would not accept it as a proof. It is easy to see, however, that the small square is exactly one-fifth of the large square, if we take for granted the well-known proposition first proved by Pythagoras that in a right-angled triangle the sum of the squares of the sides containing the right angle is equal to the square on the hypothenuse or side opposite the right angle.

In the first place, it is obvious that the four large triangles and the four small triangles are all similar, and that therefore in each the longer side containing the right angle is twice the shorter side.

Thus $KI = IA = 2\,IG$.

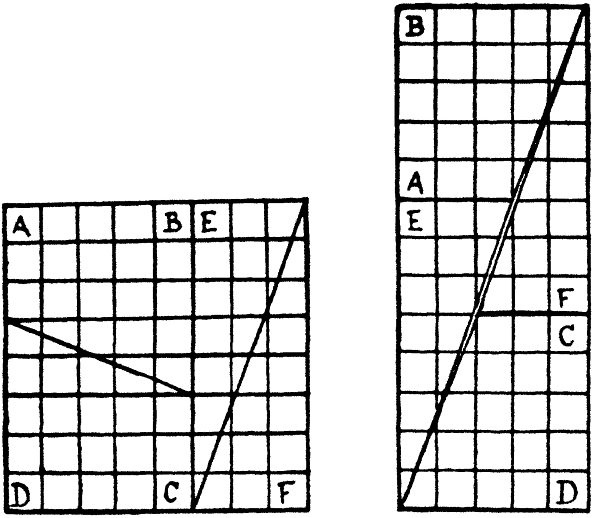
But $IA^2 + IG^2 = AG^2$.

Now the whole square is equal to $4\,AG^2$. Hence

$$4\,AG^2 = 4\,IA^2 + 4\,IG^2$$
$$= 4\,IA^2 + IA^2 = 5\,IA^2.$$

To form the five squares from the nine parts is simple enough; but it is not quite so easy to reconstruct the original large square from the pieces after they have been confusedly mingled together. Try it.

[illegible]



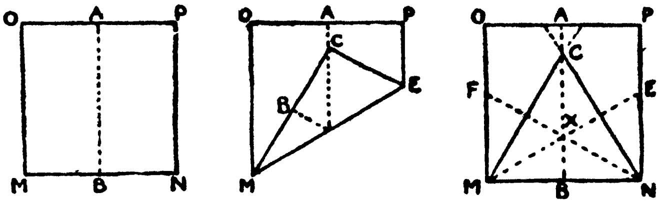
3. THE SQUARE AND RECTANGLE: 64 = 65!

DRAW a square, and divide it into sixty-four small squares like a chessboard. Cut it along the line which divides the fifth column of small squares from the sixth column. This will give two rectangles, 3 by 8, and 5 by 8. Cut the smaller rectangle along one of its diagonals so as to make two equal triangles with sides 3 and 8. Cut the larger rectangle obliquely so as to divide it into two equal quadrilaterals whose sides are 5, 5, 3. The length of the oblique section will then be $\sqrt{2^2 + 5^2} = \sqrt{29}$.

Now, if we fit the side 3 of each triangle to the side 3 of each quadrilateral so as to make what seem to be two large triangles, we may put their longest sides together and form what is apparently a rectangle of length 13 and width 5. This gives an area of 65. Apparently, 64 = 65! The puzzle is to explain this extraordinary result.

The construction seems to be all right; but the result shows that mathematicians are right in not accepting a practical construction as a proof.

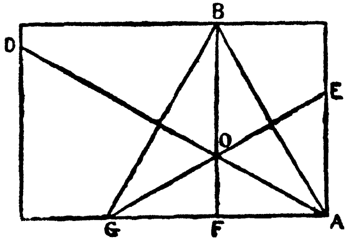
The reason will be seen if the drawing or cutting out is done with great accuracy (see the second figure). Careful inspection will then show that the triangle and quadrilateral when joined together do not form a perfect triangle. With respect to the line of length 13, the gradient of the hypothenuse of the triangle is 3/8, while the gradient of the oblique side of the quadrilateral is 2/5, which is greater than 3/8 by 1/40. Hence when the portions are pieced together to form the rectangle of 13 by 5 there is a long thin gap between the edges that run close to the diagonal line. This long thin gap has an area equal to that of one of the small squares.

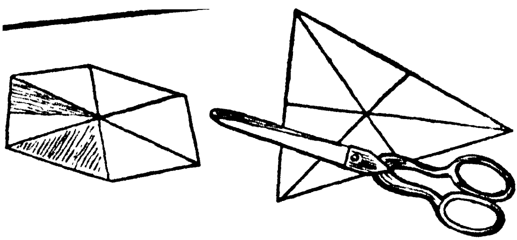


4. THE EQUILATERAL TRIANGLE—THE REGULAR HEXAGON.

THESE are easily constructed by means of the compasses. Draw a circle of any convenient size. Then with centre at any point on the circular boundary, describe an arc of the same radius so as to cut the circle in two points. With each of these points as centre describe two more arcs of the same radius cutting the circle in two other points. With each of these as centre repeat the operation. If the work is carefully done the last two points of intersection will be the same point, and the circle will be cut at six equidistant points. When these points are joined in succession by straight lines, a regular hexagon will be constructed. If we join alternate points with straight lines, the equilateral triangle is the result.

To obtain the equilateral triangle and the hexagon by folding paper proceed in this wise. Take a square or rectangle of paper, and fold it so as to get the middle line. If the paper is not square it is well to fold it along the longer middle line. Open out the paper from its fold and form another fold by bringing one of the corners on to the middle line in such a way that the fold passes through the other corner which lies equidistant on the

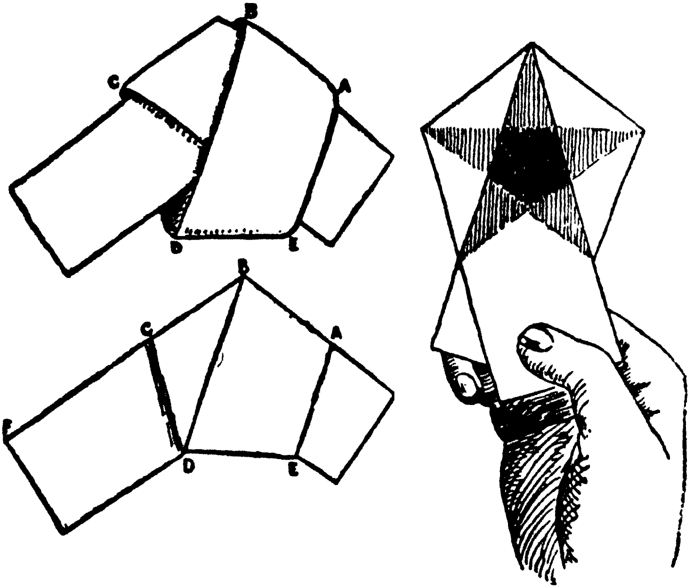




opposite side of the middle fold. That is, as indicated in the figure, the corner N is made to coincide with the point C on the middle line AB, while at the same time the corner M remains steady and the paper is folded along the line ME. The line MC is, therefore, equal to the line MN. In the same way, after unfolding the paper, bring the corner M to lie on the middle line AB, folding the paper about the line NF. Symmetry shows that the point C will be the same for both, and that MC will equal MN. Hence the lines MN, MC, NC will form an equilateral triangle.

Each of the lines ME and NF about which the foldings are made cuts the triangle symmetrically into two halves. They are two of the so-called medians of the triangle. The other median is the original fold along the middle line of the sheet of paper. These three medians meet in the point X, which is the centre of figure of the triangle.

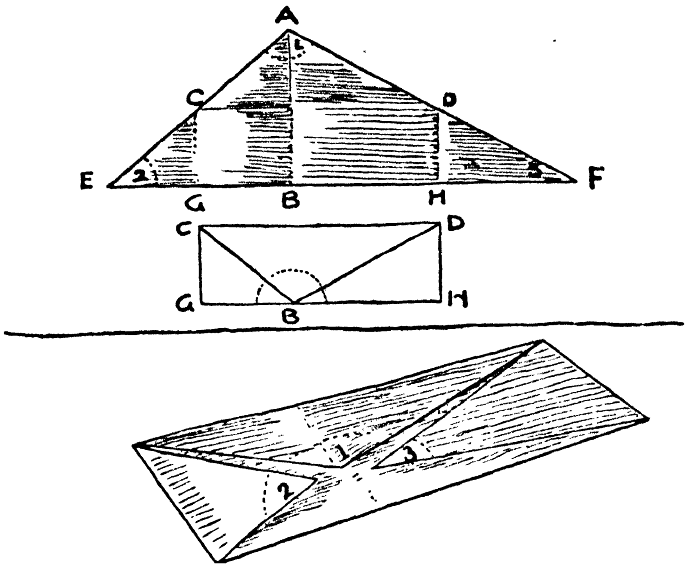
We may now cut out the triangle MNC, and use it to obtain a regular hexagon. This is done simpiy by folding the paper so as to bring the three points M, N, C to the middle point X. The outline of the folded paper will then be a perfect hexagon.



5. THE PENTAGON AND THE FIVE-POINTED STAR.

Euclid showed long ago how to construct by simple geometry the regular pentagon. The process is not, however, very easy to carry out, and it does not lend itself to great accuracy.

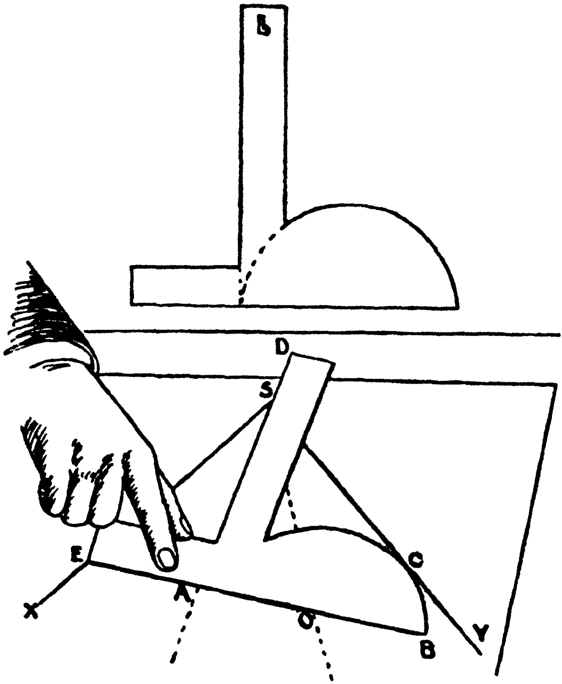
But the problem may be solved in a very simple, practical way by folding and knotting a strip of soft paper. Make a simple trefoil knot on such a strip, and then gradually pull it tighter and tighter, taking care that the strip retains throughout its flat form, and finishes without leaving any gaps between the contiguous strands. The process is indicated in the upper figure on the left, with the completed knot on the lower figure. By doubling over the one end and holding up to the light, as in the right-hand figure, we obtain the five-rayed star.



6. SUM OF ANGLES OF A TRIANGLE.

As an introduction to geometry children are often set to draw different types of triangle, and then by measuring with a protractor the three angles endeavour to verify the statement that the sum of the three angles of a triangle is equal to two right angles. This is educationally pure waste of time, for the verification is not convincing on account of the inevitable errors of observation which immature minds cannot understand. In Euclidean geometry the truth is demonstrated when the axioms and postulates laid down by Euclid are accepted as true. But a proof quite convincing to the youthful mind may be given by the simple folding of a piece of paper. Cut out of paper any form of triangle AEF. Fold it on the line AB, which is effected by noting that the two parts of the base EB and BF lie along each other. The angles ABE and ABF are, therefore, equal, and equal each to a right angle. Spread the triangle out again and fold each side so that F lies on B and E lies on B. It will then be found that when the paper is folded so as to bring A also to lie on B the sides of the folded parts run close together and the whole space GBH of two right angles is filled up with the angles at E, A, and F.

It is easy to see that the lines of fold CG, DH, bisect the parts of the base EB and BF, and that CD bisects AB, the vertical perpendicular on the base. The result of the triple folding is evidently a rectangle, so that CD is parallel to EF and equal to the half of EF.



7. THE TRISECTION OF AN ANGLE.

THE trisection of the angle is a famous problem dating from antiquity. The Greek geometers knew that it was impossible to give a general method for the trisection of an angle by use only of the straight-edge and compasses. Other curves than the circle may, however, be used; and since some of these curves may be traced by comparatively simple mechanical contrivances, various forms of trisectrix have been from time to time devised.

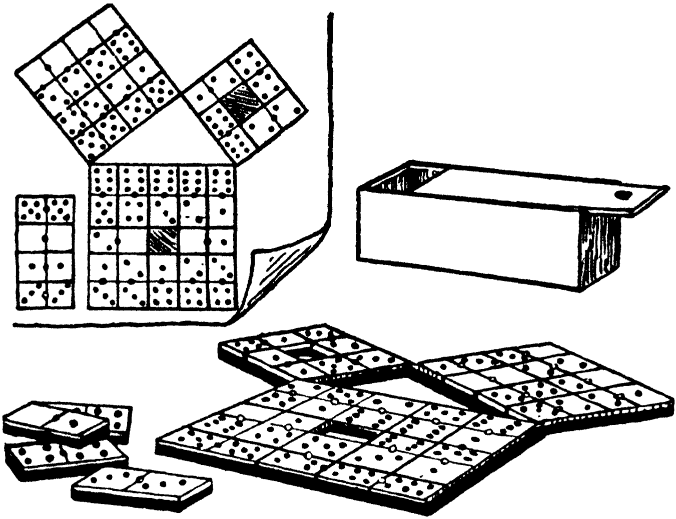
The following apparatus may be easily constructed.

Take a sheet of stout cardboard and with the centre O in a straight line EAOB, describe a semicircle of radius OA, and make AE equal to OA. Thus the points A and O trisect the line EB. Draw AD perpendicular to EB, and, therefore, tangential to the semicircle at the point A. Carefully cut out the part bordered by the line EB, the greater part of the semicircle BCA, and most of the line AD, leaving attached pieces sufficient to hold the whole firmly together. The appearance of the completed apparatus is shown in the upper figure, and the manner of using it in the lower figure.

Let XSY be the angle which is to be trisected. Place the point S on the line AD, and adjust the framework until SX passes through E and SY is tangential to the semicircle, say at C. Mark on the paper the points A and O. Remove the framework, join SA, SO, and the trisection is effected—that is to say, the angle XSY has been divided into the three equal parts XSA, ASO, OSC.

The proof is simply given. Since SA is perpendicular to the EO, and EA is equal to AO, the triangles ESA and OSA are equal in all respects, and therefore the angles ESA and OSA are equal.

Again, since the lines SA and SC are tangents to the same circle from the point S, they are equal in length. The radius OA is equal to OC, and the line SO is common to the two triangles ASO and CSO. Hence these are equal in all respects. Consequently the angle ASO is equal to the angle CSO. Each is, therefore, the third part of the angle XSY.



8. THE SQUARE OF THE HYPOTHENUSE.

THE famous theorem of Pythagoras that in any right-angled triangle the sum of the squares on the sides containing the right angle is equal to the square on the side facing the right angle, may be prettily illustrated in a particular case by means of dominoes.

Note that each domino is a rectangle composed of two squares, on which the various numbers are graphically shown. Let us regard this small square as the unit. Eight dominoes placed close in two rows of four will form a square whose side is equal to four times the unit length, and whose area will be 16 times the unit square.

If we arrange two rows of five dominoes set close side by side, and then separate them by two dominoes set in between their ends, we shall obtain 24 unit squares with an empty unit square in the middle—that is, 25 in all. This is the square of 5.

Finally arrange four dominoes round an empty unit square in the middle. We shall then have a square of 3 units length to the side, and of 9 unit squares (including the empty one) for its area.

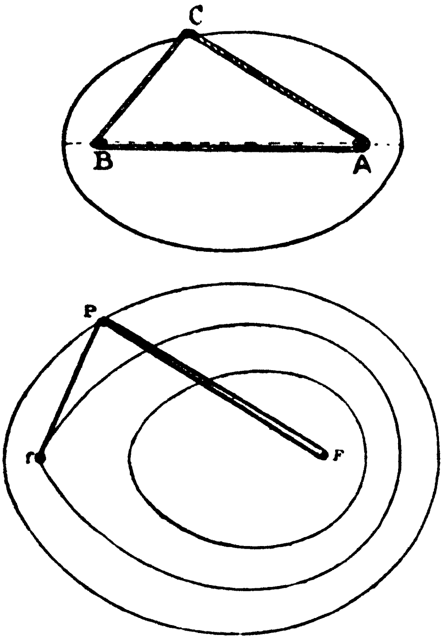
Bring these squares together as shown, and it will be found that the sides of the two smaller squares will meet at a right angle, their continuations being in the same straight lines.

Thus the triangle is a right-angled triangle with sides equal to 3, 4, and 5, and it is obvious that $3^2 + 4^2 = 5^2$ or $9 + 16 = 25$.

It will be noticed that all the dominoes are not in use. There are 28 dominoes in a full box—that is, 56 half dominoes. In the figure there are 9 + 16 + 25 = 50 small squares, but two of these are empty of dominoes. Hence only 48 half dominoes are used, leaving 8 half dominoes or 4 whole dominoes unused.

In the upper left-hand corner of the picture is shown an arrangement which possesses a further curious property. The dominoes are arranged so that the number of points on the dominoes composing the large square is equal to the sum of the number of points on those composing the other two squares. Each sum in this case is 75, making 150 in all. The dominoes not in use sum to 18, making up the necessary 168 for all the points on a complete set of dominoes.

Other arrangements are possible having the same property. All we have to do is to interchange the places of any pair of dominoes having the same sum total of points. For example, 5–2 on the four-square may be interchanged with 6–1 on the three-square, or with 4–3 on the five-square. Or the unused 3–3 may be put instead of the 4–2, or the 5–1, or the 6–0; and so on.



9. TO DRAW AN ELLIPSE.

The ellipse is the simplest of oval curves. A circular plate looked at obliquely has the form of an ellipse. Its shadow as projected on a surface inclined to the plane of the plate will also be elliptical.

The simplest method for drawing an ellipse is to do as a gardener does when he wishes to trace out an oval flower-bed. He drives into the ground two pegs a few feet apart, attaches to them the ends of a cord, and then with a third peg draws the cord taut and moves it round the two fixed pegs until a complete contour is traced out. This contour is an ellipse.

To apply the same method on paper, pin the paper down to a table or board by two strong pins a few inches apart. Take a sufficiently long string with the ends tied together to form a loop. Lay this loop on the paper so as to enclose both pins. Then, inserting a pencil point within the loop, push out the string on the one side until the whole is taut. Move the pencil point C over the paper, and the ellipse may be wholly described by one continuous motion.

The shorter the string is in comparison with the distance between the pegs, the narrower the ellipse will be compared with its length. The nearer to each other the pins are placed, the nearer is the approximation of the ellipse to the circular form. By adjustment of the relative lengths of the string and of the distance between the pins we may get a great variety of forms of ellipse, from the circle to the elongated form differing very little from a straight line described twice over.

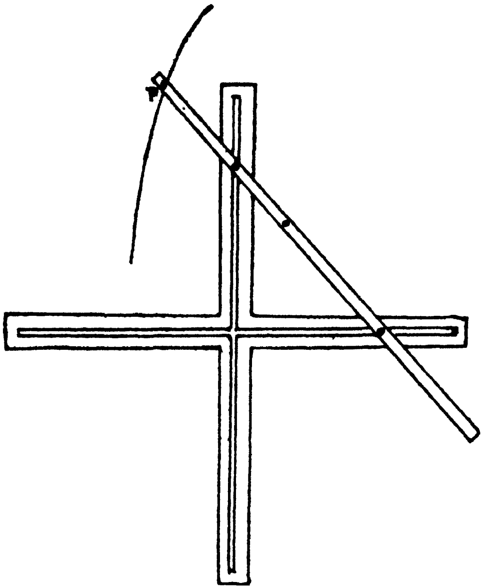
The property of the ellipse made use of in this mode of description is that the sum of the distances of any point on the curve from two fixed points is the same.

As the pencil point C moves round the curve it is evident that the one distance AC shortens at the same rate as the other distance BC lengthens. Hence the pencil point must move so as to bisect the angle between CA and BC produced. But this is the direction of the tangent to the curve at the point C.

Suppose that the inside of the ellipse is a mirror, and that A is the position of a source of light. The rays from A will be reflected from the elliptical surface in such a manner that the reflected ray makes the same angle with the tangent as the incident ray. Hence the reflected ray will pass along the direction CB. This will be true for all positions. All rays from A will, therefore, be concentrated on B after reflection. B will be the focus of rays emanating from A; and *vice versa* A will be the focus for rays emanating from B.

In astronomy the ellipse is of great importance, since it is the curve described by planets round the sun and by satellites round the planets. The planetary paths are nearly circular, but the paths described by comets are long drawn ellipses. In all cases the sun occupies one of the points A or B, each of which, from the optical property given above, is generally called a focus of the ellipse. The point half-way between the two foci is the centre. The longest diameter of the ellipse is called the major axis; and the ratio of the distance of either focus from the centre to the half major axis is known as the eccentricity of the ellipse. It is this number which determines the shape of the curve. All ellipses with the same eccentricity are said to be similar.

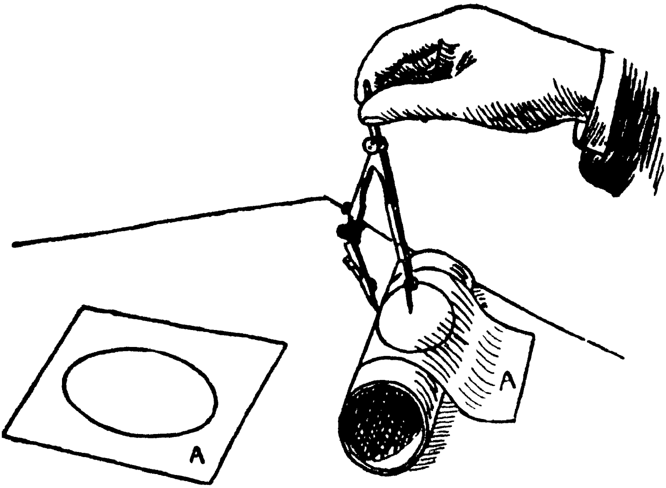
As shown in 1844 by James Clerk Maxwell, then a boy of fourteen, other forms of oval may be described by a similar use of string and foci. Thus having made small loops at the ends of a piece of string, slip one loop over one of the pins, *f*, and place the pencil in the other loop. Pass the string once round the other pin, F, and adjust the pencil until it bears against the string and keeps the whole quite taut, as in the lower figure. The pencil P will now trace one of a set of egg-shaped ovals as shown in the figure, which is taken from Maxwell's paper in the *Proceedings* of the Royal Society of Edinburgh (Vol. II., 1846). The geometrical property is that the distance from the one focus added to twice the distance from the other is constant. The



10. THE ELLIPTIC COMPASSES.

ANOTHER way of describing an ellipse is to make a rod move so that its ends move along two straight lines, which for convenience are generally taken at right angles to each other. Any point in the rod will describe an ellipse, with the exception of the end points, which describe straight lines, and of the middle point, whose path is a circle. But mathematically a circle is an ellipse of zero eccentricity.

This property has been utilized in the elliptic compasses, which may be constructed either of metal a cross, with two grooves running along the centre of each crosspiece, as shown in the figure. A third rod carries two pegs which are of a size to slide easily but not loosely in the grooves. When this third rod is applied to the cross framework (fixed to a table or to a blackboard by pins on the under side) and moved so that the pegs slide one in each groove, any point in rigid connection with the rod will describe an ellipse. A sliding piece capable of being clamped in any position may be attached bearing a pencil, or simply holes may be made in the rod in various positions through which a pencil or piece of chalk may be passed.



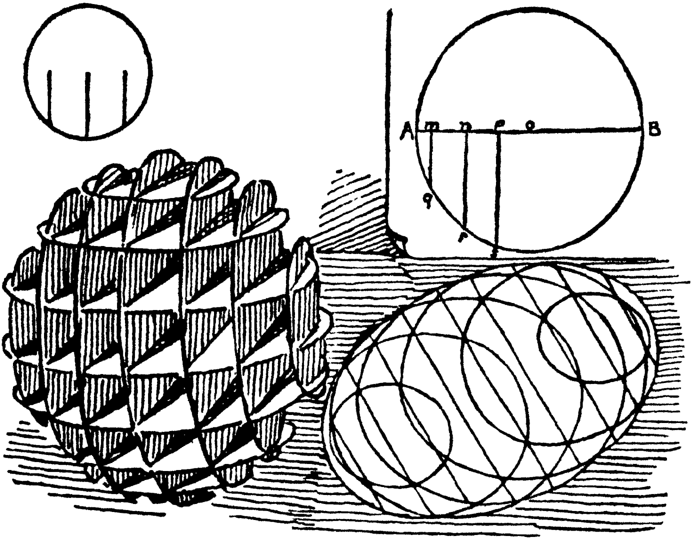
11. TO TRACE AN OVAL WITH A PAIR OF COMPASSES.

THE ellipse is the simplest form of oval. There are, however, many other forms; and if merely an oval shape is required, such a curve may be obtained by use of an ordinary pair of compasses.

It is sufficient to trace with the compasses a curve upon a piece of paper wrapped round a cylinder. This cylinder may be conveniently made of card-board, adjustable at will to any size of arc. When the paper is wrapped round it, set the point of the compasses on the top and describe what would be a circle on a plane. As the trace is being made every point on the curve will be at the same distance from the pivot of the compasses; but when the paper is flattened out the curve will appear to be an oval. The distance along the curved surface is in general greater than the distance on the flat, so that the longest axis of the oval will be in the direction which passes round the cylinder.

Mathematically expressed this oval curve is the intersection of a sphere and a cylinder. Mechanically the radius of the sphere cannot conveniently be greater than the quadrant chord in the section of the cylinder; but mathematically there need not be this limitation. The curve of section may pass round to the farther side of the cylinder. If the radius of the sphere is equal to the diameter of the cylinder, the curve of section on the unrolled paper will be like a figure of eight. For radii greater than the diameter of the cylinder the curve breaks up into two distinct and similar contours, which resemble ellipses more closely as the radius of the sphere is taken greater and greater.

at to-
, circles
dovetail



12. CONSTRUCTION OF A PAPER SPHERE.

DRAW with compasses on a sheet of paper a circle of three and a-quarter inches diameter, or one and five-eighths of an inch in radius. Draw any diameter AB, and mark off from the centre equal distances of successive half inches, *op*, *pn*, *nm*. The remainder *m*A will then be one-eighth of an inch. At the points of division draw perpendiculars *ps*, *nr*, *mq*, meeting circle·cle in the points *r*, *s*, *q*.

point radius A*o* and the three perpendiculars give the pi·ths of the radii of the circle-elements of the sphere, which are to be described on strong paper or cardboard and then cut out.

The number of circle-elements required will be as follows :—

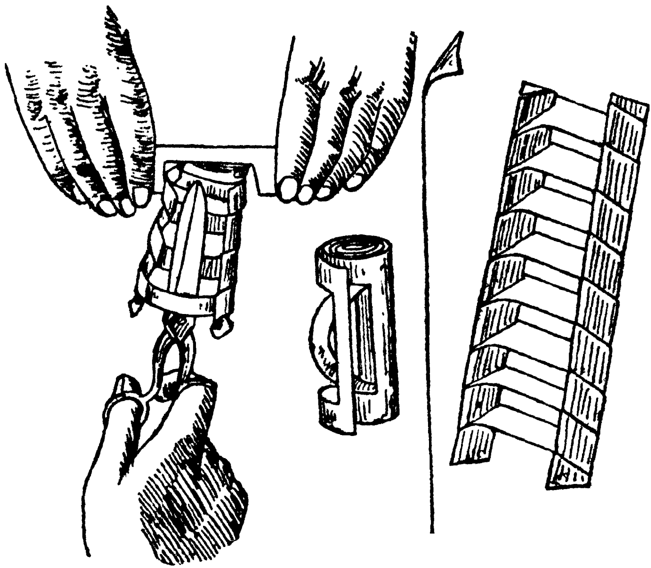
2 circles (No. 1) of radius *Ao*
4 circles (No. 2) of radius *ps*
4 circles (No. 3) of radius *nr*
4 circles (No. 4) of radius *mq*
} 14 elements in all.

Each of these circles is to be treated as was the original circle. A diameter is drawn and successive half inches marked off from the centre. From these perpendiculars are to be drawn on both sides of the diameter, and also the perpendicular through the centre of each circle. The smallest circles (No. 4) will have three perpendiculars ; those of No. 3 will have five ; and those of Nos. 2 and 1 will have seven each.

Having cut out the contours of the fourteen circles with scissors or knife, proceed to cut away very narrow slits along the perpendiculars, the narrowness being determined by the thickness of the paper or cardboard used. Each slit is cut from the rim of the circle to the diameter.

The circle-elements are now ready to be put together in the form of a sphere. Take the two circles of No. 1 and fit them into each other, dovetail fashion, by their central slits. They will form two concentric circles with a common diameter. Hold them perpendicular to one another, and then piece by piece fit in similarly the other circles in their appropriate places, two of No. 2 in the slits on each side of the central slit, two of No. 3 in the slits next to these, and two of No. 4 in the outside slits. It now remains to fit in the six remaining circles into their appropriate places at right angles to the first set. This final fitting will be found to be somewhat more troublesome to effect. When all is done properly the final appearance will be as shown in the picture. The edges of the circles will suggest a spherical surface passing over them all.

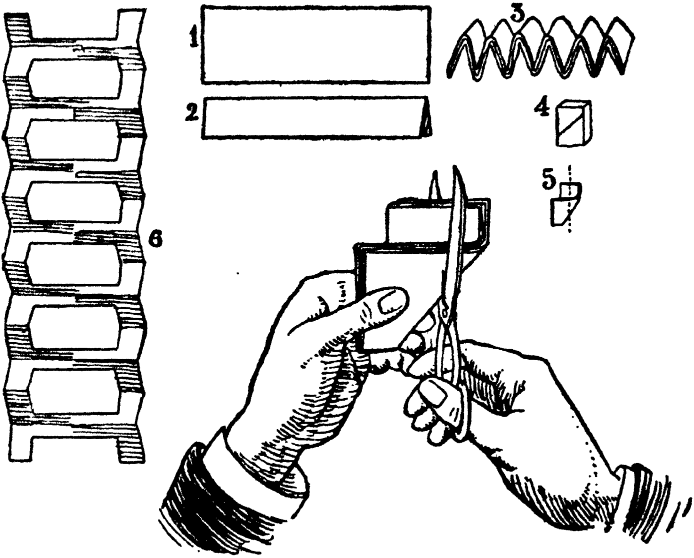
When by a slight shearing movement the angle between the two fundamental circles, on which the whole is built, is made other than a right angle, the figure will be deformed into a spheroid, which may become flatter and flatter until the whole collapses into an elliptic-shaped figure nearly in one plane. This is shown in the lower right-hand figure. From this flattened form the sphere may again be obtained by simply rotating the parallel circles of one set until they meet those of the other set at right angles.



13. THE PAPER LADDER.

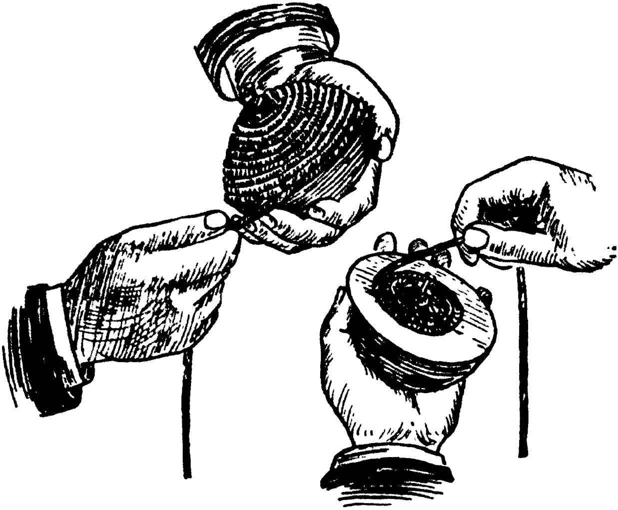
THE problem is to make a ladder out of a single sheet of paper, without using gum or other adherent, and this to be effected with three cuts with the scissors.

Take a sheet of thin yet fairly stiff paper, and roll it up into a short compact roll. Make two parallel cuts across the roll, each being about half an inch from the one end. Then make a long cut parallel to the axis of the roll and terminated by the cross cuts. This will produce a gap in the roll. Holding the roll lightly in the fingers ease out the ends of the first strip, which lies at the bottom of the gap, then taking the strip with the teeth and holding the roll lightly by its two ends, slowly draw the strip out of the gap. This operation is perhaps more easily done by asking a friend to do the drawing out. Care must be taken not to hold the ends of the roll too tightly in the hands, otherwise the paper will be apt to tear. When the process is carried out properly the whole inside of the roll will be drawn through the gap, the connecting parts of the successive strips being twisted. The final result will be a series of broad paper strips which serve as rungs in the ladder, whose upright sides are formed by the twisted parts. These should be flattened after the rungs have been all drawn out.



14. A PAPER LADDER BY A SINGLE CUT.

TAKE a single sheet of paper (Fig. 1), and double it along its length (Fig. 2). Bend it a number of times, concertina-wise, by folds about transverse lines, as in Fig. 3, and then bend the compact mass (Fig. 4) obliquely, so as to turn the one end at right angles to the other (Fig. 5). If now you cut along the dotted line and open out the paper, you will obtain the ladder of Fig. 6. To get a large number of rungs you must use a corresponding thinness of paper.

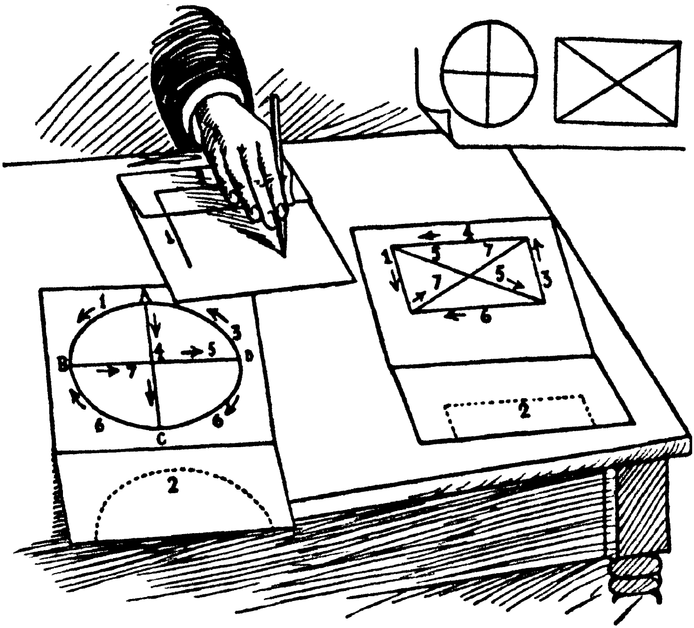


15. SURFACE OF THE SPHERE.

We have used dominoes to verify the theorem of the square of the hypothenuse; we have established the theorem of the angles of a triangle by simply folding a piece of paper; we propose now to appeal to a coiled cord to prove that the surface of a sphere is four times the area of a central plane section.

Saw a ball into exactly two halves, so as to get two hemispheres with plane circular faces. Nail one end of a cord to the centre of a plane face, and then coil the cord spirally round the centre, as shown in the lower figure of the illustration. When the whole face is covered with the cord, cut off the part so used, and lay it aside. In the same way, nail the one end of another piece of the same cord to the pole of the hemisphere and coil the cord round this pole in a spiral form, so as to lie close to the spherical surface —very much after the manner of coiling the cord on a spinning top. When the whole curved surface of the hemisphere has been covered, cut off the part of cord required. On comparing the two lengths of cord required for these two operations we shall find that the one is exactly double the other. Hence the area of the curved surface of the hemisphere is twice the area of the diametral plane, and therefore the whole surface of the sphere is four times the area of a great circle on the sphere.

This proposition was first proved mathematically by the famous Archimedes.

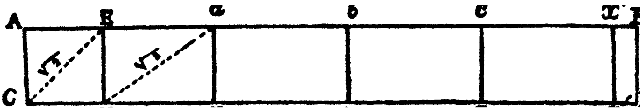


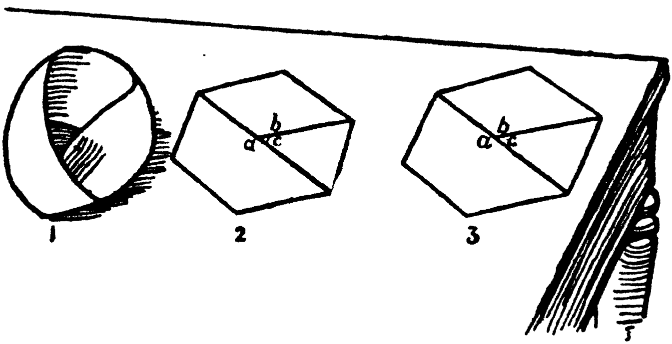
16. THE RECTANGLE AND ITS DIAGONALS.

To trace a rectangle and its two diagonals is a simple thing to do; but if we add the condition that it is to be traced by a continuous motion of the pencil, each line being only once described, the problem becomes difficult—indeed, in a strict sense, impossible. It may, however, be effected by use of a simple trick.

Double over the bottom of the paper on which the rectangle is to be drawn. Beginning at the left-hand upper corner of the rectangle, draw the vertical side on the paper and continue it on to the folded part for a little way. Move the pencil horizontally to the right to a certain distance, and then move upwards, tracing a line parallel to the first, partly on the folded part, and continuing until the right-hand upper corner is reached. Draw the upper horizontal side of the proposed rectangle, coming back to the original starting-point. From there pass downwards to the right to the point where the right-hand vertical leaves the folded part, then along the margin of the folded part and finally upwards to the right to the upper right-hand corner. Unfold the paper, and the rectangle and its diagonals will be seen complete. The process may be gone through without the fold, and then there will be two rectangles with a common side, but the upper one will have its diagonals. This shows that the trick is exactly the same as if we had drawn the base of the rectangle twice over.

By the same method we may draw at one sweep of the pencil a circle with two perpendicular diameters. Fold the lower part of the paper as before, then beginning at the top point of the proposed circle describe a quadrant, and continue with the semicircle on the folded part, and complete the circle with the fourth quadrant. Now double back the folded part so as to leave the sheet open; and then, having drawn the vertical radius to the centre and one horizontal radius to the circumference, draw the semicircle so as to complete the circle again, finishing finally with the second horizontal radius and the second vertical radius. This is, of course, practically equivalent to tracing the lower half of the circle twice over. In the figure the successive arcs and lines are numbered in the order of their tracing.





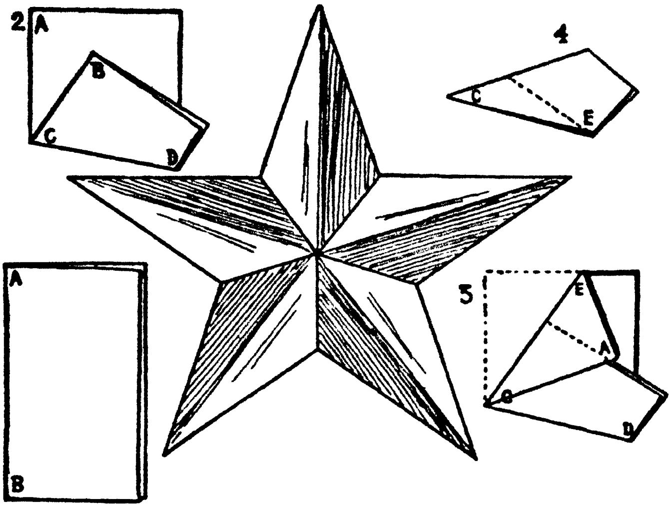
17. TO CONSTRUCT A HEXAGON BY FINGER PRESSURE.

TAKE a strip of paper about five and a-half times longer than its width, give the one end half a turn and then gum it to the other end. You will obtain a bracelet of the form shown in Fig. 1. If this curious twisted strip is pressed flat to the table, a hexagon, more or less irregular, will be produced. A regular hexagon will be obtained if the length to the width is properly adjusted.

It may be shown that, if the length of each edge of the strip is $3\sqrt{3}$ times its width, the hexagon formed in this way will be equal sided and equal angled—that is, a regular hexagon. Now $\sqrt{3}=1{\cdot}7321$, and hence $3\sqrt{3}=5{\cdot}193$. A strip of paper 1 inch broad and 5·2 inches long will give very accurately the regular hexagon.

The following simple construction gives the required ratio without any calculation. Let the strip be ABCD. Fold over the corner A into the position CEF. If the width of the strip is called unity (it may, of course, be any convenient length) the diagonal CE of the square AF is equal to $\sqrt{2}$. Now lay the length CE along EB, so that the point C will come to position a. Then, since $Fa^2=FE^2+Ea^2=1+2=3$, we have $Fa=\sqrt{3}$. We have simply to lay this length three times along aB, namely, ab, bc, and cx', to obtain the length $ax'=3\sqrt{3}$. Fold the paper along ax, and cut off the part to the left of this line. Leave a small extra length x'B and a'D for gumming purposes. Give the one end half a turn and bring x' to x and a' to a, gumming the part x'Ba'D to the paper near the end ax. This twisted band when pressed flat will give the regular hexagon, as shown in Fig. 3.

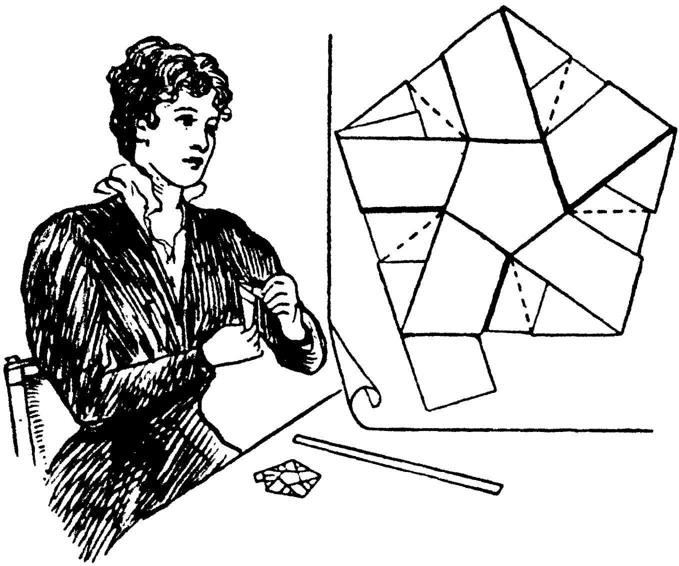
The twisted strip (Fig. 1) has many curious properties which have engaged the attention of mathematicians. If we start from any point, say, on an outward-looking part of the surface, and travel round it parallel to an edge, we shall come after one revolution to the other and inward-facing side of the surface. Again, take a pair of scissors and cut along the middle line parallel to the edges. The ring will open out into a ring of double the length and half the width, but with two half-turn twists upon it. If we cut this ring along its middle line, it will become two interlocked rings, each with two half-turn twists upon it; and so on.



18. THE FIVE-POINTED STAR WITH A SINGLE CUT.

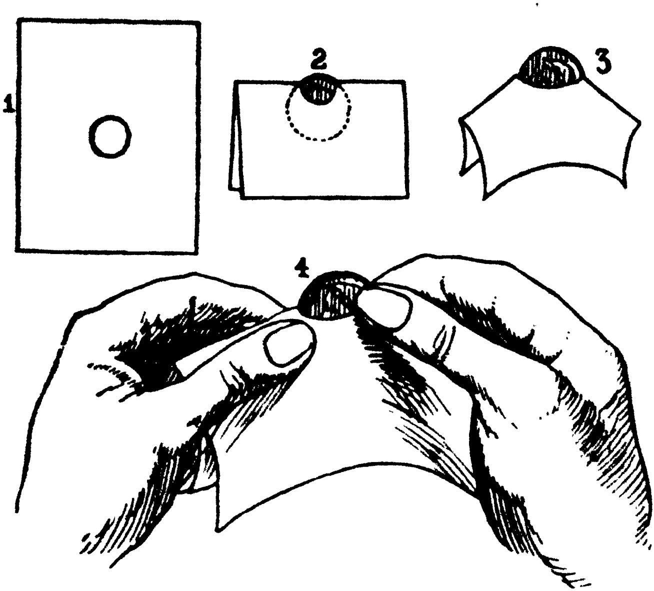
To obtain by a single cut of the scissors a five-pointed star in paper.

Take a sheet of double-paged paper as in Fig. 1, fold it about CD (Fig. 2) so that A lies in the continuation of the edge through B and the angle ACB is half the angle BCD (Fig. 2). To get this relation sufficiently accurate, all we have to do is to go on with the folding. Fold the part A along the line CB, as shown in Fig. 3. Then a final folding about the new position of CA should bring the margins CE and CD to coincide, as indicated in Fig. 4. If however, CE falls short of CD in the last folding, it is clear that we began with too small an angle ACB. Undo the foldings and readjust ACB, and then fold again as described, until the compact form of Fig. 4 is obtained. If now we cut obliquely from the position of E after the third folding to any convenient point to the right of the apex C, this triangular part cut off will, when opened out, have the form of the five-pointed star. It is important to cut so as to pass either through the position of B or to the left of that position; otherwise one of the points will be truncated.



19. THE SEVEN PENTAGONS.

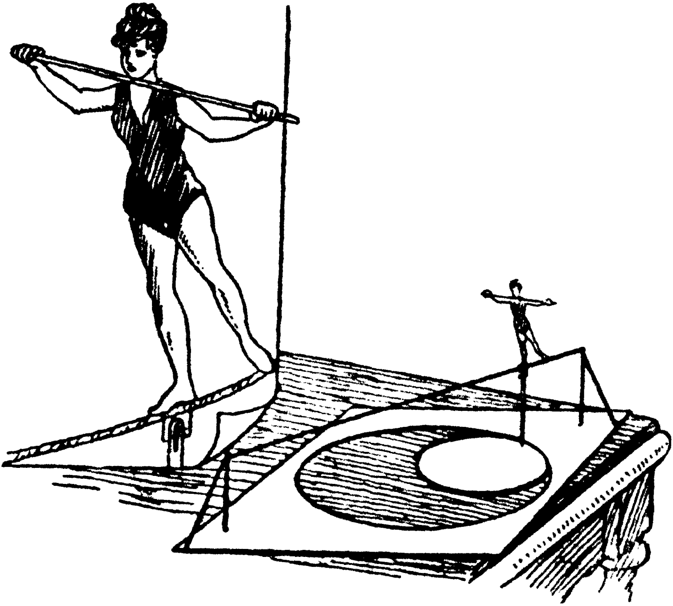
We have seen how to construct the principal regular figures by means of folded paper. By continuing to form a succession of simple knots on a strip of paper we may form a figure which contains seven pentagons. The strip must not be less than 35 times longer than it is wide. To give easy margin, make the length 40 times the width. Then beginning near one end, form the succession of single knots so that they follow one another as closely as possible. The result should be as shown in the figure. Here we have the empty space within bordered by a pentagon, which is also the form of the external contour. From each corner of the inner pentagon draw a pencil mark to the point where the fold meets the external side, as shown by the dotted lines. These pencil marks, with the contiguous edges of the external and internal pentagons, will form five other pentagons, corresponding to the knots—that is, seven in all.



20. "A CAMEL THROUGH THE NEEDLE'S EYE."

LAY a coin—a shilling or a halfpenny, for example—on a sheet of paper, and trace its contour with the sharp point of a pencil bearing close on the rim. This, when cut away, will be a hole through which the coin will just pass.

Now through the same hole we may make a much larger coin pass without tearing the paper. Fold the paper along the diameter of the hole, as shown in Fig. 2. Place a penny or a florin, or even half-a-crown, within the folded paper, so that part of the rim projects through the hole. Grip this part with the thumb and forefinger of one hand, and by a little gentle coaxing you will be able to pull the coin through without damage to the paper. The circular hole becomes drawn out, aided by the deformability of the paper.



21. CIRCULAR INTO RECTILINEAR MOTION.

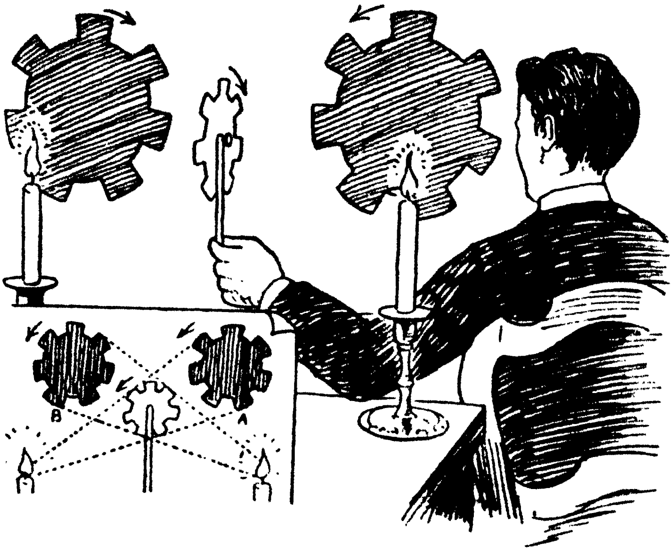
geometry of motion tells us that if one circle roll in the interior of another of twice the radius, any point in the smaller circle will describe an ellipse which will take the special limiting form of a circle when the point is the centre of the circle, and the other special limiting form of a straight line when the point lies on the circumference of the smaller circle. This last case is of importance in mechanism, since it gives the means of transforming circular motion into rectilinear motion.

The strictly straight line motion of a point on the circumference of the rolling circle may be demonstrated in a simple manner.

Cut out of a large sheet of cardboard (an old calendar, for example) a circle one foot in diameter, and out of this circular portion cut out a smaller circle of six inches diameter. Place the sheet of cardboard with the large circular hole in it on a table, and the small circle may then be made to move within it with a rolling motion on the large circular contour.

Insert the fine point of a sewing-needle as close as possible to the border of the small circle; then, as the small circle performs its rolling motion, the needle will describe a diameter of the large circular hole. To prove this, stretch a thread through the eyes of two needles placed in line with a diameter of the large circle and on opposite sides, as shown in the figure. As the small circle is made to roll round within the large circle the head of the needle attached to it will pass close to the thread.

A little variety may be given to the demonstration by fixing to the moving needle a small pasteboard figure of a tight-rope dancer, who will pass to and fro along the stretched thread as the circle continues its rolling motion.



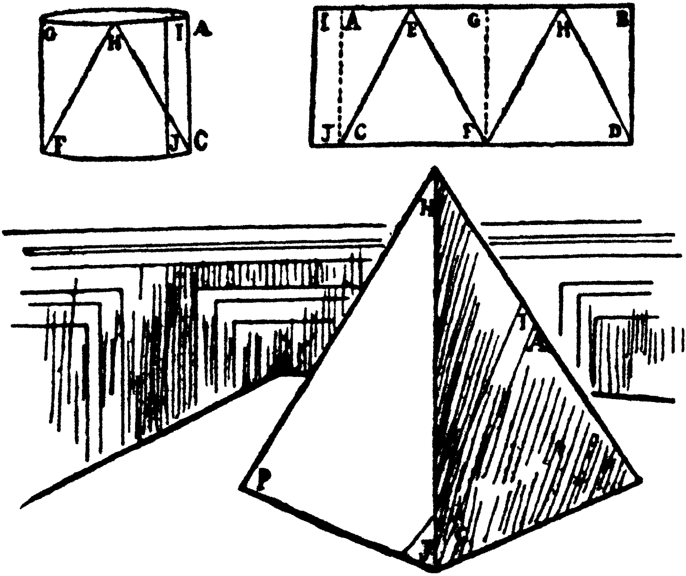
22. THE INVERSE SHADOWS.

Cut out of a piece of cardboard a circular wheel furnished with six or eight large teeth, and support it by a pin through its centre at the end of a vertical rod of wood. Place two lighted candles about a yard apart, and at the same distance from a white screen. Hold the wheel parallel to the wall, so that two shadows are cast on it. These shadows will be circular, in accordance with the geometrical truth that parallel sections of a cone are similar. If the wheel is made to turn round, the shadows also will turn in the same direction, as shown in the small figure to the left of the illustration.

There is, of course, nothing unexpected in this. But what of this problem: Can the shadows be made to turn in opposite directions?

The problem, impossible to solve though it may seem to many of our readers, is solved very prettily by taking advantage of a theorem in geometry regarding cones and their sections. Let a cone be constructed by drawing lines from a point to the circumference of a circle set oblique with regard to the point. Not only will all sections of the cone by planes parallel to the circle be also circles, but there is another set of parallel planes inclined to the first set which will also give circular sections. These are known as the circular sections of Apollonius, the ancient geometer who discovered them.

To demonstrate the existence of these other circular sections, set the wheel at right angles to the screen, and move it to and fro along the line equidistant from the candles. We shall soon by trial obtain circular shadows again—the sub-contrary sections, as they are called; and now if we rotate the wheel the two shadows will appear to be rotating in opposite directions. The arrangement is shown in the figure.



23. A CYLINDER TRANSFORMED INTO A PYRAMID.

TAKE a strip of paper ABCD, with a small added part IJ, which is to be gummed under the end BD in such a way that BD coincides with AC. The strip is now a cylinder of height AC, and circumference AB.

Flatten the cylinder by folding it along the lines AC and GF half-way round. Mark the middle points E and H of AG and GB respectively, open out the cylinder, and fold it again along the oblique lines CE, EF, FH, HD. HGE will fall in line with H(BA)E, and CF will fall in line with FD. The result will be a tetrahedron, a four-sided figure each of whose sides is a triangle. Set on one face, it will appear as a triangular pyramid.

When the triangles are equilateral the figure becomes the regular tetrahedron. It will be formed when there is a certain ratio between the length and width of the strip used for making the cylinder in the first instance. The ratio is easily found from the upper right-hand figure. Here ECF and HFD are to be equilateral triangles. Let x be the side and h (= AC) the height of each triangle.

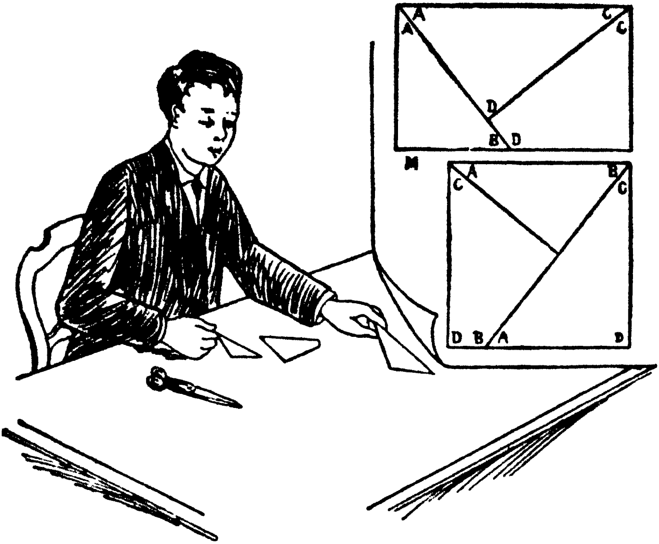
Then, by the well-known property of the right-angled triangle—

$$x^2 = CE^2 = AC^2 + AE^2$$
$$= h^2 + \frac{x^2}{4},$$
$$\text{or } \tfrac{3}{4}x^2 = h^2,$$
$$\text{or } x = 2h/\sqrt{3}.$$

Now the length of the strip is

$$= h \times 2{\cdot}308.$$

For example, if h is 1 inch, the length of the strip must be 2·308 inches plus (say) one-eighth of an inch for the gumming operation.



24. BY TWO CUTS TO CHANGE A RECTANGLE INTO A SQUARE.

LET AC be one of the long sides of the rectangle visiting card, for example. Through A draw a straight line AB, meeting the opposite side in B, and from C draw the line CD perpendicular to the line AB.

There will be one position for the line AB which will make the perpendicular CD equal in length to

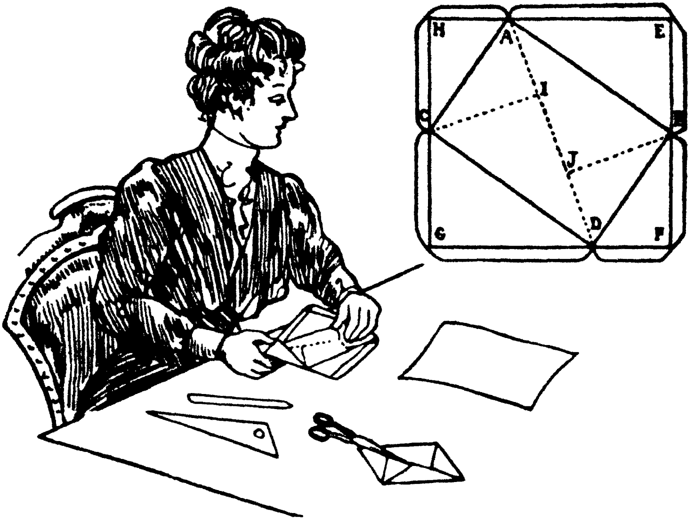
When it is found, then the three segments obtained by cutting along AB and then along CD may be arranged in the form of a square.

These equal lengths AB and CD constitute two sides of the square. Thus if a is the length of the rectangle and b the width, then $AB^2 = CD^2 = ab$.

Also $AB^2 = AM^2 + MB^2$, or $ab = b^2 + x^2$, or $x^2 = b(a-b)$ where x is the length MB. And thus the distance of B from M is the geometric mean of a and $a-b$.

For example, suppose the rectangle to be 3 inches long and 2 inches wide. Then the length MB will be $\sqrt{2(3-2)} = \sqrt{2} = 1{\cdot}414$. Measure this distance along the side, and join AB. By means of a set square draw the line CD perpendicular to AB. Cut along the lines AB and CD, and rearrange the pieces to form the square whose side is $\sqrt{2 \times 3} = \sqrt{6} = 2{\cdot}45$.

This construction is not possible with a rectangle whose one side is greater than twice the other. The point D will then fall outside the figure, and the long side will be longer than the greatest length, the diagonal namely, which can be drawn within the square equal in area to the rectangle.



25. THE MAXIMUM ENVELOPE.

GIVEN a rectangular sheet of paper, to form out of it a letter envelope of the greatest possible size.

Let the rectangle be EFGH drawn on a slightly larger sheet of paper so that there may be a uniform margin all round.

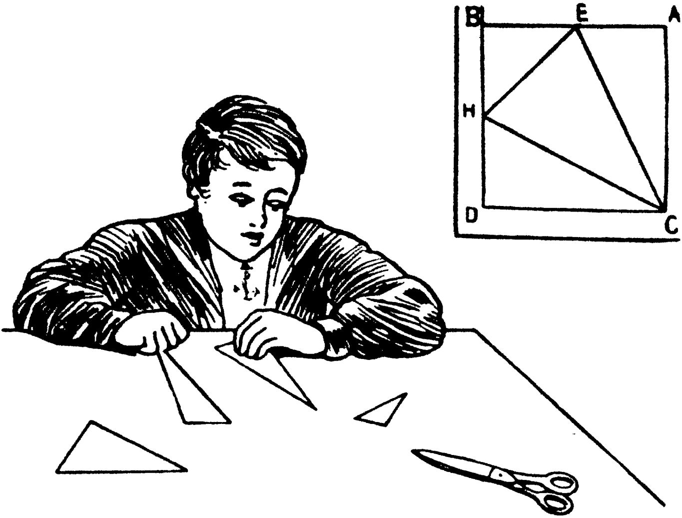
Mark the points B and C which bisect respectively the shorter sides EF, GH.

Bisect BC, and with this point as origin describe a circle passing through B and C, and cutting the other sides in two points. Let A, D be two of these points lying the one to the left and the other to the right of the central vertical line.

If we join CA, AB, and CD, DB we construct another rectangle ABCD.

We may also find the points A or D by using a set square, and placing it so that the right angle lies on the line HE or GF, and the straight enclosing lines pass through C and B.

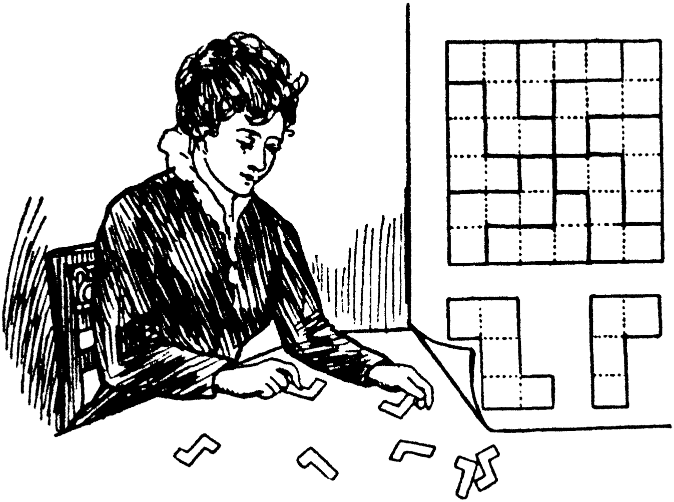
Now bend the outside corners round the lines AB, BD, DC, CA, and they will fill in exactly the same area, the edges touching along the dotted lines AD, CI, BJ. The margin, which should be notched at the point A, B, C, D, and rounded at the corner, serves for gumming purposes; and the envelope is complete.



26. PUZZLE SQUARES.

Cut off one of the corners BEH of a square sheet of paper, and cut up the remaining five-sided figure into three triangles along lines passing through the opposite corner. Mix up the four triangles in any haphazard order, throw them on the table, and challenge one of the company to piece them together to form a square. It is surprising how long he will take in general to solve this problem.

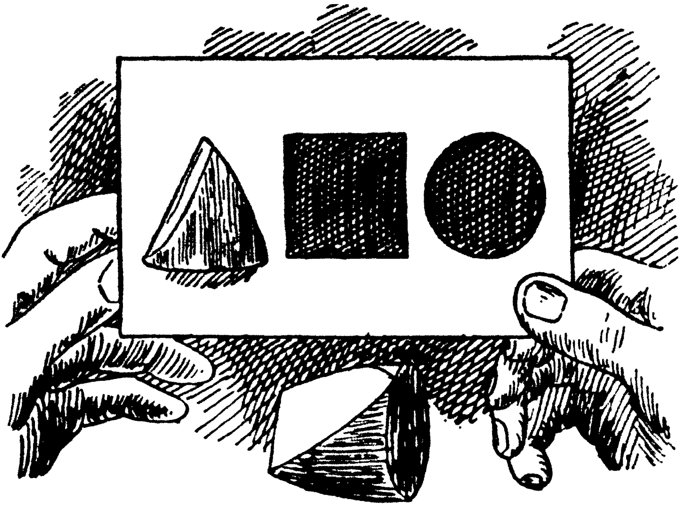
A more troublesome puzzle may be prepared as follows. Draw across the square two perpendicular lines such that each cuts one pair of opposite sides, and cut up the square along these lines. Then challenge any one to piece the parts together so as to form the original square. The solver will probably be misled by the fact that each of the four quadrilaterals so obtained has a right angle, and will imagine that this right angle should form one of the corners of the square.



27. THE FOUR Z'S AND THE FOUR L'S.

DRAW seven equidistant parallel lines, and at right angles to these an exactly similar set of seven equidistant lines. The external lines will form a square containing thirty-six small squares.

Mark with a heavier line, or with a different colour, the full lines, as shown in the diagram. It will be seen that these are symmetrically disposed with reference to the centre of the square. Cut along these specially marked lines so that the square is divided into eight parts, four of which resemble the letter L and the other four may, with a stretch of the imagination, be regarded as resembling the letter Z. Shake them well together and scatter them on the table, and then try to build up the square again. Or, better still, invite some one who rather fancies himself as a solver of puzzles to reconstruct the square. He will find it no easy matter.



28. THE UNIVERSAL PLUG.

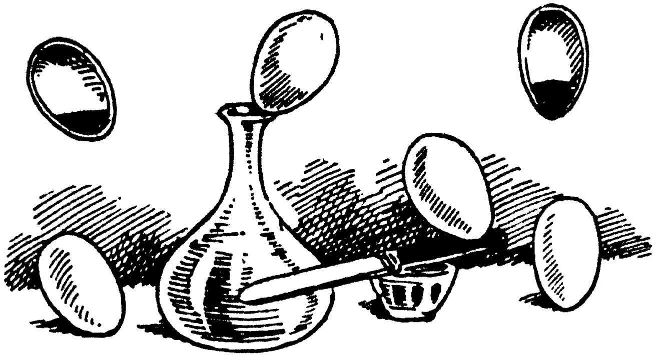
Cut out three holes in a piece of cardboard—a circle, a square, and an equilateral triangle. The height and base of the triangle must be equal to the side of the square and to the diameter of the circle.

The problem is to make one plug which will fill completely the three openings.

The problem is solved thus:

A cylinder of circular section equal to the circular hole, if made of height equal to its diameter, will evidently fill completely the circle and the square.

All that has to be done now is to make it fit the cylinder into the wedge form, with the thin edge of the wedge equal and parallel to one of the diameters of the circle. This plug will fill up the triangle when the edge of the wedge is directed towards the observer; and it will fill the square hole when the wedge is turned through a right angle, so that the edge runs along one of the sides of the square.



PART II.—PHYSICAL EXPERIMENTS.

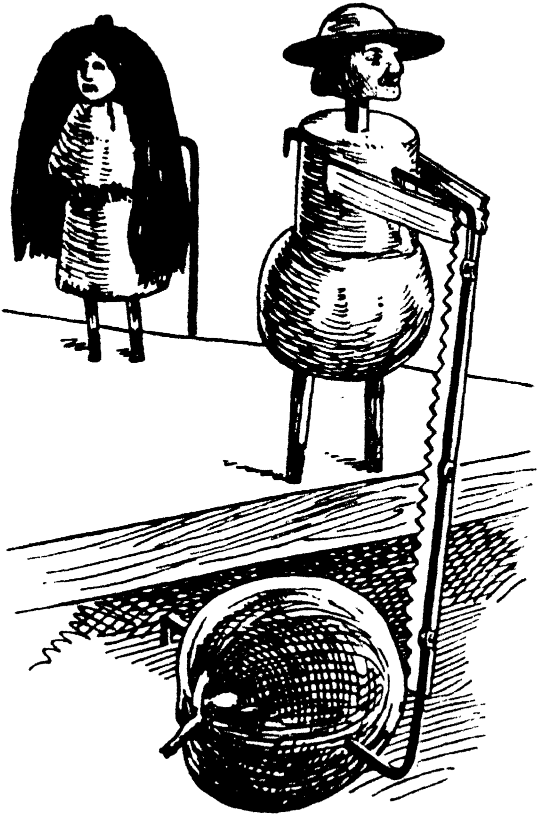
I. Weight and Equilibrium of Solids.

29. THE OBEDIENT EGG—THE DISOBEDIENT EGG.

Empty an egg by piercing a small hole in the shell. When the interior has become perfectly dry pour into it some very fine sand, sufficient to fill it about one quarter full, then close the hole with a little white sealing wax, leaving the egg indistinguishable from an ordinary egg.

If now, at breakfast, you skilfully introduce this prepared egg into your egg-cup, you may announce that your egg is very obedient, and will take any position into which you may wish to place it. The egg, in fact, will balance itself on the handle of a knife or the edge of a jug or decanter, etc., whether set on its end or in any oblique position, apparently in defiance of the laws of equilibrium. A slight shake will suffice to bring the sand into the desired position within the egg and so secure its equilibrium.

To produce the disobedient egg, introduce within it a few grains of lead mixed with small pieces of sealing wax. A gentle heating on the stove with the egg in an erect position will bring the lead and the melted wax to the lower end, to which the whole mass will adhere on cooling, thus permanently fixing the centre of gravity at a point close to this end. Such an egg will refuse to remain in any but the upright position.



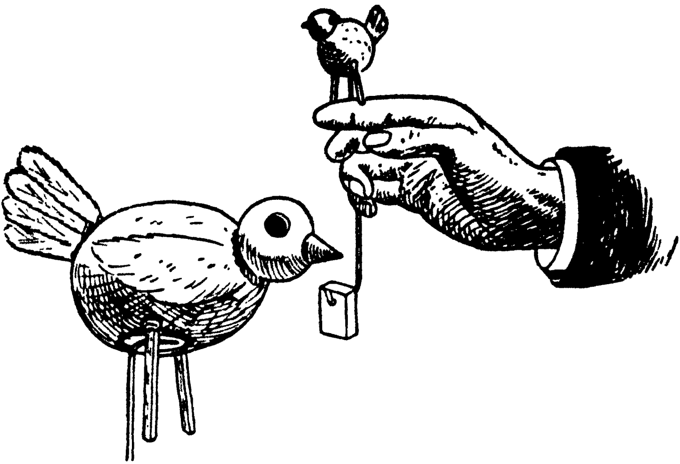
30. THE SAWYER.

By means of corks and matches a variety of animals may be very simply represented. When a biped, whether bird or man, is to be imitated, there is a difficulty about the balancing, unless a third point of support is introduced.

By the following arrangement, however, a suitable balance may be obtained, and the action imitated of a man working the upper end of a vertical saw. Insert into the rounded end of the cork of a champagne bottle two matches to serve as legs. The cylindrical part of the cork will then be the body, while the rounded part will suggest the bulging pantaloons of a Bretagne peasant. The head may be shaped out of a piece of bread, or nut, and fixed to the body by a short piece of match representing the neck, and surmounted by a broad-brimmed hat. The arms extended horizontally in front may be made of two strips of cardboard pasted to the sides of the cork. Bend the ends of a thickish iron wire at right angles so as to form three sides of a rectangle, the ends being about 2 inches long, and the long side about a foot or fifteen inches. The one end is stuck well into the breast of the little man, and the other is fixed into an apple or orange or other sufficiently heavy body. A serrated strip of cardboard fixed to the iron wire will complete the illusion.

This figure, set near the edge of a table, will be balanced by the weight at the lower end of the iron wire, and a slight oscillation imparted to it will give it a motion resembling that of a man working the end of a long saw.

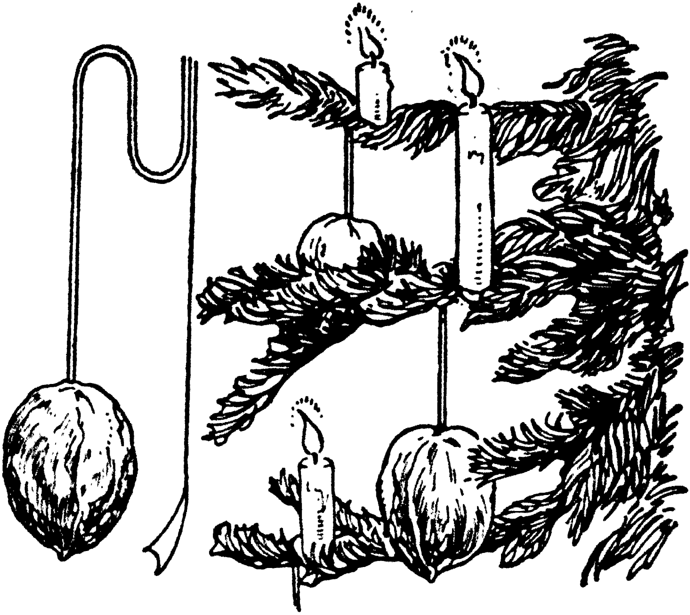
The same principle may be applied in the manufacture of other puppets, which may be made to face and bow to the audience by inserting the iron wire into the back instead of the breast.



31. THE BIRD ON THE BOUGH.

THE same method of lowering the centre of gravity may be used to obtain a bird balancing itself on a swaying branch. The body of the bird is an empty hen's egg open towards one end. This opening is closed with a ball of bread which forms the head. Two nail heads represent the eyes, and a piece of pointed wood the beak. The ball of bread should be prolonged within the shell and fixed with sealing wax. A few feathers pasted on behind will form the tail, and the resemblance to a bird may be still further increased by suitably painting the body or covering it with finely divided wool. Two matches fixed with wax will serve for feet.

The iron wire intended to support the counterpoise is bent at right angles at both ends, so as to form two hooks of an inch and a-half in length. The one hook is fixed under the shell a little behind the feet; and to the other is attached a sufficient counterpoise. The bird may then stand steady on the finger, or even on a branch of a tree where the gentle wind will make it sway and balance like a real bird.

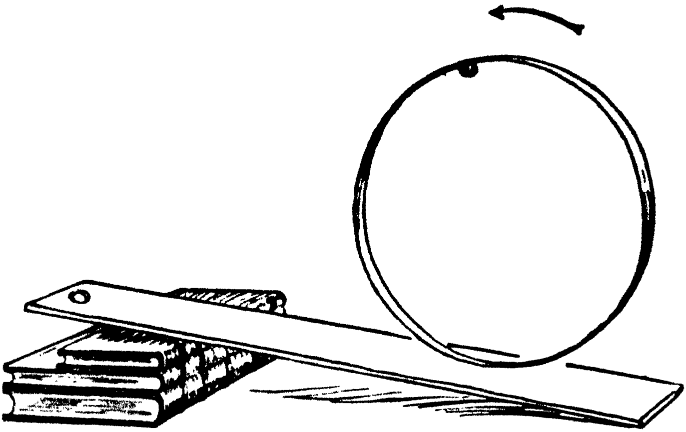


32. THE CANDLES ON THE CHRISTMAS TREE.

The decoration of a Christmas tree offers no great difficulty; the one essential is a little taste. Some guidance may, however, be necessary as regards the fixing of the candles to the ends of the branches.

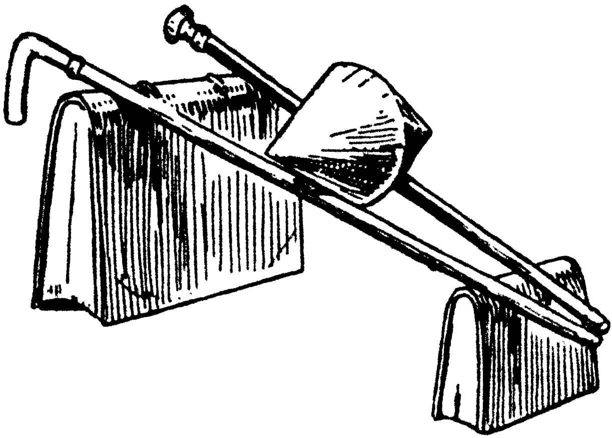
The main point is to attach the candles so as to have them absolutely vertical. Otherwise they will drop wax on people seated near the tree, and may even cause a conflagration.

The following method is at once simple and practical. Bend the end of an iron wire into a double hook as shown in the picture. Push the small end of the hook vertically into the base of the candle, and the long end into one of the gilt nuts or other decorations of Christmas trees. The inner hook is then hung over a branch, and the counterpoise at the end of the wire will keep the candle erect, whatever slope the branch may happen to have.



33. THE RING ROLLING UP THE INCLINED PLANE.

Make a ring of stout paper, attaching to the inside surface any small but comparatively heavy object such as a button or a drop of sealing-wax. Place the ring on a flat ruler inclined at a fair-sized angle, taking care that the small weight is as high as possible, and is further up the plane than the point of contact of plane and ring. When the ring is left to itself it will appear to roll up the plane. What happens is that the centre of gravity of ring and attached weight moves down as the ring rolls up. After a few to-and-fro oscillations the ring will come to rest; and in this position the centre of gravity will be at its lowest possible position, and vertically above the point of support.

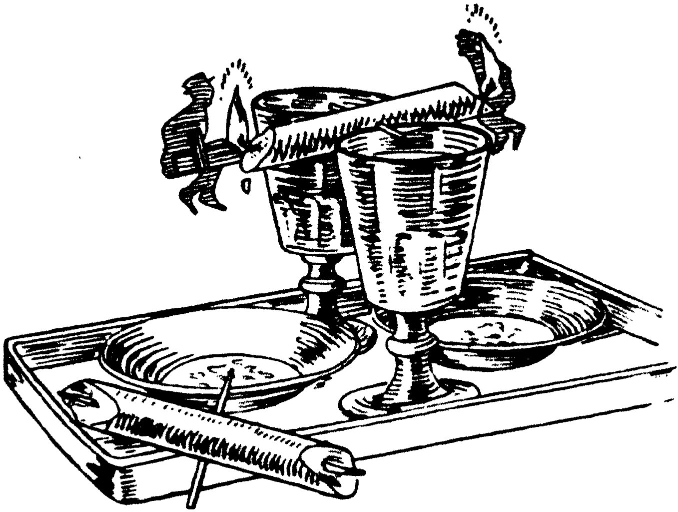


34. BODY ROLLING UP INCLINED RAILS.

All bodies tend to move so that the centre of gravity occupies the lowest possible position. This fundamental principle is verified by the following experiment, which at first sight seems to contradict it.

Glue together by their bases two conical lamp shades, or two cones of the same size made out of cardboard, so as to form a double cone. Form an inclined plane with two sticks resting on two books of different height, but with the sticks so arranged as to be further apart at the upper ends than at the lower. The angle contained between them may be readily adjusted by trial so that when the cone is placed on the lower part of the two sticks it will seem to advance upwards towards the upper ends.

It is a curious illusion. Although the parts of the cone in contact with the sticks pass upwards to the upper ends, the axis of the cone in which the centre of gravity lies will be seen to fall in level in virtue of the geometrical nature of the guides.



35. THE CANDLE SEE-SAW.

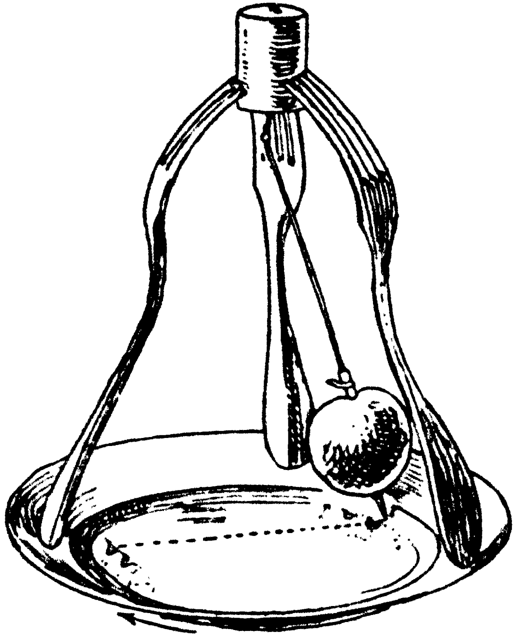
HERE is a new prime mover which needs neither steam, nor compressed air, nor electricity. Boiler, cylinder, piston—there are none; it is simply a candle.

Insert on two sides of a candle perpendicular to its length and at its middle section the heads of two pins previously heated. These two pins form the axis of the prime mover, and are laid on the edges of two tumblers of equal size wide enough apart to allow the candle to pass between them.

The two ends of the wick are lighted, and plates or saucers placed so as to receive the falling drops of melted wax. It is almost certain that the drops will fall off from the ends at different times. With the fall of one drop the equilibrium is destroyed, and the candle will descend on the heavier side. Then this side is lightened, and the candle swings back again. A see-saw motion will be started, and will continue more or less regularly until the candle is consumed.

Is it wise so to make "a candle burn at both ends"? Well, the interests of science must be served, and some sacrifice must be made. In any case the candle manufacturer will lodge no complaint.

The familiar see-saw will be the better imitated if we attach to the side of the candle a strip of cardboard bearing at its two ends little pasteboard figures.



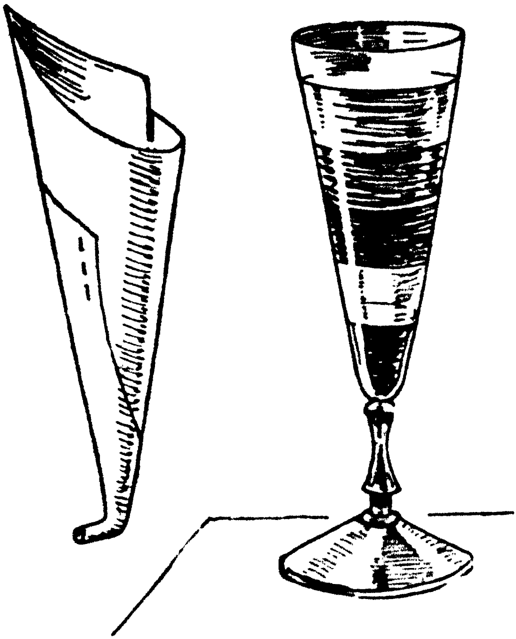
36. THE FOUCAULT PENDULUM.

When a long and carefully suspended pendulum is set swinging in a vertical plane, the plane of swing will appear to revolve relatively to the room. The truth is that the room revolves with the earth, and that the plane of motion of the pendulum tends to remain fixed in space in accordance with the laws of dynamics. This is the experiment by which Foucault in 1851 demonstrated to the eye the fact that the earth revolves on its polar axis.

The principle of the experiment may be readily shown at table by means of an apple or orange, three forks and a cork, and a few other simple accessories. Pierce the apple by a match or other wooden peg long enough to project at both sides. To the one end attach a thread. This forms the pendulum.

Attach the other end of the thread to the head of a pin stuck into a piece of cork, which is to be supported on the prongs of three forks with their handles resting on the side of a plate. Adjust the length of the thread so that the lower end of the peg reaches close to, but without touching, the plate. The suspended apple may then be set swinging to and fro like a pendulum. The extremities of the swing may be marked by two small heaps of sugar or salt, through which the point of the peg may be made to pass as it swings to and fro. So long as the plate remains fixed the pendulum point will time after time pass through the furrow in the heap of sugar which it cut out at the first swing.

But now set the plate, forks, and cork slowly revolving round the vertical. It will be seen that the pendulum will remain moving in the original plane, and will cut out fresh furrows in the heaps of sugar.

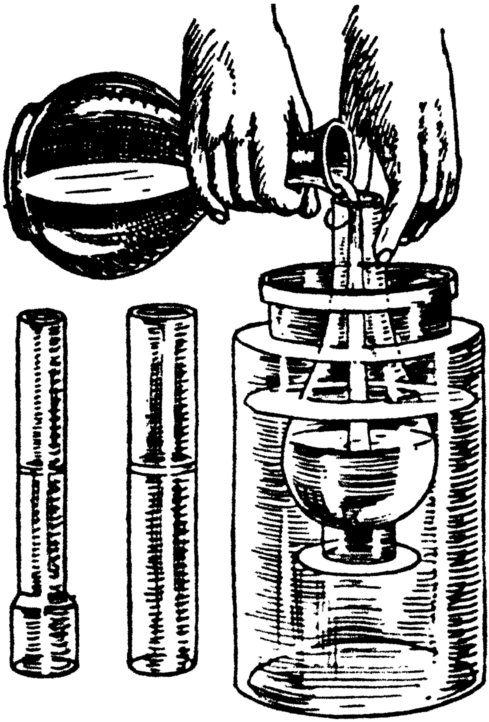


II. Equilibrium of Fluids: Pressure.

37. Superposed Liquids.

To superpose a series of liquids of different density so as not to mix one with another may be effected as follows.

Construct several cones of paper, pinning the sides together, and turning the point through a right angle. Then cut away the pointed end so as to leave an aperture of the size of the head of a large pin. Pour into the bottom of a long taper glass a little cold sweetened coffee. Adjust one of the paper cones so that the short bent end lies along the surface of the coffee, and gently pour in some ordinary water until it forms a layer of the same depth as the coffee. By means of a second paper cone with its opening at the upper level of the water, pour in a third layer consisting of a red wine. By the same method add a fourth layer of oil, and finally a layer of alcohol or spirit of wine. These five layers will keep distinct for a considerable time, although gradually the process of diffusion of each layer into the neighbouring layers will begin to assert itself.



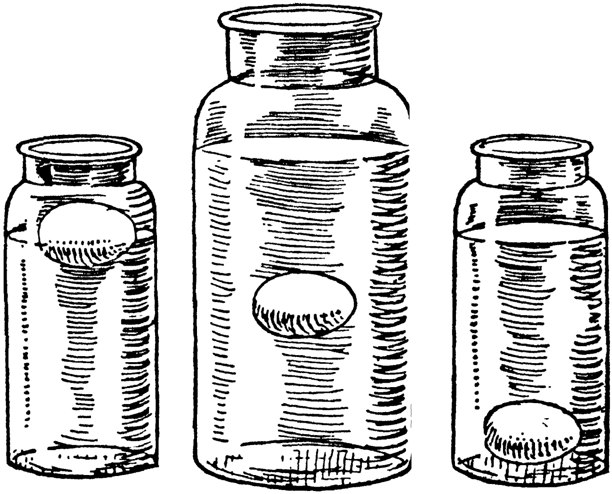
38. THE PRINCIPLE OF ARCHIMEDES.

When a tumbler or other hollow vessel is placed bottom down on the surface of water and gradually pushed downwards, an increasing resistance will be felt. This is due to the upward pressure of the water in contact with the walls of the vessel. If the tumbler is perfectly cylindrical and vertical, this upward total pressure acts on the horizontal surface, and its value depends on the depth and on the area of the surface. It is measured, in fact, by the weight of a column of water with base equal in area to the bottom of the tumbler, and of a height equal to the depth of the bottom of the tumbler below the surface of the water in which it is immersed. This is a special case of the principle of Archimedes, the greatest natural philosopher of ancient times, who proved that any body immersed in a fluid was buoyed up by a total upward pressure equal to the weight of the fluid displaced.

To show that the upward pressure on a horizontal surface facing downwards is due to the depth of the surface in the water, the following simple experiment may be made. The apparatus consists of a wide-mouthed glass jar not quite full of water, one or more lamp shades, and a disk of stiff cardboard large enough to cover the lower end of the lamp shade. Press the cardboard disk close to the end of the lamp shade, and immerse it gently in water, keeping the cardboard pressed to the glass until it is well below the surface of the water. Thereafter the cardboard will remain itself in position, being held by the upward pressure of the water below it.

If the cardboard fits tightly to the glass edge no water will pass within the lamp shade. If now we hold this shade in a fixed position and gently pour water into its interior, the cardboard will adhere to the glass so long as the level of water within the lamp shade is lower than the level of water outside. But as soon as the levels become equal the cardboard will slip off, being no longer held by an unbalanced upward pressure. The experiment may be made more telling by pouring in water coloured with a little aniline.

It matters not what shape of lamp shade be used, whether bulging or cylindrical, the result is always the same: the cardboard becomes loosened as soon as the water within the shade comes level with that without. The total upward pressure which supports the disk depends only on the depth and on the area involved. The quantity of water in the interior of the lamp shade is not the determining factor, but simply the *height* of water within it.

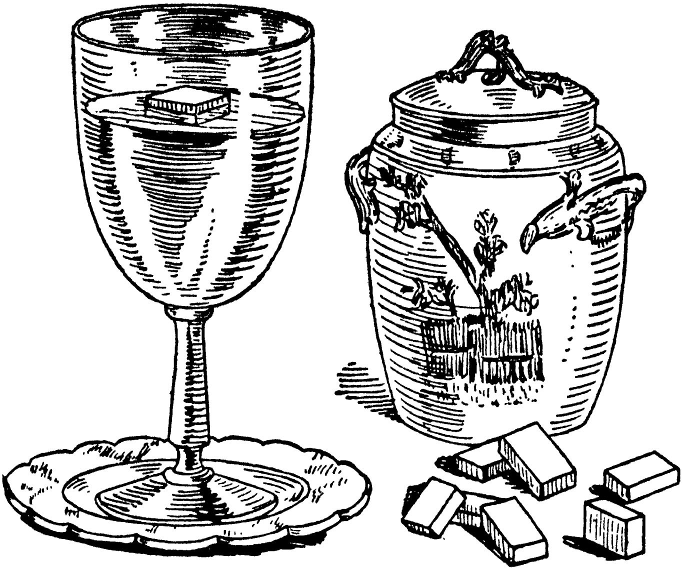


39. THE PRINCIPLE OF ARCHIMEDES (*continued*).

TAKE two glass jars and fill the one with fresh water and the other with a strong solution of brine. It will be found on trial that a fresh egg will sink in the fresh water and float on the surface of the salt water. The reason of this, as expressed in terms of the Archimedes principle, is that the specific gravity of the brine is greater than that of the egg, so that the weight of the egg can be supported by the upward pressure due to the displacement of a smaller bulk of brine. On the other hand, the specific gravity of the egg is greater than that of fresh water, so that the weight of the egg is greater than the total upward pressure of the displaced water.

Let now the one jar be filled only to about one-third of its height with the brine, and place the egg floating on it. Take note of the depth to which it sinks in the brine, and then pour in gently a sufficient quantity of fresh water so as to cover the egg. As this is being done the egg will be seen to rise somewhat in level, owing to the buoyancy of the water that is being added. When sufficient water has been poured in, the egg will appear to be floating in the midst of the liquid.

If the two liquids are stirred briskly together so as to form one liquid of an intermediate density, the egg may either sink or swim according as the density of the mixture is less or greater than the apparent density of the egg. If the egg sinks to the bottom, stir in a little more brine; if it rises towards the surface, stir in a little more water. In this way, after a few trials, a single liquid will be obtained of specific gravity exactly equal to that of the egg, which will, therefore, float in any position in the midst of the liquid.



40. A LUMP OF SUGAR FLOATING ON WATER.

THE following curious experiment requires some preliminary preparation. Dip some lumps of sugar in ordinary collodion, and then place them in an airy place for a day or two till all the ether has evaporated. They have still the appearance of ordinary lumps of sugar. If placed in the sugar basin they would not suggest any trickery.

The experiment may now be made to the bewilderment of the uninitiated. Drop one of the prepared lumps of sugar into a glass of water. It will first sink to the bottom, but after a short interval float up again to the surface, and remain there for an indefinite time.

The truth is that it is not the sugar which floats, but only so to speak its form. The cotton of the collodion which fills the pores of the sugar still retains, though cleared from the dissolved sugar, the geometrical form and the white crystalline aspect of the original lump. To maintain the mystification the glass must be removed without any one touching the "floating sugar." Should one of the spectators try to pick it out of the water, there will be nothing but a soft, spongy substance in place of the solid lump of which it is the substitute.

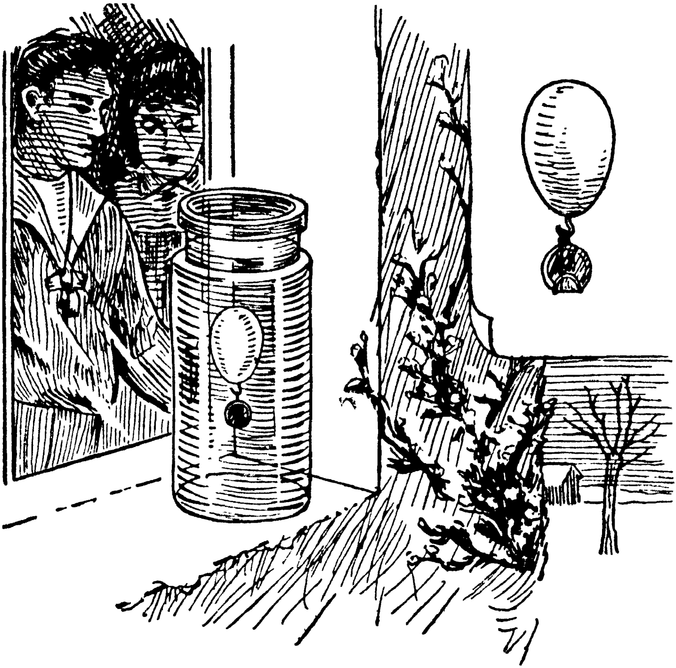
41. FREE INTERCHANGE.

HALVE an orange, and consume the contents so as to leave the peel in the form of two hemispheres. In the vertex of one of these hemispheres pierce two holes side by side large enough to grip firmly two goose-quills—toothpicks, for example. Set the orange peel with the concavity upwards at the middle of a tumbler, which should be slightly less in diameter than the orange peel, so as to hold the latter by friction. Push the one quill tube down until it reaches nearly to the bottom of the tumbler, and adjust the other so as to project a very little below the orange peel.

The experiment is to be made with two liquids of different density, a lighter (L) and a heavier (H). These may be, for example, wine and water, or water and milk.

Pour the L liquid into the cup made by the orange peel; it will pass through the one quill tube into the vessel below. Allow a sufficient quantity to pass until it just touches the bottom of the peel.

Now fill up the tumbler with the heavier liquid H. Immediately you will see ascending through the liquid H a filament of the liquid L issuing from the top of the higher quill tube. After a short time the heavier liquid will be found below and the lighter liquid above. There will be a complete interchange in the positions of the two liquids.



42. MAXIMUM DENSITY POINT OF WATER.

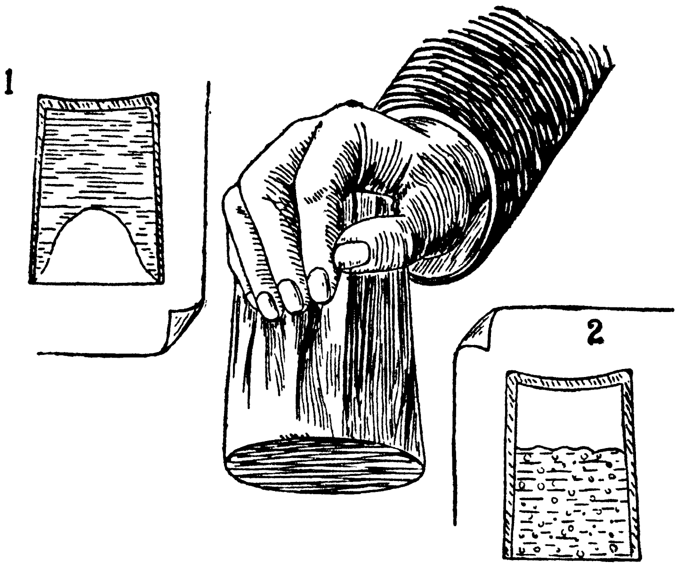
Ice floats on water, and is, therefore, of less density. This shows that as water freezes it expands. But this expansion with lowering of temperature begins several degrees above the freezing-point. There is a definite temperature, 4° centigrade or 39·2° Fahrenheit, for which fresh water has its maximum density. If water at this temperature is heated or cooled it will begin to expand; and as it is further cooled it will continue expanding until at the freezing-point it becomes ice.

Various experiments have been devised for demonstrating this fact, with apparatus of more or less delicate construction. We may prove it by means of an empty egg and a jar full of water. We must, however, operate in the winter.

Take, then, an empty egg-shell, and seal the holes with wax, fixing to it at the same time a hook of iron wire. Fill the jar with water of temperature about 50° F., and attach to the egg a few small coins, so as to load it sufficiently to make it just sink to the bottom. When this is accomplished, and the lowest point of the load just touches the bottom of the jar, place the whole on the window-sill in the open frosty air. As the jar and its contents are cooled the temperature will fall, and the density of the water will increase, and you will see the egg slowly rising upwards through the liquid. When the temperature reaches 39·2° F. the egg will become stationary. The water has attained its maximum density. As the temperature falls below this temperature the water begins again to expand, becomes less dense, and the egg descends towards the bottom.

Bring the jar and its contents back into the warm room, and gradually as the water in the jar gains in temperature the process described above will be repeated in the opposite order. The egg will first rise until the temperature reaches 39·2° F., and then will descend again as the temperature rises higher.

If it is not winter time, we may perform the experiment by taking a little extra trouble. We may cool the water by adding ice, or surround it by a larger vessel containing a mixture of ice and salt.



43. DECEPTIVE BOILING.

Fill a tumbler three-quarters full of water, cover it with a handkerchief of strong linen, pressing it firmly all round the inside until the middle of the handkerchief comes in contact with the surface of the liquid. Apply the left hand firmly on the opening of the tumbler, and with the right hand holding tightly the borders of the handkerchief, invert the tumbler. In case of accidents the experiment should be performed over a basin. On removing the left hand you will see that not only does no drop of liquid escape, but the handkerchief preserves its concave form within the tumbler owing to the atmospheric pressure (see Fig. 1 in the drawing). Now pull steadily on the borders of the handkerchief until the part supporting the water is stretched tightly across the opening. The liquid within the tumbler will fall and assume a horizontal surface with a partial vacuum above. Bubbles of air will at once begin to pass across the meshes of the linen and up through the water accumulating in the upper closed region. To the spectator it will appear as if the water were boiling. Hence the paradox: to boil cold water by the heat of the hand.

44. DENSITY INCREASED BY HEATING.

When a solid body is heated it expands and occupies a somewhat greater volume than it did at the lower temperature. As a consequence the density, or specific gravity, is diminished. When the body is brought back to the original temperature it will recover its original density.

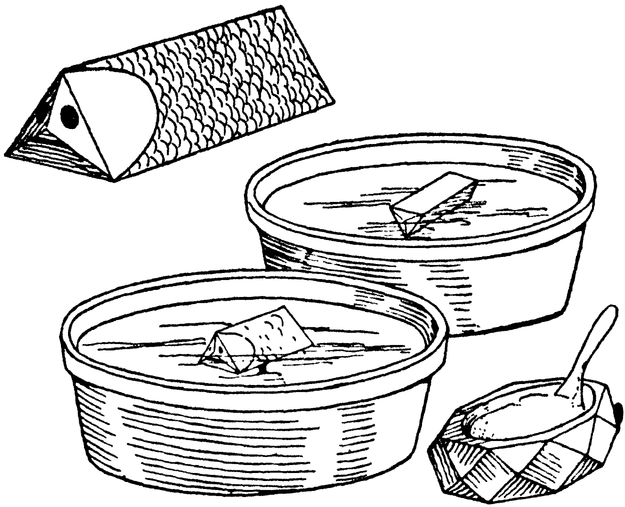
The following experiment at first sight seems to contradict this principle. Take a piece of pumice stone, such as is frequently used for rubbing stains off the hands, and place it in water. It floats, not because the solid material of which it is composed is lighter than water, but because the substance is extremely porous, and its pores are filled with air. The apparent density is, consequently, much less than it would be if the rocky material were not porous.

Heat the water in which the pumice is floating, and bring it to the boil. The air in the pores will expand with the rise of temperature, and bubble out from the surface of the pumice into the water. Continue the boiling some little time, in order that the whole mass may be heated through and through and the contained air expanded to the uttermost. The pumice will continue to float with much the same fraction of its bulk immersed; for the expanded air still fills the pores, and the diminution of weight of the pumice and its contents is negligible.

The boiling having continued for a few minutes, remove the flame and fill up the vessel with cold water. Drain off half and fill in more cold water, and so on until the temperature is brought back to its original value. The pumice will now either sink to the bottom, or if it does not quite sink it will float with nearly its whole bulk immersed.

What has happened is that water has taken the place of the air which was expelled by the heating. With a rise of temperature from ordinary temperatures to the boiling-point of water, air will expand nearly one-third of its original bulk, so that about this fraction of the air originally filling the pores will be removed; and if the pumice is kept well immersed during the cooling this fraction of the space of the pores will be filled with water instead of air. The pumice will thus become apparently more dense than it was at first.

If left for some days in a dry, warm place, the pumice will return nearly to its original condition. It may be brought back more rapidly to the original state by heating it on a sand bath and driving the water out of the pores.



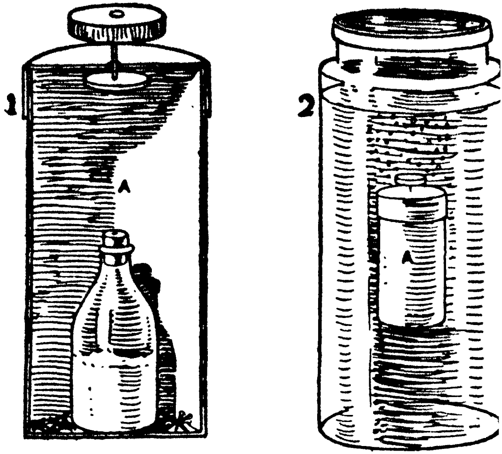
45. THE FISH THAT DIES AND LIVES AGAIN.

TAKE a piece of fir or other light wood, and cut it in the form of a triangular prism about 2 inches in length and three-quarters of an inch in width of side. Paint one edge black and leave the opposite face white. A rough similitude of a face may be made at one end, with two eyes and a long mouth, as shown in the picture.

When placed in salt water this model will float with the edge upward and look like a fish near the surface of the water. But place it in fresh water, and it will at once turn over so that the back is underneath, and the white face is looking upward.

The fish lives in the salt water, but floats dead in fresh water!

The reason depends upon the laws of floating bodies which shipbuilders must consider carefully when designing a new form of vessel. In the present case the prism is light compared with the salt water, but relatively heavy compared with the fresh water. The same difference in the manner of floating would be shown by two prisms of which the one was made of a heavy wood and the other of a light wood or cork. The light prism will float in fresh water with edge down and face up; but the prism made of the heavy wood will float with one face looking downwards.



46. THE AUTOMATIC PLUNGER.

Take a large glass jar full of water, as shown in Fig. 2, and place within it a small cardboard cylinder whose interior and mode of construction are indicated in the relatively enlarged Fig. 1.

A few small holes must be pierced through the base of the cylinder, and a circular hole bored through the centre of the cover. Through this hole pass a short rod, such as a pin or a piece of iron wire, connecting two disks, of which the lower and smaller is made of cardboard, and the upper and larger of a broad cork. This simple apparatus will act as a kind of double valve. Sprinkle the bottom of the box with a number of nails to act as ballast, and place also on the bottom a small bottle containing two Seidlitz powders well mixed together. Through the cork of the small bottle a fairly large hole should be pierced so as to admit of a sufficiently rapid but not too rapid influx of water. Finally close the cylindrical box with the cover and valve in position.

As soon as this box is set in the water it will sink owing to the influx of water through the small holes in the base. When the water reaches the level of the cork of the small bottle, it will flow in upon the mixed powder and produce a great development of carbonic acid gas. The pressure of this gas will drive the water out of the box, the valve above remaining closed owing to the floating upward of the cork. The box with its contents will thus become so light that it will ascend through the water until it approaches the surface. When it has ascended high enough the cork will cease to pull upward, and the valve will open, allowing the gas to escape and the water to flow in from below. After sufficient influx of water the box will sink again, the valve will close, the disengaged gas will force out the water, and the box will rise once more to the surface. This rising and falling will go on as long as there is a sufficiency of powder to be acted upon by the water.

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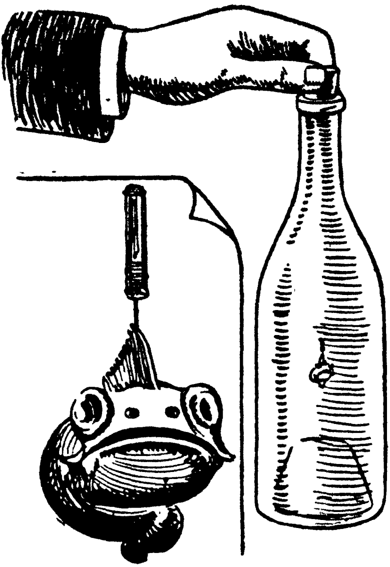


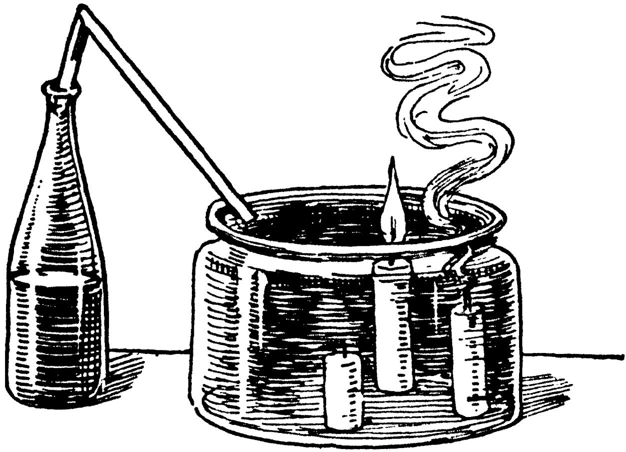
47. THE CARTESIAN DIVER.

A SIMPLE form of the Cartesian diver—named after the famous philosopher Descartes—may be constructed as follows :—

Cut out of a sheet of tinned paper or tinsel any grotesque figure, and attach it by a fine thread to a quill tube about 2 inches long—a quill toothpick, for example. The ends of this tube are to be closed with sealing-wax, and through the lower end a small hole is to be pierced by means of a hot needle. The little diver will act as ballast, keeping the tube vertical when placed in a bottle full of liquid. The amount of air entrapped within the tube should be adjusted so that the whole floats just immersed in the liquid.

If a well-fitting cork be pushed down in the neck of the bottle, the slightly greater pressure exerted on the interior will compress the air in the quill tube, and a corresponding quantity of liquid will pass into the tube from below. This will increase the average density of the diver, causing it to descend to the bottom of the bottle. By slight movements of the cork the diver may be made to rise and fall at will.

Instead of an ordinary bottle a wide-mouthed jar may be used if over the mouth of the jar a sheet of india-rubber is stretched and tied tightly to the jar by means of a string. By an appropriate pressure applied to this rubber covering the diver may be made to rise and fall in the same way as already described.

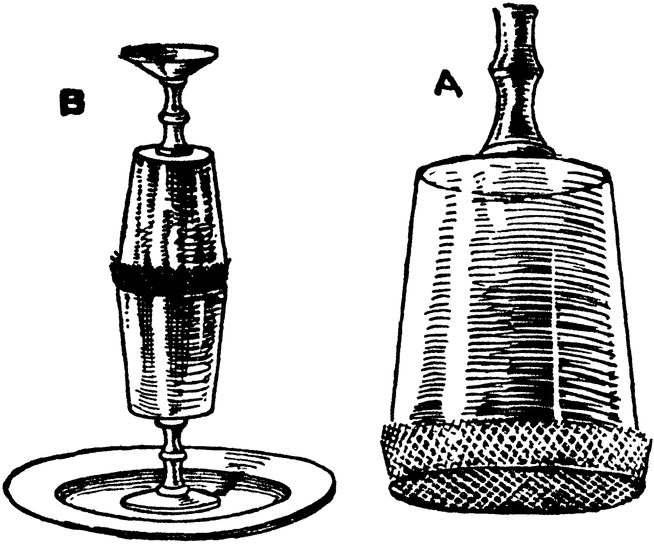


48. CARBONIC ACID GAS DENSER THAN AIR.

THIS may be simply shown in the following manner.

First construct a siphon by wrapping a sheet of paper round a rectangular ruler; gum the edge firmly, and then withdraw the ruler; cut the paper tube so constructed obliquely, dividing it into two unequal lengths, roughly as one to three; place the obliquely cut ends together, so that the two parts make an acute angle with each other, and carefully cement them with strips of gummed paper. Take next a bottle and fill it half full with a mixture of one part of strong vinegar to two parts of water, and drop into the bottle small crystals of soda. Bubbles of carbonic acid gas will begin to be given off.

By means of the siphon lead the carbonic acid gas to the edge of a wide-mouthed glass vessel, in which two or three candles of different lengths are burning. The carbonic acid gas, on account of its greater density, will descend through the air to the bottom of the vessel, and gradually fill it up. As the level of the layer of carbonic acid rises it will extinguish the various candle lights in succession, the shortest candle first and the longest last.



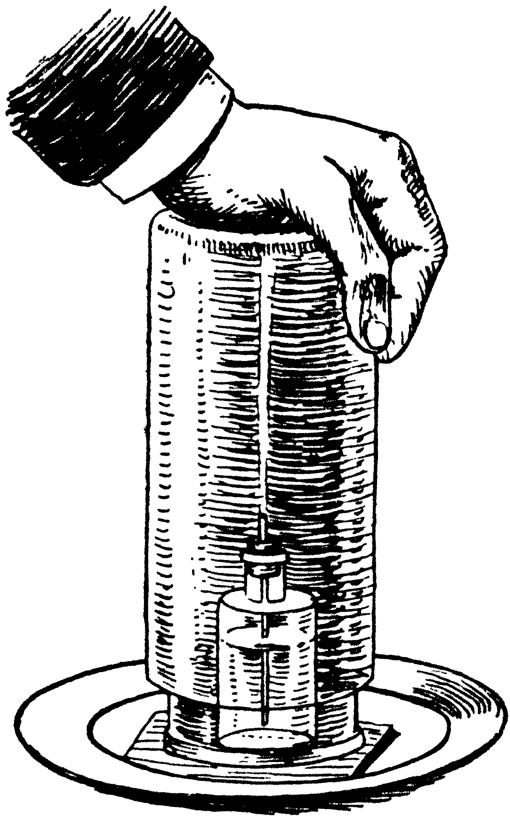
49. THE DANAIDS' RECOVERY.

FILL to the brim two glasses of the same size, the one with water, the other with red wine. Place over the glass containing the water a piece of tulle a little larger than the glass, and previously wetted.

Press the edges of the tulle back round the rim of the glass; place the flat of the one hand so as to rest over the tulle and on the rim, and quickly turn the glass upside down. Gently remove the hand by slipping it horizontally from under the inverted glass, and the water will be found to remain within the glass and over the tulle (as in Fig. A). This is exactly the same kind of experiment as that in which a card is placed over the glass full of water and the whole inverted. The pressure of the air acting upwards on the card supports the weight of the water pressing down on it. When the open network of the tulle is substituted for the card, capillarity prevents the water escaping through the meshes, and the atmospheric pressure supports the weight of water as before.

With the water supported in this way gently place the inverted glass over the glass filled with the wine in exact apposition (see Fig. B). Immediately thin filaments of red wine will be seen passing upwards through the meshes into the water above. The lighter wine will gradually accumulate at the top, and push the heavier water down into the lower vessel, and after a short time the wine and water will have changed places.

The eternal punishment of the daughters of Danaus was to try and fill a sieve with water. The above experiment shows how a non-leaking sieve may be constructed; so might the Danaids have completed their supposed hopeless task.



50. THE MINIATURE FOUNTAIN.

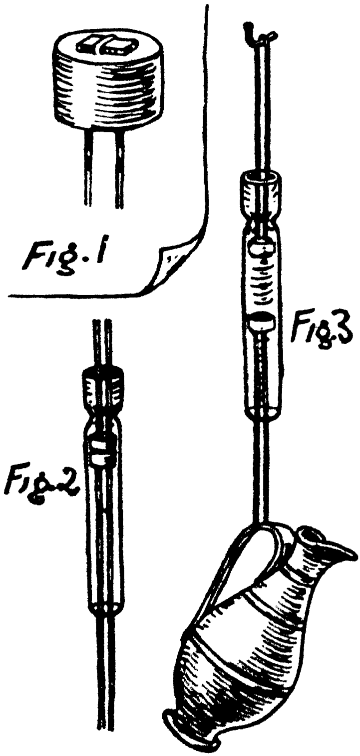
FILL a small medicine bottle three-quarters full of water. Pierce the cork with a small hole sufficient to allow a thin straw or hollow stem of grass to pass through and reach nearly to the bottom of the bottle when the cork is pushed well into the mouth.

The space between the straw and the cork should be hermetically sealed.

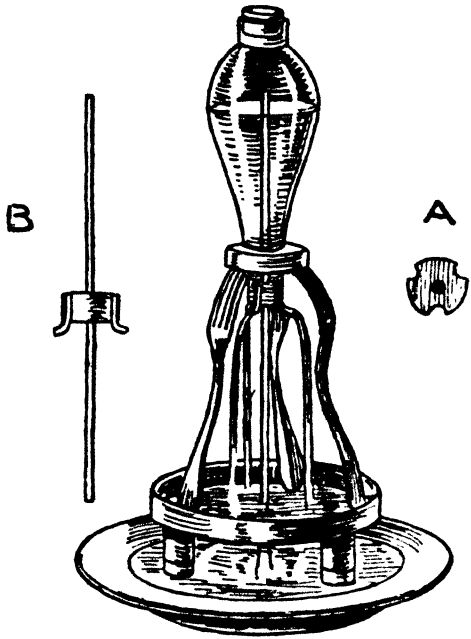
Place the small bottle on several sheets of blotting-paper well soaked, and then invert over it a large glass jar whose air contents have been heated for a few moments by means of a candle flame held within it. By pressing it well down on the blotting-paper we make sure that no air enters from below. As the air in the jar cools its pressure diminishes, and the pressure of the air within the bottle will force the liquid through the straw and upwards as a fine jet of water which impinges on the base of the inverted jar and breaks into a thousand crystal drops.

51. WEIGHT SUPPORTED BY ATMOSPHERIC PRESSURE.

TAKE a cylindrical lamp shade with a constriction near one end, and two corks fitting within the shade as accurately as possible. Each cork is pierced with two small holes through which twine is passed; and to prevent the twine cutting through the cork it should pass round a piece of wood of breadth equal to the distance between the holes (see Fig. 1).



The corks are placed close together in the long cylindrical part, and the pieces of twine pass in opposite directions through the lamp shade, as shown in Fig. 2. The upper cork, which should be close to the constriction, is now suspended by means of the twine from a hook in the wall; and the twine from the lower cork may be tied to a jug or other heavy object. The weight of the jug will pull down the cork in the tube, but only to a certain distance. For the separation of the corks will increase the volume, and therefore diminish the density and pressure of the air between them, and the pressure of the atmosphere acting upward on the lower cork will support it and the connected weight. Water may now be poured into the jug so as to increase the weight; but this will simply draw down the cork a further distance, diminishing further the pressure in the air within the lamp shade and still maintaining the equilibrium.



52. THE INTERMITTENT FOUNTAIN.

In the following experiment the apparatus may be constructed from articles usually obtainable in most households.

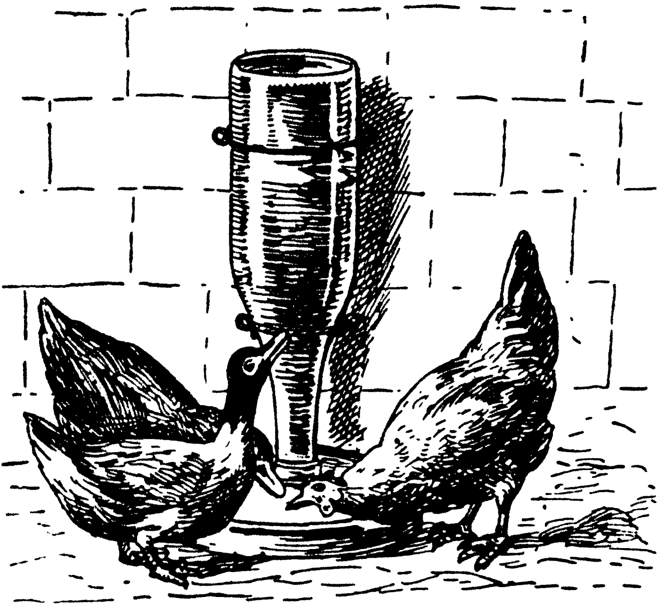
A lamp shade of the widely bulging form constitutes the reservoir when filled with water. Both ends are closed by well-fitting corks, and the shade is inverted and supported by having its tapering end passed through a hole in a wide cork such as is used for stopping large pickle bottles. Into the lower surface of this cork three forks of equal length are inserted at a slight outward obliquity. These forks form a tripod whose feet rest within the upturned lid of a tin-plate box, which in its turn is supported on three corks or bits of wood resting on the bottom of a large soup plate. In this lid a small hole is pierced by means of a nail or bradawl.

The lower cork which fits into the inverted end of the lamp shade is pierced with a small central hole large enough to allow a stick of macaroni to pass. The upper end of this macaroni stick reaches well up the interior of the glass shade, and its lower end just falls short of touching the lid of the tin-plate-box. Along the side of this cork three small grooves are cut (as in Fig. A), admitting the placing of small bent tubes of macaroni. These may be bent by softening them in tepid water, and then drying them by a gentle heat (see Fig. B).

The spaces between the tubes and the cork should be hermetically sealed.

The upper cork is now removed, the lamp shade filled up with water nearly to the level of the top of the macaroni tube, and the cork inserted in position again. The water will at once begin to escape through the small side tubes, since the region above the water surface in the lamp shade is in connection with the outer air through the long macaroni tube. But, owing to the smallness of the hole in the tin-plate lid, the water fills in to it more quickly than it escapes, and in due course the lower end of the macaroni tube becomes immersed in the rising water, and the space above the water surface in the reservoir is cut off from connection with the outside air. As the water continues to flow out this region of air expands and the pressure diminishes, so that very soon the water ceases to flow. The fountain, in fact, stops supplying water.

As soon as this flow is arrested the contents in the tin-plate lid begin to diminish, being gradually carried off through the small hole into the plate below. In due course the lower end of the macaroni is left free of water, the air rushes in to the interior of the lamp shade, and the fountain begins again to flow. This intermittence will continue so long as there is water within the lamp shade.

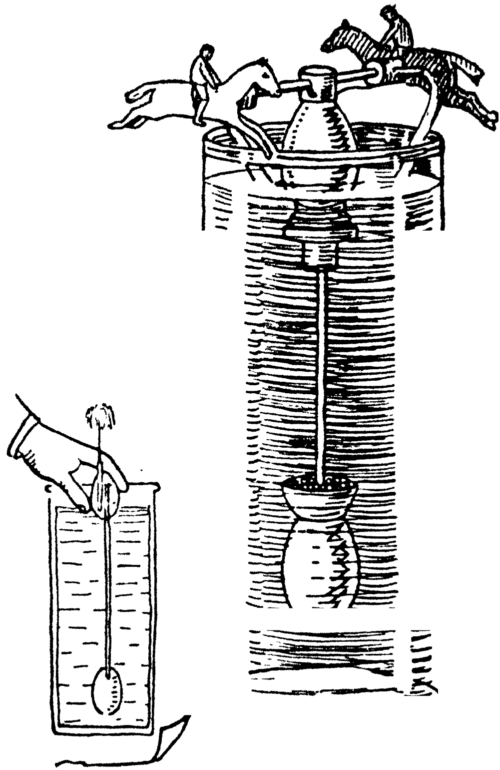


53. WATER TROUGH FOR POULTRY.

WATER set out in open vessels in a poultry yard soon becomes dirty, and, moreover, quickly evaporates in the warm air. The following simple arrangement provides a water trough free from these imperfections.

Fix to a wall on the shady side of the poultry yard an inverted bottle full of water, with its mouth a short distance above the hollow dish out of which the fowls come to drink. The water will flow into the dish until the mouth of the bottle is immersed below the surface of the water, when, in virtue of the atmospheric pressure acting on the outside surface, the contents of the bottle will be prevented from escaping. As the water in the dish is drunk or evaporates the level will ultimately fall below the level of the mouth of the bottle, some air will pass in and water will flow out. The dish will thus be kept permanently filled with a sufficient quantity of water so long as there is water in the bottle.

Installed in the shade, one or more of these simple troughs will be greatly appreciated by the frequenters of the poultry yard.



54. A JET OF WINE ISSUING FROM WATER.

PIERCE each of two hens' eggs with two holes, one at each end. Connect them by a long straw of rye about ten inches long. The straw should end near the top of the upper egg, which for reference we shall call A, but should not penetrate further into the top of the lower egg, B, than is needed for secure fastening. A second straw three or four inches long is passed through the upper hole of A, and reaches nearly to the bottom of the egg. All the joints must be made secure by means of sealing-wax.

The lower opening of the egg B is kept open. Its width should be about the quarter of an inch.

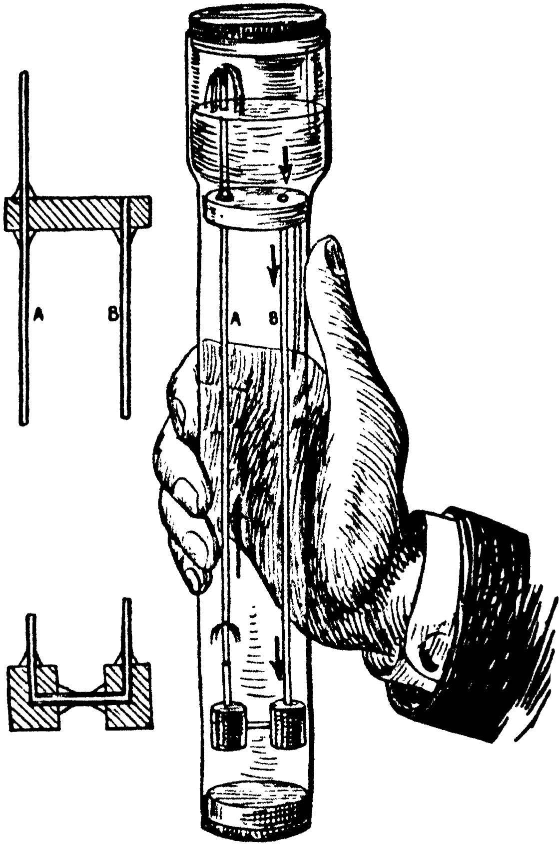
If the egg A is filled beforehand with red wine and the apparatus is immersed vertically in a large jar of water, the pressure of water will force liquid into the lower shell B, compress the air in it, and pass on the increase of pressure to the top of the shell A, forcing out the wine through the short straw as a jet of liquid. The height to which the jet is projected will depend on the length of the connecting straw, and on the depth of the lower egg in the water. This is a simple case of what is known as the Fountain of Hero, who flourished at Alexandria 150 B.C.

A small addition to this apparatus will transform it into a Barker's Mill. For this purpose the small vertical straw is fitted into a hole bored half through a cork cemented to the top of egg A. At right angles to this hole a horizontal cross hole is bored right through the cork, and pieces of straw fitted in on each side. These horizontal straws are fitted each into a small cork, from which at right angles another small straw is fitted. These straws form elbow-shaped tubes in continuation with the central upward tube, so that when the pressure is sufficient the water is forced up from the egg A, and through the vertical and horizontal straws, finally issuing in two streams oppositely directed at right angles to the cross tubes which fit into the central cork. The back pressure of the issuing jets pushes the whole apparatus round in the opposite direction, causing it to revolve about its vertical axis.

To start the movement, the apparatus should be held upside down, and water poured in at the opening in the bottom of egg B until the two eggs are fully filled. When it is set upright in the water contained in the large jar, the water in the upper egg will be forced out as the wine was in the experiment first described.

To add to the interest two horses with their riders may be cut out of cardboard and fixed to the end corks so as to face in the direction opposite to that in which the short straws are facing.

In these experiments it is advisable to use goose eggs, which are not only larger than hens' eggs, but, having a thicker shell, are more easily pierced with suitable holes.



55. HYDRAULIC PARADOX.

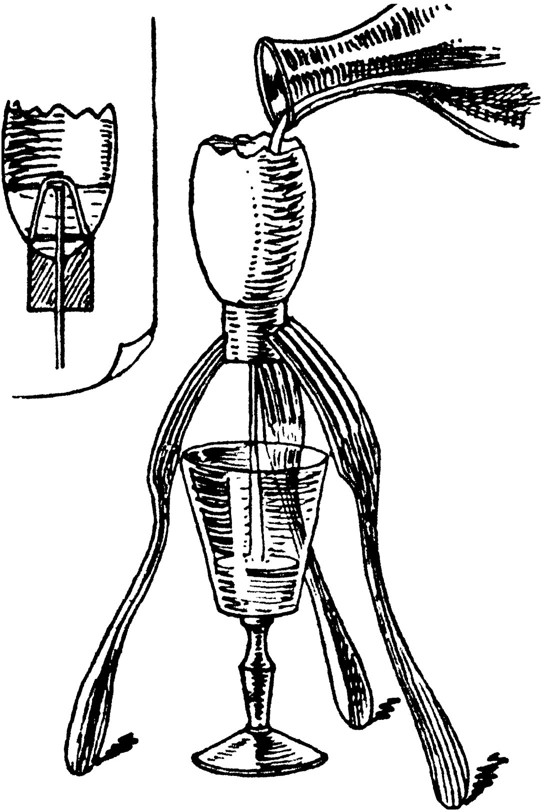
INTO an inverted lamp shade of cylindrical form fix three corks, one at the extremity of the straight cylinder, another at the expanded end, and the third into the narrow cylinder at the place where it enlarges. The three corks must fit so tightly as to prevent water passing between them and the glass surface. To this end the top and bottom corks may conveniently be covered with kid. The middle cork is pierced with two holes through which pass two large straws of rye. The one straw, B, is made flush with the upper surface of the middle cork, and its lower end reaches to within a short distance from the lowest cork. Here a double bend is formed by means of two corks suitably bored with two holes meeting at right angles at the centre. The short connecting tube should be made of the same size of straw as the straw B; but the short upright straw in the second cork must be of fine bore. The joints between the straws and the corks must be made secure by means of sealing-wax. The second straw, A, of the same size as B, reaches above the surface of the middle cork almost to the lower surface of the upper cork, while its lower end must be brought to within a short distance vertically above the orifice of the small nozzle.

The enlarged space between the upper and middle corks forms the reservoir; and when this is filled about two-thirds full of water, the water will pass down tube B, and be ejected as a fine jet from the nozzle up towards the lower opening of the tube A.

When the adjustments are properly made the water projected upward into the tube A will appear to be ejected from the upper end of this tube to a higher height than the level of the surface of water in the reservoir. This apparently contradicts the hydraulic axiom that water cannot rise above its own level. This is the paradox; but the contradiction is only apparent.

For, in the first place, not all the water passes up the tube A—some of it falls back into the bottom of the narrow cylinder; and, in the second place, the fall of level of the water surface in the reservoir produces a partial vacuum in the air above the water, and a certain suction is produced along the tube A from below upwards.

The water gradually collects below, but the action may again be started by refilling the reservoir to the necessary height.



56. THE VASE OF TANTALUS.

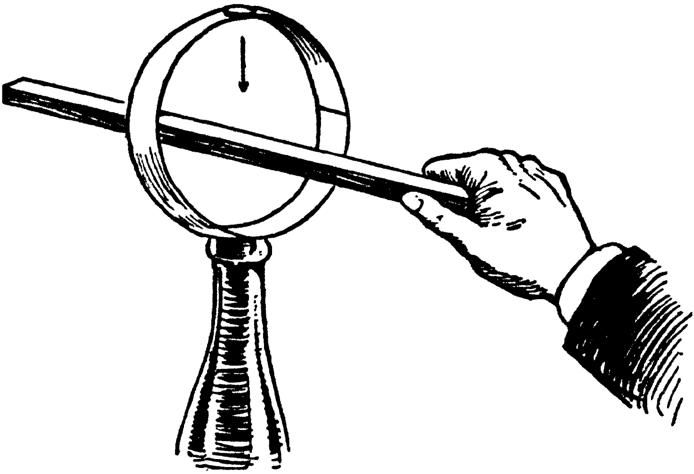
A SMALL hole is pierced in the end of an egg shell whose other end is cut off. A short straw passes through the hole, penetrating a short distance within the shell. The shell is set with the wide opening above, and a thimble is placed inside the shell so as to cover the projecting end of the straw. The shell is supported on a cork, through which also the piece of straw passes, and the whole is supported on a tripod of three forks whose prongs grip the cork.

A glass is placed below the lower end of the straw, and water is poured into the shell. As soon as the level of the water reaches the upper end of the straw covered by the thimble, the water is siphoned off through the straw into the glass below.

If we arrange matters so as to have a continuous supply of water flowing into the shell, the efflux through the straw will take place spasmodically. The outflow will begin when the level of the water is above the end of the straw, the thimble playing the rôle of a siphon, and will cease when the level of water sinks below the edge of the thimble. As the water fills up again in the shell no outflow will occur until the critical level is reached, when there will be a rapid efflux once more.

Since the water in the shell never reaches above a certain level, although it approaches this level steadily, the experiment reminds us of the old classical tale of Tantalus.

The principle of this experiment is made use of in the self-acting mechanism for the flushing of drains.



III. Inertia and Momentum.

57. THE COIN AND THE PAPER RING.

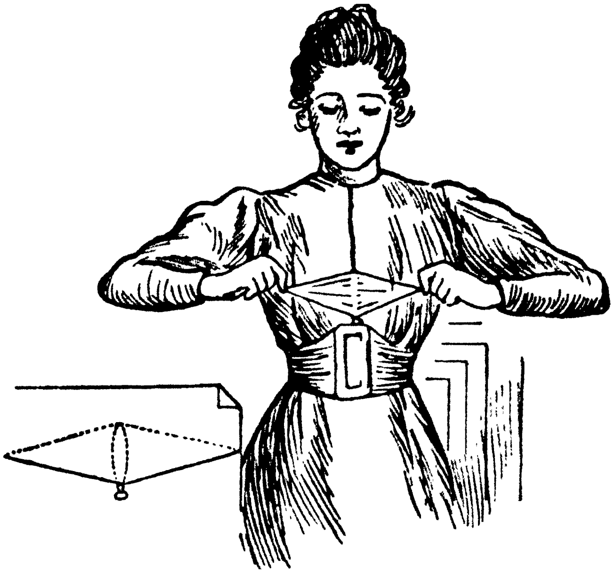
Place vertically on the top of a wide-mouthed bottle a ring of paper some four or five inches in diameter, and lay on the highest point of the ring a coin of diameter slightly larger than the mouth of the bottle.

Introduce the end of a stick within the ring, and then with a sudden horizontal stroke hit the paper ring from its pedestal. The coin will drop vertically on to the top of the bottle, partaking of no horizontal motion, and thus exemplifying the law of inertia.

Many similar experiments can be done with the simplest of apparatus.

For example, lay a playing-card horizontally on the end of a finger, and place above it a good-sized coin; then with a sharp fillip from the other hand project the card horizontally. It will flutter to the ground; but the coin will remain perched on the finger.

Or, again, lay a strip of paper, half hanging over the table or the mantelpiece, and place at the end of the strip a heavy coin—a half-crown, for example—resting upright on its rim. Give the overhanging part of the paper a sudden vertical blow with a baton or ruler. The paper will fall to the ground, leaving the coin unmoved standing on its rim.



58. MOMENT OF INERTIA.

WHEN a solid body is rotating about any axis, the parts of the body at a distance from the axis are evidently moving faster than parts which are nearer. The energy of the rotating body will, therefore, depend more upon the more distant than upon the less distant parts. It also depends upon the rate of rotation.

There are, therefore, these two factors which determine the energy—namely, the rate of rotation, and what is known as the moment of inertia, which simply means the distribution of the matter composing the body properly measured with regard to the axis of rotation.

Now if no retarding forces act on the rotating body, it will continue to rotate with undiminished energy. If, then, by any means we bring the body as a whole more closely round the axis of rotation, and in this way decrease the moment of inertia, the body will begin to spin faster in order that the energy may remain unchanged.

This principle may be enunciated in the following concise statement.

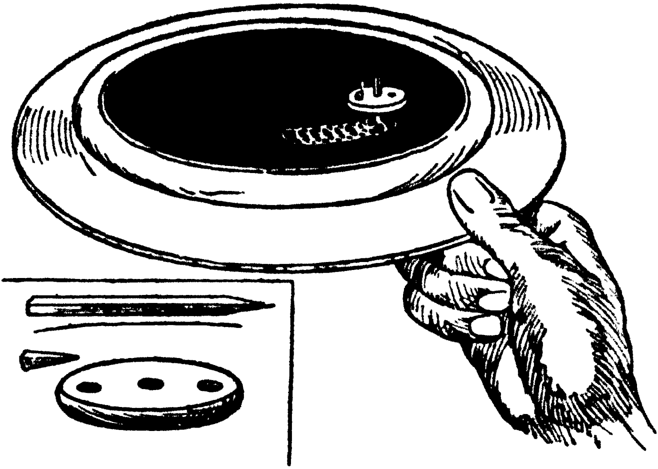
If the moment of inertia of a rotating body decreases in virtue of any cause whatever, the body, conserving its initial energy, will simultaneously increase its rate of rotation.

The numerical relation is that, for constant energy of rotation, the square of the rate of rotation varies inversely as the moment of inertia.

To verify this law, thread a heavy button on a string, take the two ends of the string between the finger and thumb of the two hands, and with the string somewhat loose give a slow rotation to the button. Then ceasing the turning action of the hands, draw them away from each other, tightening the string, and bringing the button nearer the central axis of rotation. The double cone described by the two portions of the string becomes more acute, the moment of inertia diminishes with the approach of the button towards the axis of rotation, and there will be a sudden increase in the velocity of the button.

As another example, consider a skater with outstretched arms turning on one skate through a small arc. By simply bringing his arms close to his side, he will suddenly increase his rate of spin.

The simple principle is illustrated, although not in so simple a form, by the manner in which water escapes from a basin through a hole at the bottom. At first the liquid as it escapes will have a slight rotational motion; but as the level gets lower and the distance of the water particles from the vertical axis through the hole gets smaller, the water will acquire an ever-increasing rate of rotation.



59. RECORDING OF MOVEMENTS.

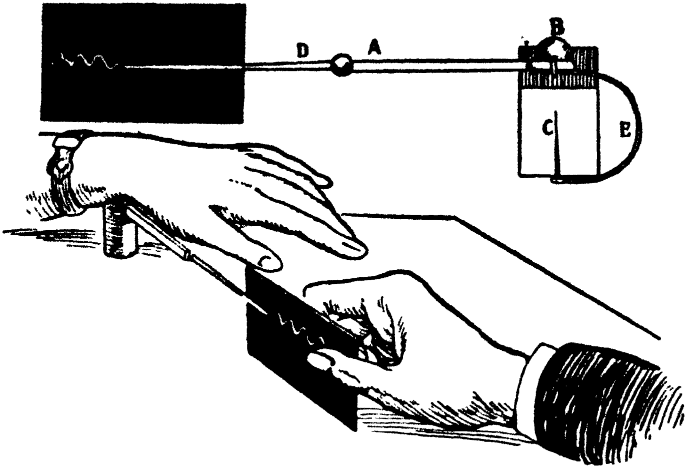
The automatic registration of movements is of great value in many scientific investigations. In the barograph a pen, mechanically connected to the barometer, registers the amount and change of the barometric pressure by a continuous line marked on a slowly rotating cylinder. In the seismograph the motions of the ground due to an earthquake are recorded by a pen registering on a moving surface, or by a ray of light photographically recorded on a moving surface of sensitive paper.

The following simple experiment exemplifies the principle of registration.

Construct a teetotum with a flat disk of lead pierced with three holes, one through the centre and the others near the edge. For reasons of symmetry the three holes must be in the same line at equal distances apart. Through the central hole pass a peg sharpened at the lower end or pivot. Through one of the other holes pass a thin piece of stiff hair taken from a brush, fixing it in the hole by means of a small plug. These are shown in the figures to the left of the picture. The point of the hair must not be lower than the pivot point.

The registering part of the apparatus is now complete. To form the appropriate surface on which the record is to be traced, slowly move the lower surface of a plate to and fro over a smoky flame until it is covered with a uniform layer of lampblack. Holding this surface uppermost in the one hand, spin the teetotum on it with the other. By varying the inclination of the plate slightly the teetotum may be made to travel in large or small arcs all over the surface. At the same time the small hair, acting as a style, will trace out beautiful intersecting systems of rings, which may be varied in detail indefinitely by slight movements of the plate.

If the teetotum moves steadily round a large circle, the number of intersecting loops may easily be counted. Each loop is obtained by one rotation. Consequently by counting the number of loops traced in a given time we can measure the rate of rotation of the teetotum.



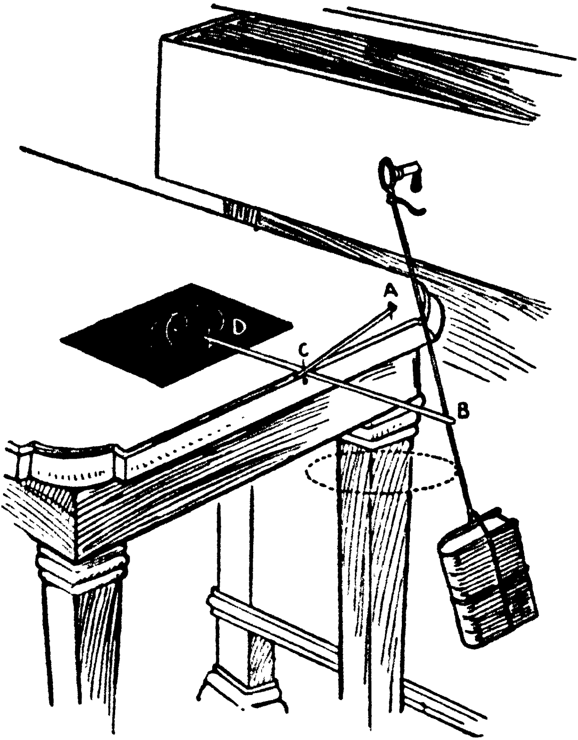
60. THE SPHYGMOGRAPH.

WITH cork, pin, match, boot-button, and goose quill we may construct a sphygmograph and take the record of our pulse beat.

The essential thing is a lever of large magnification, on the short arm of which the beating of the pulse will act, while the long arm will magnify this motion and record it on a moving lamp-black surface.

The lever is built up of the button, match, and quill, the one end of the match being set in the ring of the button, while into a slit at the other end a thin slice of the quill is inserted. This rests within a slot cut in the cork; and the pivot or fulcrum of the lever is a pin passing in succession through one wall of the slot, the match, and the other wall, the hole in the match being a short distance in front of the button. In the upper diagram, which shows the lever and the middle vertical section of the cork, the pivot pin is represented by a small circle on the match A, B being the button and D the thin slice of quill. The curved part E is a somewhat thicker slice of the quill, acting as a kind of spring supporting the lever. The one end of this quill is pinned on the under surface of the cork, and the other is tightly caught in the ring of the button. Things must be adjusted so that the lever is horizontal, and the button projects slightly above the level of the cork.

Blacken a card above the flame of a candle, lay the apparatus on the table, and ask a friend to lay his pulse on the button. At each beat of the pulse the button is pushed down and then recovers. Simultaneously the far end of the lever rises and falls. Place the card vertical with its edge resting on the table, bring the blackened surface into light touch with the tracer at the end of the lever, and draw the card slowly and steadily along. There will appear on the blackened surface a tracing of the curve of pulsation, a curve which varies with age, state of health, fatigue, etc. By collecting the sphygmograms of your friends you will possess a novel kind of autograph album.



61. THE CONICAL PENDULUM.

If we pull a pendulum to one side and then leave it to itself, it will swing as a simple pendulum to and fro through the lowest position. But if, instead of leaving it to itself, we give it a lateral motion at start, it will not pass through the lowest point, but will move round it in a curve which is approximately elliptical. Owing to various dynamic causes, this approximately elliptical path will slowly revolve in the direction in which the bob of the pendulum is moving, and consequently will form a succession of intersecting curves. The path is, in fact, an interlacing spiral, of which any one loop has a contour very similar to an ellipse.

A simple method of tracing the movement is shown in the figure. The conical pendulum is formed by means of a heavy book attached to a string whose other end is tied to a key projecting from a chest of drawers; but any other convenient mode of suspension will serve the purpose. Also a sphere or upright cylinder would, from their greater symmetry, be more suitable than a book.

An articulated system of two straws, AC and BD, pinned together in T-form at C, supplies the recording apparatus. To keep the whole as light as possible, the straws might be halved along their length; their semicircular sections will give them sufficient rigidity. The end A of the one straw is fixed by a pin to the table. The end B of the other straw is slit to receive the pendulum string, to which it is then fixed with a little sealing-wax. The end D is pierced through with a fine needle, which rests on a plate of glass covered with lamp-black and placed on the table.

Start the pendulum to describe its conical motion. The connecting straws will move with it, and the needle at D will trace a horizontal projection of the path traced by the bob. It may be mentioned that the regularity of the change in the motion of the pendulum is governed by the mechanism of the connecting linkwork of straws.

To make the pure conical pendulum go through its changing motions with steady regularity, we should attach the upper end of the string, not to a solid support, but to the bottom of a short V-shaped piece of string whose ends are fixed to the support. This is known as Blackburn's Pendulum. A pendulum so suspended swings to and fro in the plane of the V with a slightly shorter period than in the perpendicular plane.

If the bob of such a pendulum is a funnel with its wide opening looking up and its narrow opening down, we can fill the funnel with fine sand. Then as the pendulum goes through its motions the escaping sand will gather in heaps along lines on the table below; and these lines will trace the form of the path of the pendulum bob. It is well to attach a narrow-bored glass tube by means of a rubber tube to the end of the funnel so as to diminish the rate of outflow of the sand.

62. THE WALL OF CORDS.

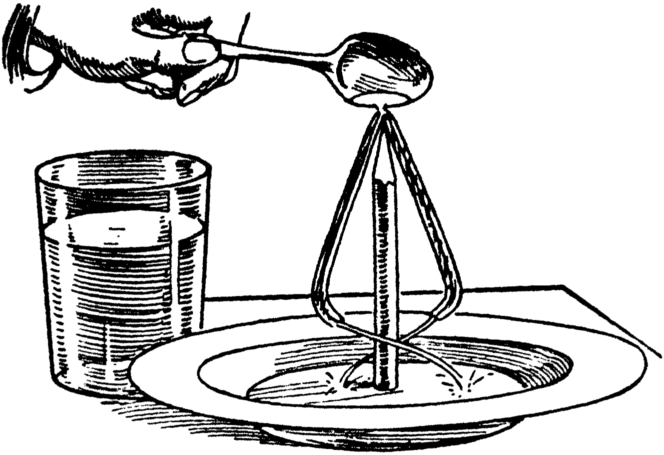
STRIKE with a cane the lower end of a cord suspended vertically: you will be surprised to see what an insignificant effect is produced. The cord as a whole experiences a very slight displacement. The free end below the part struck is pulled up by the sudden increase of tension in the cord, and wraps itself round the cane with a considerable velocity which is killed by impact with the cane.

In the striking experiment known as the Wall of Cords, a fragile object is placed behind a set of cords hung parallel to each other in a vertical plane, and nearly reaching the ground. One of the company is invited to strike the object as hard as he can. To his surprise, and perhaps annoyance, his blows, however violent, never reach the object, and make but a small impression on the protecting cords.

Note that there is no resistance to a slow motion through the cords ; it is the impulse of a sudden blow which is resisted and practically destroyed.

A swimmer who has become entangled among weeds should remember the lesson of this experiment. Any struggling with more or less rapid strokes of the legs will lead to greater entanglement. The best plan is to float on the back, and by a gentle movement of the hands swim slowly and quietly away. The long runners will gradually slip off, regaining their original parallel directions.

A neat trick depending on the same principle is to tie a cord on your wrist while you continue to hold the ends in your two hands. Each end is held between forefinger and thumb, and the cord lies slightly slack between the two hands. By a sudden movement the right hand is carried forward and then quickly backward, so that the string, which for the moment hangs vertically from the right hand, strikes the part of the string some three or four inches away from where the string leaves the forefinger and thumb of the left hand. The result is that the part of the string beyond the point struck will curl round the striking part and loop itself on to the left hand. A few trials will soon make perfect. The chief point is not to strike too near the left hand. When struck at the proper place, the string gracefully forms a knotted loop over the wrist.

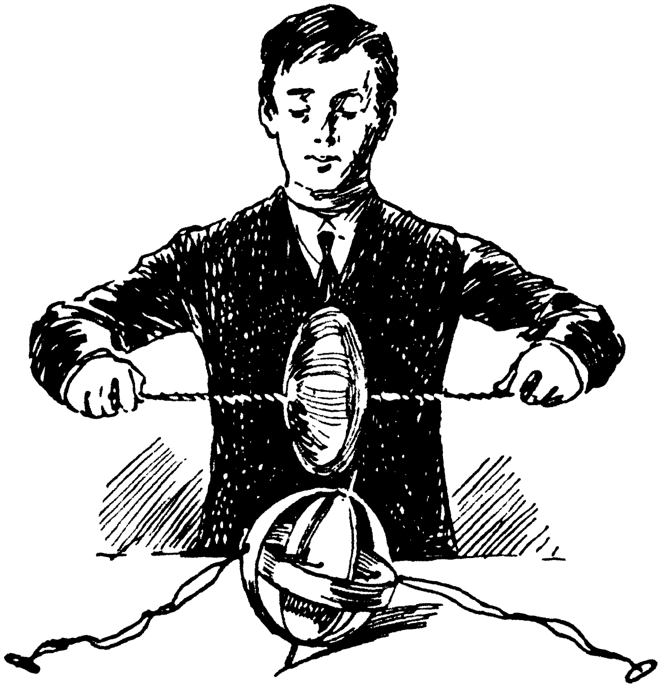


63. BARKER'S MILL.

CEMENT two hairpins together side by side with seccotine, or tie them with threads so as to form a kind of hollow gutter between the two pins. Turn the free ends of the pins by means of pincers at right angles to the plane of the two pins so as to point in opposite directions.

Set a sharp-pointed pencil, slightly longer than the pins, on its blunt end in the centre of a soup plate, and on its point place the vertex of the united hairpins. The apparatus is now ready for action. Pour a little water out of a spoon into the top of the pins. The water will flow down the miniature gutters and round the turn, although after the turn the groove between the pins is on a vertical face.

Capillarity prevents the water falling off till it comes to the end, when it will be projected outwards with the velocity due to the height fallen through. The reaction will set the pins rotating round the vertical in the opposite direction. The motion may be maintained by continually adding water above.



64. THE FIGURE OF THE EARTH.

The slight departure of the earth from the truly spherical form is explained as due to its rotation about the polar axis. This may be illustrated by means of the following simple apparatus.

The foundation is the well-known children's toy of the whirling disk. A thick disk of cardboard is bored near the centre with two small holes, through which a string is passed, forming a double strand.

The ends are held in the hands, and by a rotatory movement the double string is twisted upon itself. By rhythmical movement of the hand to and fro the disk is kept in rapid rotation, first in one direction and then in the other, as the cords are untwisted and twisted again and again.

Remove the string, and stick into the edge of the disk four sprigs of iron wire forming the projecting ends of two diameters at right angles to each other.

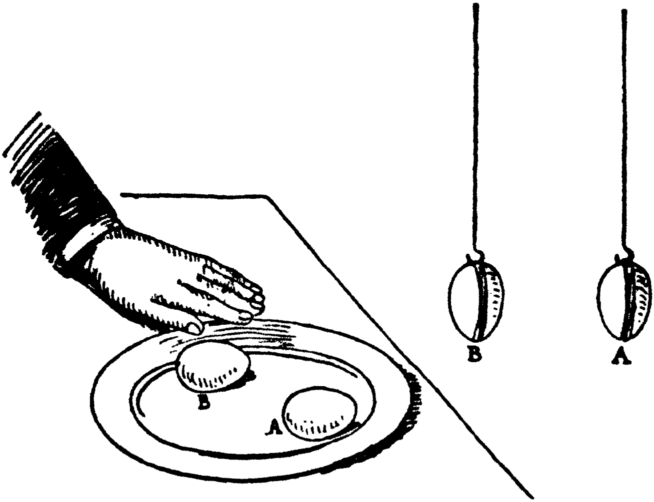
Make two circular rings of strips of strong paper, slightly larger than the circumference of the cardboard disk; place one within the other, and gum them where they cross symmetrically at right angles. The parts where the strips cross will represent the poles of the earth, and the circular strips themselves will represent four meridian lines.

In the centre of the four semicircular arcs pierce small "equatorial" holes, and at the "poles" where they overlap cut holes large enough to allow the double string to pass by which the rotation of the disk is to be sustained. Place the circular strips round the original disk so that the iron sprigs slip through the equatorial holes, and the double string is threaded through the two holes in the disk, and also through the two "poles."

If now the ends of the double string are held in the hand, and by a rotatory movement of the disk twisted one with the other, the to-and-fro movement of the hands will impart to the disk and the connected strips rapid rotation, in virtue of which the strips will lose their circular form and expand outwards along the equatorial line, the small holes sliding out radially along the iron sprigs, while at the same time there will be an evident flattening of the polar regions through which the double cord passes.

The force required to keep a body moving in a circle depends on the speed of the body and on the radius of the circle. The parts of the strips farther from the poles are moving with greater speed than the nearer parts, and therefore as they rotate they pull more strongly on the strip, which accordingly flattens out. This is an illustration of what is known as centrifugal force.

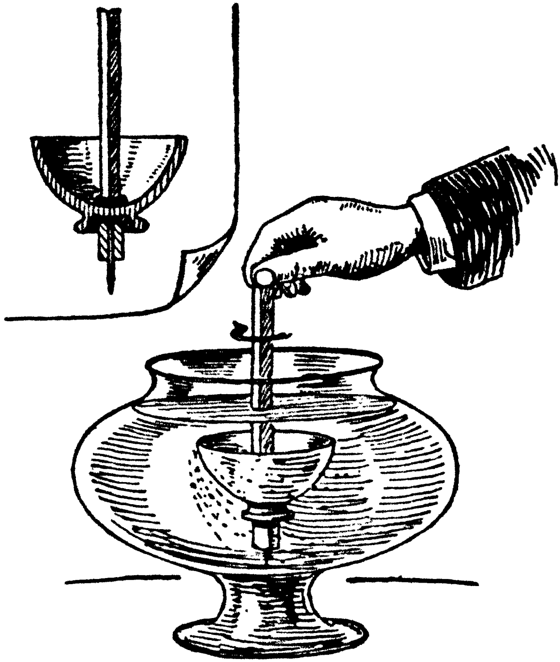
Another simple illustration is given by tying the two ends of a short chain to a piece of string whose upper end is held in the fingers. If the string is rotated in the fingers or between the hands the chain will appear to open out. If by means of a rotating mechanism a steady rotation of the string is maintained, the chain may be made to open out so far as to become a horizontal circle rotating in the air.



65. DYNAMICS OF FRESH AND HARD-BOILED EGGS.

Stretch round the two eggs in the direction of their length two rubber bands, and suspend them by hooks at the ends of two iron wires, as shown in the figure. Turn the two eggs within the fingers so as to give to each rubber band the same number of twists, and then set them free. The hard-boiled egg will rotate briskly so as to untwist the rubber band and twist it up the opposite direction, then untwist and retwist again for several times before coming to rest. The fresh egg will come to rest almost immediately. In the former case the whole mass partakes of the movement just like any solid body. In the latter case the fluid within the shell does not take up as a whole the movement of the shell, but rapidly kills off the energy on account of fluid friction or viscosity.

Another way of bringing out the difference is to spin them on a plate, and when they are spinning arrest the movement momentarily by placing the hand on them. When released the hard-boiled egg will remain quiescent, but the fresh egg will begin again to move. In this case the rotation given to the fluid contents by the initial spinning is not destroyed when the shell is brought to rest, and will set the shell in motion again if the restraint is immediately withdrawn.



66. THE WASHING OUT OF GOLD.

By means of sealing-wax cement to the bottom of a small bowl an upright wooden rod—a school ruler, for example. Similarly, cement to the outside bottom a cork with a strong needle projecting downward in line with the rod, and as nearly central as possible.

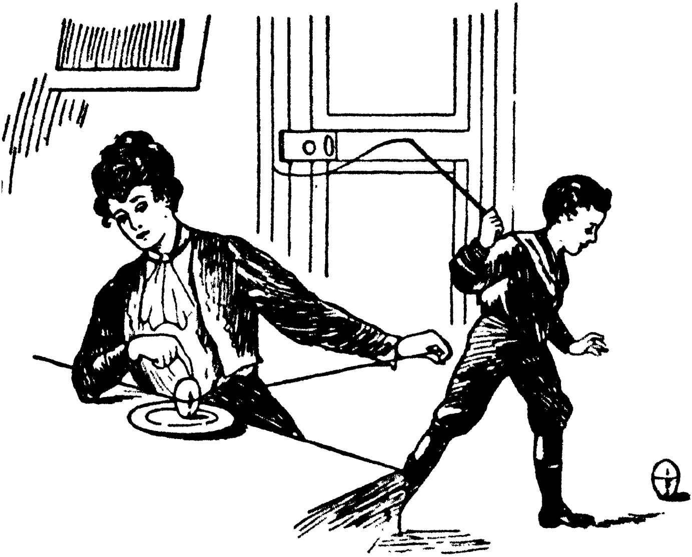
Let there be in a neighbouring vessel some fine sand in which a small piece of lead or other heavy particle is lost to view. It is required to separate out the heavy particle. To effect this hold the small bowl within a large basin or tureen (represented in the figure by a transparent glass aquarium so as to allow the whole to be visible). Fill up the tureen with water till the level is an inch or two above the rim of the bowl, drop into the bowl a few handfuls of the sand, and rotate the bowl to the right and to the left several times in succession, thereby permitting the heavy particle, if present, to descend to the bottom of the bowl. Then, rapidly rotating the bowl in one direction, we see the sand spreading out and up in virtue of centrifugal force, finally escaping over the rim of the bowl. By filling in more sand into the bowl and repeating the process we ultimately leave the heavier particle alone in the bottom of the bowl.

67. A WHIRLPOOL IN A CARAFE.

A CARAFE half full of water is closed with a cork, with a knitting-needle fixed at its centre, and passing downwards through the water till the lower end is above two inches from the bottom. A broad cork with a large hole in its centre encircles the needle, and floats on the surface of the water (see the figure on the right).

The problem is to disengage the needle and the floating cork without touching the cork which closes the neck of the bottle.

The trick is effected thus. Whirl the carafe rapidly round four or five times, and then leave it to itself. In virtue of centrifugal force the water will rise up the sides of the bottle, forming a great hollow, which will leave the end of the knitting-needle for the moment quite out of the water. The cork descending with the water surface will slip off the knitting-needle, and will be found floating free when, with the cessation of motion, the surface of the liquid has regained its horizontal position. We have in miniature the image of a boat caught in the maelström.



68. THE EGG SPINNING-TOP.

WRAP round the middle of a hard-boiled egg a few turns of string, and then set the egg with one of its ends on a plate, keeping the long axis vertical by means of the forefinger of the free hand. A sudden pull on the string will set the egg spinning like a top or teetotum on the plate. This is one way of solving the problem of Columbus, how to make an egg stand on its end.

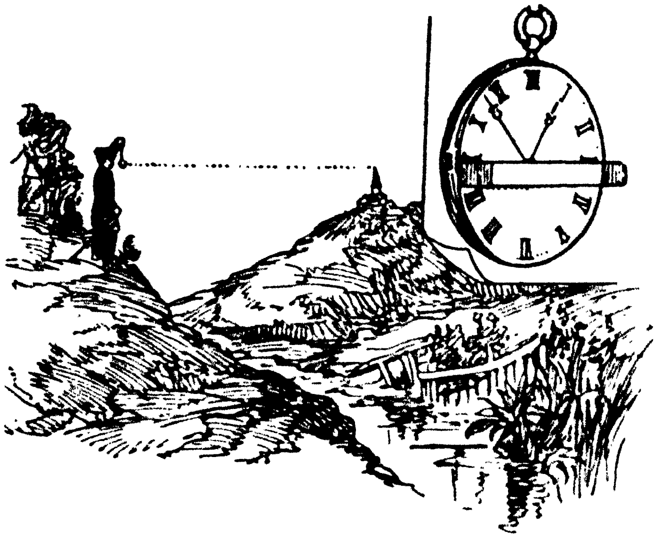
Instead of having the egg spinning smoothly in one place, you may use it as a whipping-top, lashing it with a whip of threads or of eel's skin. There is danger of a real egg being broken under this rough treatment, and it might be better to substitute an egg of wood—a "darner," for example—which may be set careering all round the room without fear of catastrophe.

69. THE PRINCIPLE OF THE PULLEY-BLOCK—A CHILD PULLING AGAINST FOUR MEN.

Ask four of the company to arrange themselves in pairs to pull against each other in a tug-of-war of a novel kind. Each pair will grasp the long shafts of a separate broom. Then placing them about a yard apart, tie to one of the shafts a rope, and pass the rope four or five times round the shafts, care being taken not to allow the cords to cross one another. Holding the free end in your hand, you tell the four stalwarts that you will bring the two shafts together, however much they may resist by pulling with all their strength. You simply have to retire rapidly, pulling the rope with all the force you can exert, and the shafts with their struggling holders will be drawn together. The principle is the same as in blocks of pulleys. Whatever pull you exert on the rope will produce between the shafts an attracting pull proportional to the number of strands of rope between them. For example, if the rope has been carried round the shafts five complete times, giving ten connecting strands, the force which you exert on the rope will be increased tenfold between the shafts, and your friends holding the shafts will not be able to resist this.

The relation between force and distance is the same as is met with in pulleys—what is gained in power is lost in speed. If the shafts approach each other by one foot, the free end of the string will pass through ten feet. If you cannot retire with this speed, you must pull the rope rapidly through your hands.

A very amusing variation on this experiment is to perform it on a smooth, well-waxed floor. Give the free end into the hands of a small boy, and he will be able to resist the efforts of the four men in pulling the shafts away from each other. It is a novel kind of tug-of-war.



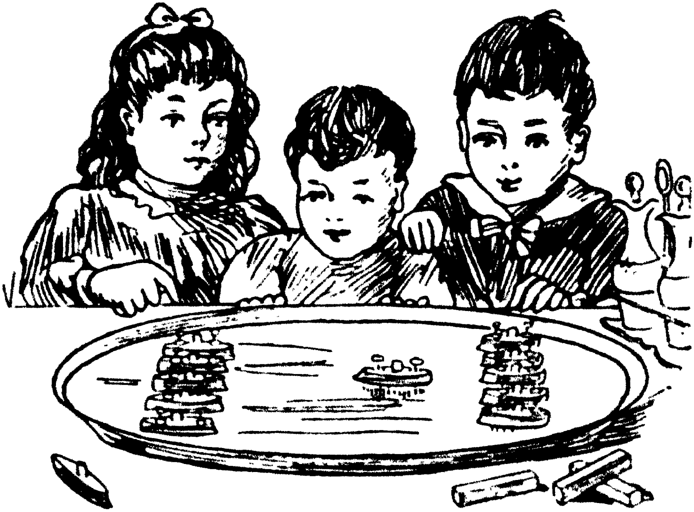
70. LEVELLING: THE WATCH LEVEL.

It may chance that an officer, or traveller, or engineer may wish to determine the difference of level between two points in a district. There are several forms of apparatus in use for effecting this purpose. These are called *Levels*. But it may be that none of these is accessible. In such a contingency it is possible to use a pocket watch as a level good enough for temporary purposes.

For this end take a strip of paper a little longer than the diameter of the watch, and bend the ends at right angles. Wetting the back of the paper with the tongue, lay it on the glass face of the watch so that the upper surface is coincident with the diameter which passes from the hour III to the hour IX.

Now suspend the watch by a string through the ring. The diameter from XII to VI will be very nearly vertical, and the III–IX diameter will be perpendicular to it. Thus the upper line of the paper will be very approximately level.

To find what point across a valley is at the same level as your eye, lift the watch by means of the attached string, and, looking over the two bends of the paper, bring their edges into the same line with your eye. The part seen immediately above this on a distant building or hillside will then be at the same level as the eye.



71. REVIEW OF THE FLEET.

Cut out of chalk small models of the ships of a fleet—battleships, cruisers, torpedo-boat destroyers. The masts, funnels, conning-towers, and other accessories may be made with bits of matches and coloured paper, and the whole painted over with ink to give them the usual gray appearance. The bottoms must be flat.

Having drawn them up in battle array on a flat tray, pour into the tray some vinegar. At once each ship will be surrounded by a fringe of foam, and will begin to move about in various ways until in a short time the whole will be in disorder and confusion. The effect is very striking and curious, but the explanation is simple enough. When brought into contact with vinegar the chalk decomposes, producing carbonic acid gas. This coming off in bubbles generates the foam, and the disengagement of gas is so powerful as to push the little ships here and there with considerable force, and even to lift them slightly above the surface on which they rest.

The same reactionary effect is observed when an egg is put into a bowl of vinegar. The bubbles of carbonic acid gas disengaged by the action of the vinegar on the shell cause the egg to rotate about its long axis.

IV. Capillarity and Surface Tension.

72. SURFACE TENSION: SOAP BUBBLES AND FILMS.

In order to understand the phenomena of capillarity aright we must think of every fluid surface as being the seat of a tension or force very similar to what exists in a stretched sheet or band of india-rubber. The stretched sheet tends to contract until the strained condition or state of tension ceases to exist. The same holds for every liquid surface.

To show directly this surface tension we must give the liquid a certain amount of tenacity or power of holding together. This is best done by means of soap solutions.

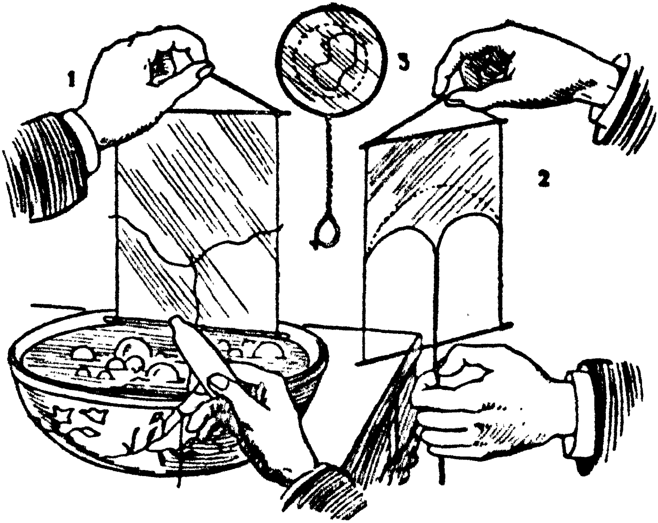
There is nothing more fascinating than playing with soap bubbles, and almost every child knows how to blow a bubble. The first essential is a good soap solution, and this may be made with ordinary yellow soap with a little pure glycerine or sugar added to give length of life to the film.

Bend round a bottle a piece of thin iron wire, and twist the ends together to make a handle for the ring so formed. Dip this ring in the soap solution, and remove it carefully. Across the area there will be seen a thin film of liquid. Holding it in a vertical plane, blow gently on it, and it will bulge outwards on the opposite side, assuming the form of a pouch more or less elongated. When the blowing ceases it will gradually contract to the original size. This shows that there is a tension in the film drawing it together to the smallest possible area consistent with the conditions of existence.

This experiment may be done without any artificial apparatus, by simply supporting the film within the ring formed by the thumb and forefinger meeting at their extremities. Dip this part of the hand into the soap solution, and gently withdraw it. A glance will show if the film is there. Place the hand funnel-wise before the mouth and blow gently, and the film will be seen extending outwards in a long-shaped pouch. When the blowing ceases the film contracts to its original size.

73. THE SLIDING BRIDGE.

Bend a piece of thickish wire into the form of a rectangle, and lay across it a bridge of much thinner wire, with the ends bent down so as to prevent it slipping off. Dip the rectangle with the bridge in any position into the soap solution. When withdrawn it will be seen to be supporting two films, one on each side of the bridge. With a pointed wedge of blotting paper remove the film from the one side of the bridge, and at once the remaining film will contract and draw the bridge to the end of the rectangle. Before the removal of the one film the tensions in the two films pulling equally on the bridge balance the one against the other; but as soon as the one film is removed the other contracts to the utmost, thus demonstrating the existence of surface tension, and the tendency of all surfaces to contract to the least area possible under the conditions.



74. FILMS WITH FLEXIBLE BOUNDARIES.

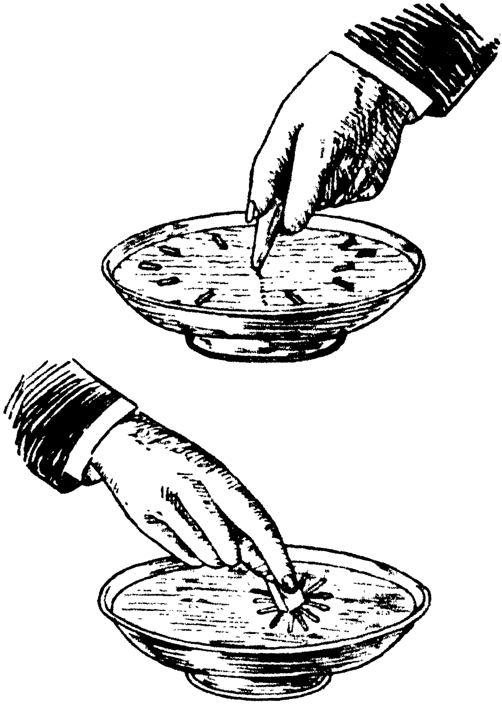
Tie the ends of a light thread to the opposite sides of the circular wire described in Section 72, and let the thread be slack. When the film is formed on the circular wire the thread will move about within the film, but will assume no definite form. Remove the film from one side, and the tension in the film on the other side will pull the thread at every point with equal pull, so that it will assume the form of a circular arc.

If the thread is made double for part of its length, and the film be removed from within the doubled thread, the films on the two sides will contract to the greatest possible extent, so as to have the least possible area. Hence the film-free region between the two threads will have the greatest possible area under the conditions. They will, therefore, form a perfect circle, since the circle is the form of contour which with given circumference encloses the greatest area. This is indicated by the dotted circle in Fig. 3.

Another similar experiment is illustrated in Figs. 1 and 2. Two knitting-needles form the top and bottom of a rectangle whose vertical sides are made of threads of equal length tied to the ends of the needles. These threads are continued above to form a loop by which the framework may be held. The middle points of the vertical threads are connected by a third thread somewhat longer than the needles so as to hang loosely, and to the centre of this thread is tied a fourth thread with free hanging end.

Dip this in a basin of soap solution, and then slowly draw it out, with the liquid film filling in the whole rectangle. Touch the film below the cross thread with a pointed piece of blotting paper, so as to destroy the film in this part. The film above will contract, and draw the cross thread into the form of a circular arc, as indicated by the dotted line in Fig. 2. Now take hold of the loose hanging end and draw it down. The thread will then take the form of two small circular arcs, as shown in the figure.

Beautiful forms of films may also be obtained by means of a wire bent into the form of a cube. When this is rotated slowly round in the soap solution, films will be formed on four of the sides. If a fifth film is obtained on the end face and the cube is then lifted out, this fifth film will contract towards the centre of the cube, drawing the centre parts of the other films with it. There will be formed two truncated pyramids with the truncated square end in common. Along the edges of this square centre three films meet, and since the surface tension is the same in all, they must meet at the same angles —namely, 120°.



75. THE GLUTTONOUS MATCHES.

Frequently young children show great reluctance to submit to being washed, and will sometimes flee from the sight of soap and towel; but towards the offer of a piece of sugar or toffee they will run with delight.

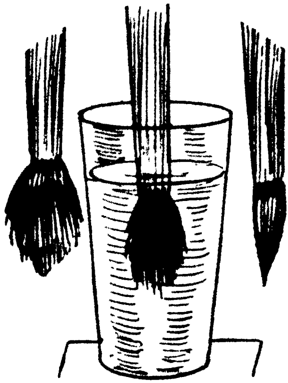
The following experiment will amuse them, and show that even matches have the same evil tendencies!

Float a number of matches in a basin of water, disposing them star-like, with their inner pointing ends touching. At the centre of the star immerse a small pointed end of soap. At once the matches will be driven outwards, as if under the influence of a powerful repulsion.

To bring them back again, it is sufficient to present to them a piece of sugar immersed in the water. Immediately the matches will rush towards it.

The apparent repulsion of the soap is due to smaller surface tension over the surface of water when the water is made soapy. The uncontaminated part will retain its original surface tension, and will exert upon the boundary between the pure and soapy water an outward pull stronger than the inward pull exerted by the soapy surface. When, on the other hand, the lump of sugar is placed in the water, it draws the water into the pores in virtue of capillary action. This creates an inward current of water which draws the matches together again.

The tug of war between two surface tensions of different strengths is also shown when a little alcohol is dropped into a lake of ink resting on a horizontal glass plate. The ink, which is simply coloured water, pulls by virtue of its surface tension more strongly outwards than the alcohol pulls inwards. Consequently there is formed a shallow lake of alcohol in a sea of ink.



76. THE SURFACE SKIN ON PURE WATER.

To blow bubbles and obtain permanent thin films of liquid we must use soap solution. This is not because soap solution has a stronger surface tension than pure water (the experiment just described proves that it has not), but because the pure water has no appreciable tenacity, and cannot hold together as the soap solution does.

There are, however, several well-known effects which prove the existence of a surface film on pure water.

For example, see how a raindrop accumulating on the window sash gradually increases in size, bulging downward until it becomes too large to be supported by the surface film, when it drops off.

Raindrops as they fall in air are spherical, being under the moulding action of the tension in the surface film only For gravity has a moulding influence only when part of the drop is fixed. In the manufacture of small shot the melted metal is allowed to drop from a height in small portions. Each rapidly takes the spherical form as it falls, and when suddenly cooled in water retains the spherical shape. When sealing-wax is melted the sharp edges become rounded, and would indeed become spherical if it were not for the distorting action of gravity.

A paint-brush when dry shows all the hairs standing apart. When dipped in water and taken out the hairs cling together, and the reason given for this is usually stated in the simple form—they cling together because they are wet. But if we look at the brush when it is under the water, and therefore thoroughly wet, we see the hairs still standing apart; hence their clinging together when removed from the water cannot simply be because they are wet. There must be some other reason. This other reason is the contracting action of the surface film which encloses the hairs. It *proves the existence of this tension in the surface* of the water.

77. CAPILLARITY.

In the phenomena of capillarity we have many examples of the effect of surface tension. The most striking of these have to do with the ascent of water in thin tubes; hence the name from *capilla*, a hair. But we shall first take some simpler cases.

When a liquid consisting mainly of water, such as tea, coffee, lemonade, and the like, is poured into a clean—that is, non-greasy—vessel, it is seen to ascend at the margin, where it comes in touch with the walls of the vessel. Close to the wall the liquid surface assumes a concave shape curving upwards as it meets the wall. Now, according to hydrostatic laws, we should expect the surface to be quite level, because the pressure is the same over it.

This curving upwards is a necessary consequence of the fact that water wets the clean glass or porcelain surface. But since there is a tension in the surface film, the curvature necessarily requires that this tension produces a pressure towards the concave side, just as a stretched rubber band round the finger presses inwards on the finger. Hence there is less pressure on the convex side within the liquid than there would be if there were no curvature. The water just beneath the curved portion belongs, in fact, to a region of less pressure than that associated with the water beneath the uncurved surface. It must, therefore, be at a higher level. Thus a concave surface of water necessarily rises in level.

The manner in which mercury curves down to meet the walls of the containing vessels belongs to the same class of phenomena. The pressure is increased below the convex surface, which therefore falls in level. See also next section.

78. CAPILLARY ATTRACTION AND REPULSION.

Set floating on water a number of small bodies thoroughly wetted, such as corks, matches, straws, and the like. When brought near each other they will rush together as if strongly attracted, and continue to cling together, requiring a definite force to pull them apart. The reason is that in the space between the floating bodies the layer of water acquires an increased concavity, with a corresponding diminution of pressure below the concave surface film. The atmospheric pressure bearing on the farther sides of the floating bodies pushes them closer until they come into close contact. In exactly similar fashion such floating bodies, on approaching the sides of the vessel, are drawn towards the wall and stick there. For the same reason air bubbles, which often rise from melting sugar and accumulate on the surface of tea or coffee, cling together in clumps, and adhere to the sides of the cup; for evidently an air bubble with its shell of liquid is as wet an object as can be obtained.

A similar attraction is observed between floating bodies which are not wetted by the liquid—such, for example, as disks of solid paraffin floating on water. Drops of water on paraffin do not spread out as they do on clean glass, but remain distinct drops with a spheroidal form. The same effect is observed with drops of water on a greased glass surface.

In such cases the water does not spread out or rise upwards as it comes in touch with the paraffin or the greasy surface. On the contrary, it curves down against a vertical surface, making the liquid surface convex instead of concave. Beneath the convexity the pressure is increased, and the water sinks below the level where there is no curvature.

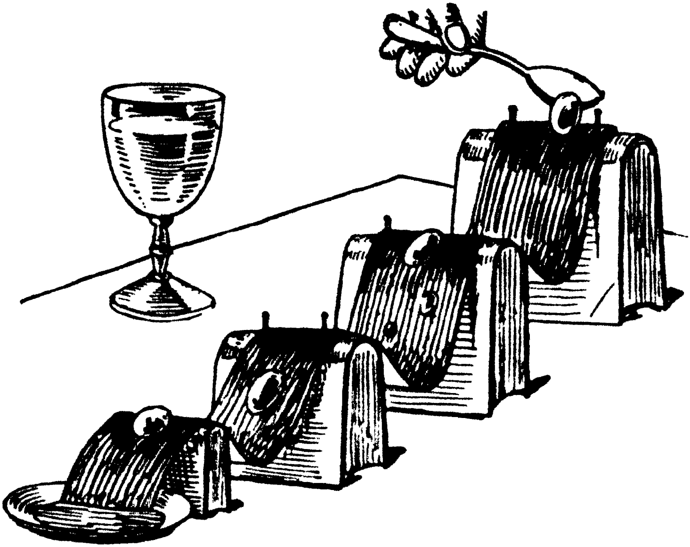
It will be found, however, that when two floating disks of paraffin are brought close to each other they will attract one another, and cling together in exactly the same manner as the corks, matches, or air bubbles. The reason is that, owing to the depression of the liquid between the floating bodies there is greater pressure pushing them together in virtue of the higher level of the liquid on the farther sides.

The most striking way of showing this experiment is to float small iron spheres, such as are used in ball bearings of bicycle wheels, on a surface of mercury. The convexity of the mercury surface where it meets the iron or the walls of the containing vessel is clearly visible, even at a distance.

But now try to bring together a piece of cork (C in figure) and a disk of paraffin (P) as they both float on the water surface. The one will push the other ahead of it, and there will be no attraction. On the contrary, they will repel each other when brought close together. In the region between the two bodies the liquid will not rise so high on the wet body, or be depressed so low on the unwetted body, as it is respectively on the farther sides. Hence there is less pressure on the farther sides than on the sides facing each other across the narrow space, and there is apparent repulsion.

To make a needle float on water, draw it through between the finger and thumb so as to make its surface somewhat greasy or oily. Then lay it lightly on the water surface. Instead of sinking, it will, if the experiment is properly done, depress the water beneath it into a hollow with convex sides. The needle is supported by the upward pressure of the depressed water, just as in the usual applications of the Archimedes principle.

When water-flies or spiders walk over water, the same kind of depression is produced wherever the feet touch the surface. There is a dimple on the surface with its convex side upward. The animal is supported by the pressure due to the displaced water.



79. THE SWITCHBACK TRACK.

When a drop of water falls on a sheet of paper it gradually spreads out over a large area. It wets it.

This will not, however, happen with oiled paper or with paper which has been lamp-blacked, or, indeed, with any surface which is not wetted by the water.

Take, then, a band of fairly strong paper as long as possible. Several pieces gummed together will serve the purpose. Pass it through the smoky flame of a lamp, or preferably cover one of the sides with black lead. Set upright on the table a series of books of diminishing size. Pin to the backs the band of paper in such a way as to produce a series of undulations. This is the switchback track, the last section of which ends in a plate. Take a spoonful of water and drop it on the topmost ridge. It will roll like a flattened ball down the first descent, and then in virtue of the momentum so gained will ascend to the next ridge, and so on from ridge to ridge until it reaches its goal in the plate.

A succession of drops of different sizes will have all the appearance of running a race the one with the other.

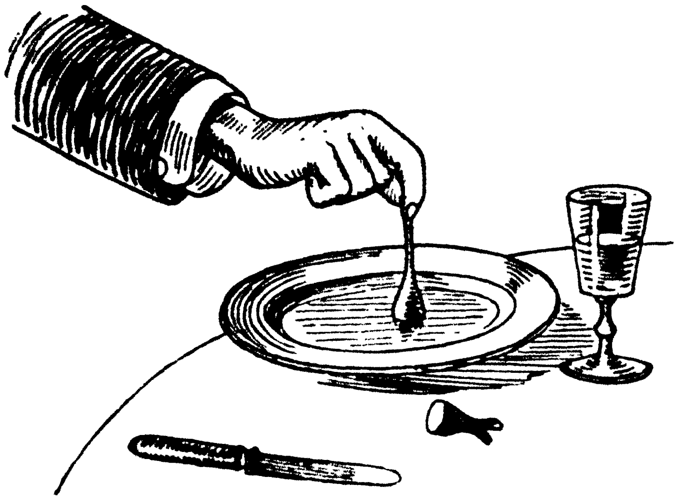
80. CAPILLARY RISE GREATER IN THE NARROWER SPACE.

Take two clean glass plates of the same size, and bind them together by means of clamps or, more simply, by means of an elastic band. Insert a wire or the point of the blade of a knife between the surfaces at one edge, so that the two plates will contain between them a fine tapering wedge of air. Immerse this in a dish of coloured water, with the common edge of the two plates perpendicular to the surface. At once the liquid will be seen rising between the plates to higher and higher heights the nearer the position is to the common edge. Between the plates will be formed a wedge of water whose upper surface will trace out a curve known as the rectangular hyperbola. This curve is such that if we multiply the distance of any point on it from the base by its distance from the vertical through the common edge, the product is always the same. In this way we can experimentally verify the law that the rise of water in a narrow space between two surfaces is inversely as the width of the space.

The same law holds for narrow tubes: the narrower the bore the higher the rise. The surface of the water within the tube is concave upwards; and the total upward pressure due to the surface tension acting over the concave surface supports the column of liquid in the part of the tube which is above the level of the liquid outside.

On the other hand, mercury is depressed in a narrow tube, the surface being convex upwards.

When the atmospheric pressure is being measured in terms of the height of mercury in the barometric tube, a correction must be applied on account of this capillary depression. The amount of this depression is greater as the diameter of the tube is less.



81. THE BOY'S SUCKER: THE RADISH LIFTER.

two plates of glass—say, two photographic plates, quarter-plate size. If pressed together they will show very little, if any, tendency to adhere. But wet the one surface, and then press the surface of the other plate to it. When set horizontal, and the upper plate is gripped by the fingers and raised, it will support the lower plate hanging to it. If the system is slightly inclined, the lower plate will slip off slantingly, but it will not fall off directly in the vertical line.

The layer of water between the two plates forms a thin film whose outer edge is concave outward.

This reduces the pressure within the film, and the externally acting pressure of the air downwards on the upper plate and upwards on the lower plate holds them together.

This is the principle of the boy's sucker, which is simply a well-wetted piece of leather with a string knotted on the lower end, and passed through a hole in the centre of the leather. When the leather is pressed down on a stone it will adhere to it in virtue of capillary action, so that the stone may be lifted at the end of the string.

The rise and spread of water in porous bodies are all examples of capillarity—such, for example, as the moistening of sugar, or the absorbing action of blotting-paper, unsized paper, linen, flannel, etc., etc.

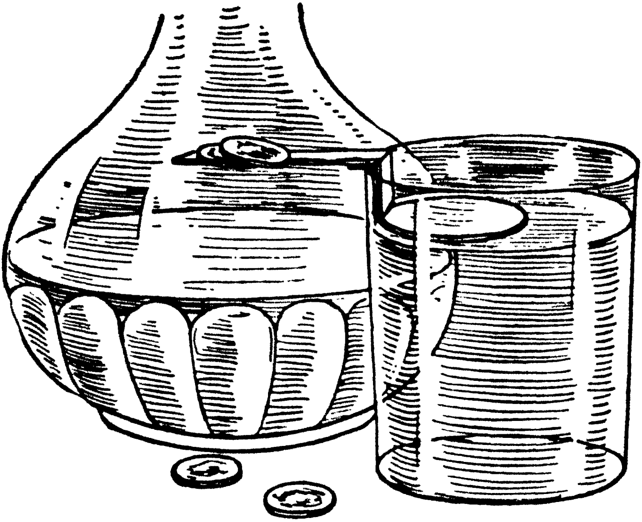
The experiment may be performed at the table by means of a simple radish. Cut the radish across, and slightly scoop out the surface of the part with the tapering end. Rub it over the plate, and then pull vertically on the end of the radish. The plate will be lifted as if the two bodies were glued together.

82. PAPER DIPPED IN INK, BUT NOT INKED.

For this experiment you must have a good-sized ink-bottle with a large mouth.

A piece of white paper is rolled up as a cylinder and plunged into the ink-bottle, and then withdrawn covered with ink. The stained paper is laid on a plate in witness that the ink-bottle was full of black ink. To replace the ink which has been removed, you fill up the ink-bottle out of an ordinary bottle of ink and repeat the experiment. On this occasion, however, the paper comes out as white as it went in, to the amazement of the spectators.

There is, of course, a little trick of deception. The ink-bottle is full of ink, but the bottle out of which a new supply was supposed to be obtained does not contain ink. It once did, and bears the outside legend; but it is an old bottle, quite dry within, into which previously some finely-powdered resin has been introduced. The company believe that you have added more ink to the ink-bottle, but instead you have sprinkled the surface of the ink with this finely-divided resin. This fine powder prevents the ink from touching any body which may be immersed in it for a few moments. A slight shake will disengage any resin clinging to the paper as it is withdrawn in the second experiment.



83. COHESION.

CONSTRUCT out of cardboard a trowel-shaped figure consisting of a rectangle and circle joined together, as shown in the figure. The bend in the handle of the trowel may be strengthened by means of a second strip gummed to it or fixed with sealing-wax. Place the apparatus on the rim of a tumbler with the circle and connecting part of the rectangle close to the inner surface, and then balance it with a coin appropriately set on the strip projecting beyond the edge. The circular disk should be absolutely horizontal.

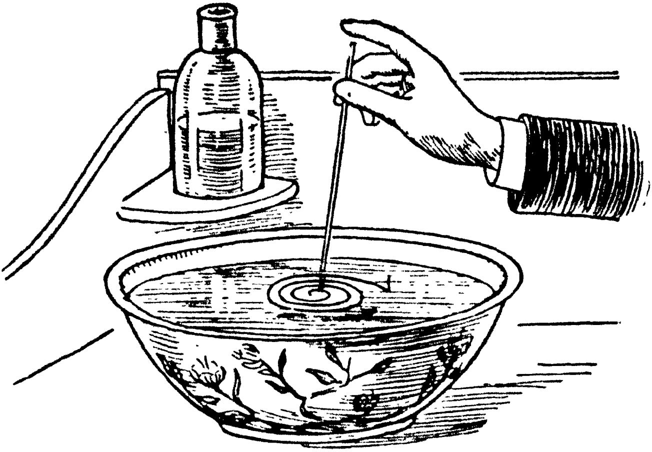
When equilibrium has been secured, pour water into the tumbler until the liquid surface comes in contact with the lower surface of the circular disk.

You will now be able to add another coin to the extremity of the projecting rectangle, and even several coins, before the disk is pulled away from the liquid.

This is an example of the force of cohesion, and demonstrates the existence of an attractive force between the particles of different bodies, where these are brought into close touch.

When the disk is separated from the water, some liquid remains adhering to it. It is not therefore so much the force of adhesion between disk and water that is being overcome as the cohesion between water and water.

The same experiment may, however, be made with a glass disk resting on a mercury surface. It will be found that a considerable pull is needed to separate them; and in this case the separation of solid and liquid is complete.



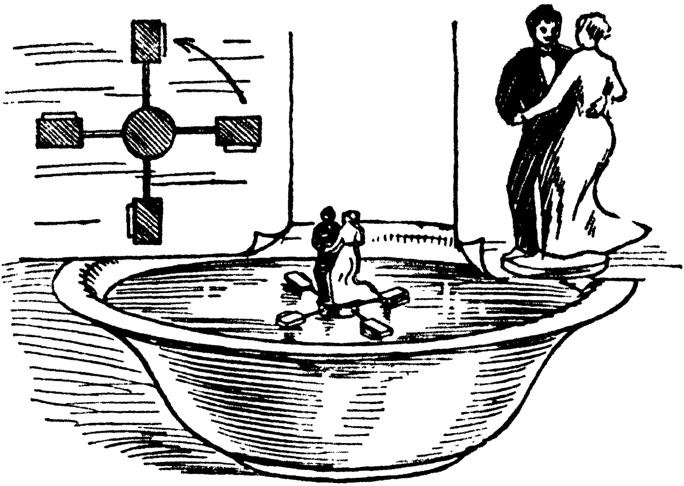
84. THE ROTATING SPIRAL.

MAKE a small flat spiral with very thin iron wire, and coat it lightly with oil, so that it may float on water.

Take a little soap solution in a pipette (a hollow straw will serve the purpose) and allow it to drop in the centre of the spiral. The spiral will begin to rotate in the direction of the arrow.

The soap solution has less surface tension than the pure water, and the resultant pull on the spiral is always away from where the solution is in greatest concentration. On account of the spiral form round the region into which the soap solution is dropped, the outward pull acting on the wire of the first turn is eccentric with regard to this inner region, and causes rotation in the direction indicated.

Other liquids, such as alcohol, rum, or brandy, may be used instead of soap solution.



85. THE CAMPHOR MILL.

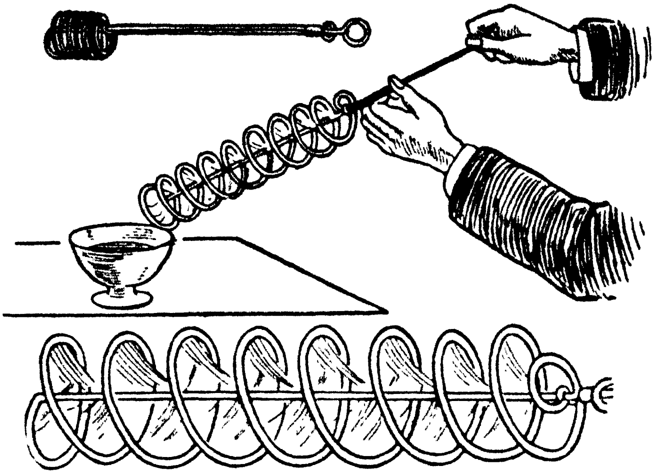
FORM a cross with two sewing-needles passed through a small cork, and to the four extremities attach small rectangular pieces cut out of the same light material. On the one vertical face of each of these pieces gum a small disk of camphor, the camphor faces all looking in the same direction round the centre.

Place this in a basin of water, and at once it will begin to spin round rapidly, and may continue so to do for days.

The reason is that the camphor dissolving in the water greatly reduces the surface tension of the liquid on the side towards which the camphor strips face. The surface tension on the other side of each of the corks pulls them round in the direction shown by the arrow.

Two light pasteboard figures of a couple in waltzing attitude may be fixed to the central cork, and these enthusiasts will dance indefatigably till the water surface becomes fairly uniformly contaminated with the camphor.

If small chips of camphor be dropped on a water surface, they will be set in lively motion on account of the unequal dissolving at different points.



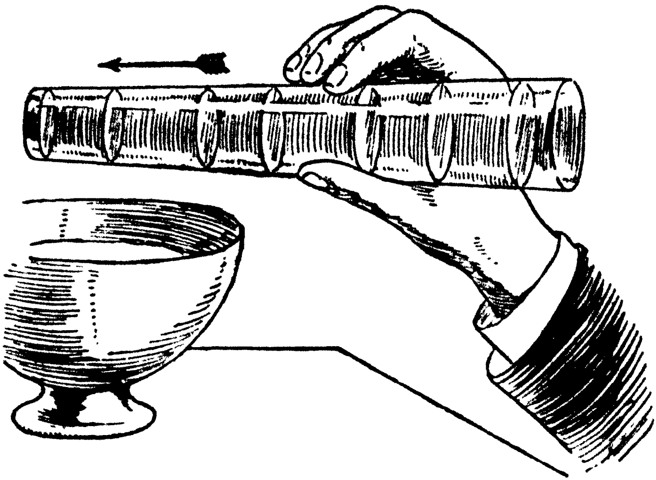
86. THE HELIX.

TAKE one of the cardboard tubes used for sending journals and music through the post, and pass through it the one end of a thin iron wire. Ask a friend to hold it in the axis of the tube, and then wrap the rest of the wire round the tube as you would wind cotton thread on a reel, laying the coils of wire in juxtaposition, and passing backwards towards the beginning of the axis. After eight or ten turns have been made, draw the whole wire out of the tube, twist an eyelet on it near the last turn, placing the part of the wire which has not been coiled close to the straight part which forms the axis, and serves as handle for holding the helix.

These parallel parts are tied together with thin iron wire, loosely enough to allow the one straight portion to be moved to and fro along the other. The drawings will show more clearly than words the form of the apparatus.

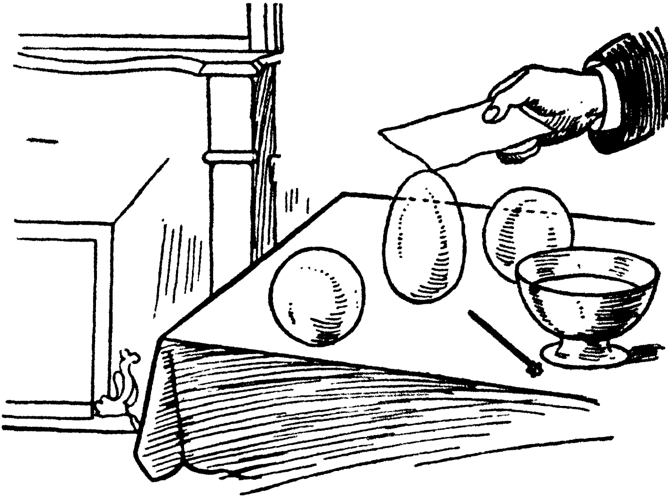
A small ring terminates both ends of the wire; and when the ring of the handle is held in the left hand, the other ring may be moved to and fro by the action of the right hand. During these motions the helix will be lengthened or shortened, varying the pitch of the screw. With the helix in its shortest form plunge it into a bowl of soap solution, and gradually draw the helix out coil by coil. Each of the coils will be adorned with a thin soap film reproducing the form of a helicoidal surface, and showing beautiful iridescence as the light plays upon it.

For the explanation of this iridescence, see Section 137.



87. SOAP FILMS IN A CONICAL TUBE.

ANOTHER example of the contraction of soap films to the smallest area possible is to take a lamp-glass of conical or tapering form, and after moistening the interior dip the wide end in the soap solution, holding the glass vertical. Draw it carefully out, and you will see the film formed across the end. If the tube is now held horizontal the film will begin to move towards the narrow end, contracting as it moves. Dip the wide end again into the solution, and go through the same process: a second film will form, and follow the first one moving along the tube. In this way by successive dippings a procession of films may be made to pass along the tube, as if each were trying to catch up on its predecessor.



88. ELECTRIFICATION OF SOAP BUBBLES.

FLANNEL and woollen stuffs in general, when well dried, may serve to support soap bubbles without bursting; and it is even possible in winter to play ball with a bubble if the hands are covered with knitted woollen gloves.

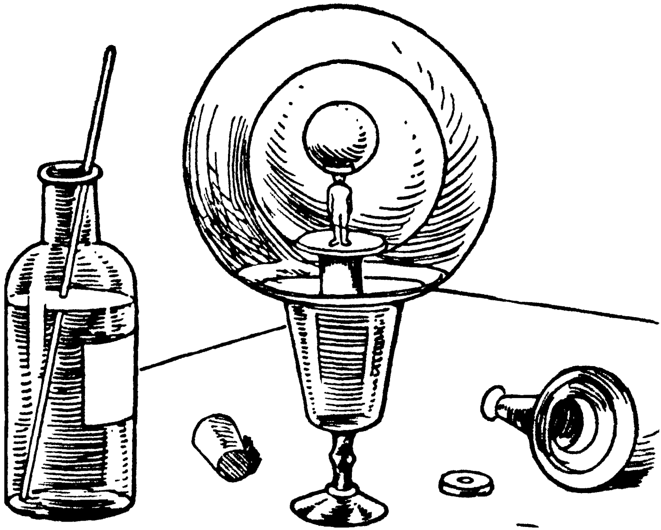
Suppose, then, that there are several soap bubbles lying on a woollen cover laid on the table. Dry a piece of stiff paper before the fire, and then electrify it by rubbing it briskly with a rough brush. Hold the paper above one of the soap bubbles. The bubble will elongate and take an oval shape, and when the paper is brought near enough it will rise from the table towards the paper like a balloon filled with gas. Several bubbles may be acted on in succession, and made to perform an electric dance.

A piece of sealing-wax rubbed with flannel, or a rod of glass rubbed with silk, will act more efficiently than the paper in virtue of its higher electrification.

89. THE FLOWERS OF ICE.

WHEN a cloud forms in a very cold region the water vapour, instead of changing into raindrops, condenses into small crystals of ice, which cohere together and fall as snowflakes. The constituent crystals are of the hexagonal system, and group themselves into a great variety of beautiful star-like forms. The parts are symmetrically disposed around an axis, the six structural lines of symmetry perpendicular to this axis making equal angles with one another. These "flowers" of ice are best observed when the snow is cold and dry. Looked at through a lens, a snowflake resting on a black piece of cloth will show these varied forms of crystal grouping. A few of the forms met with are represented, greatly magnified, in the illustration.

The main part of the illustration shows another way of observing their formation—namely, by blowing a soap bubble outside on a cold, frosty day. Very soon the small crystalline needles of ice are seen forming in the thin film, and gradually grouping themselves together in the varied forms mentioned above.



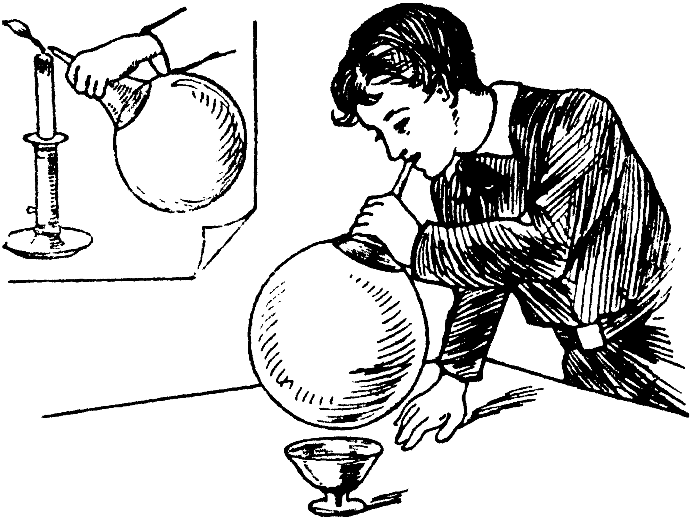
90. THREE SOAP BUBBLES ONE WITHIN THE OTHER.

Small bubbles only can be blown at the end of narrow tubes, such, for example, as form the sliding rods for light curtains. If we place on the end of the tube a disk of cork pierced with a hole, the bubbles obtainable will be larger, for they have as base the surface of the cork. Large bubbles are best obtained by means of funnels such as are used for filtering or decanting—a child's trumpet will serve the purpose admirably. The ordinary clay pipe is not satisfactory for experiments of an elaborate kind. It is apt to break, and, besides, the bore of the shank is too narrow in relation to the opening of the bowl to allow of rapid increase in the size of the bubble.

We are now prepared to blow three bubbles of diminishing size, the greater enclosing the less. Set a saucer on a pedestal—say, a long-stalked wine-glass. Pour a little soap solution into the saucer, and place upright in the centre a good-sized cork. Over this lay a crown or four-shilling piece (or any disk of about the same size), in the centre of which a small porcelain doll is set erect, fixed with a little seccotine for greater security, and carrying on his head a threepenny bit, or cardboard disk of the same size, also fixed with gum or seccotine. The whole arrangement must be well moistened with the soap solution.

Dip the mouth of the trumpet or funnel into the solution, and then, holding it over the head of the little figure, blow the first bubble. It will not collapse on contact with the wet objects, but will expand until it encloses the whole and rests on the saucer. Stop blowing when the bubble has become six or eight inches in diameter, and leave it resting on the saucer. This is the outside bubble, within which the others are to be blown.

Take now the tube, dip it in the soap solution, and wet it well along its length. Boldly push the end through the wall of the large bubble, which will not collapse, dip it in the soap solution in the saucer, and blow the second bubble above the head of the figure. Cease blowing when this second bubble, resting on the crown piece, has attained a diameter of three or four inches. Draw out the tube, dip it in the bottle containing the solution, push it through both bubbles, and blow the third bubble of an inch diameter, so as to rest on the upper disk.



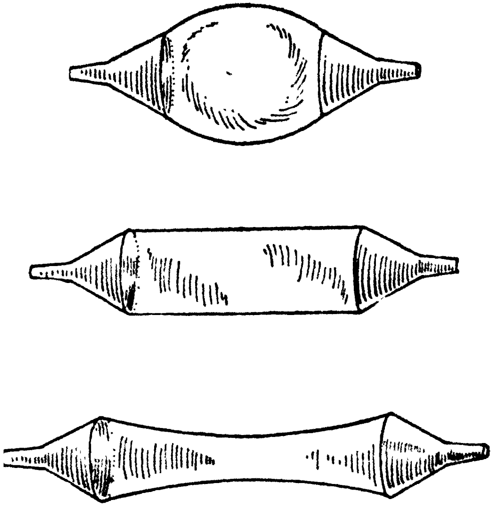
91. THE SOAP BUBBLE AS AN AIR BLAST.

In blowing a soap bubble you must exert a considerable force to overcome the inward pressure due to the tension acting over the curved surface.

The work done is measured by the product of twice the surface tension and the area of the surface; it is *twice* because there are two surfaces to the thin film.

If we stop blowing and do not disconnect the bubble from the funnel, it will gradually contract, expelling the enclosed air. The existence of this air blast may be demonstrated to a large company by bringing the nozzle of the tube close to a candle flame, which will be observed to bend to the blast and finally be extinguished.

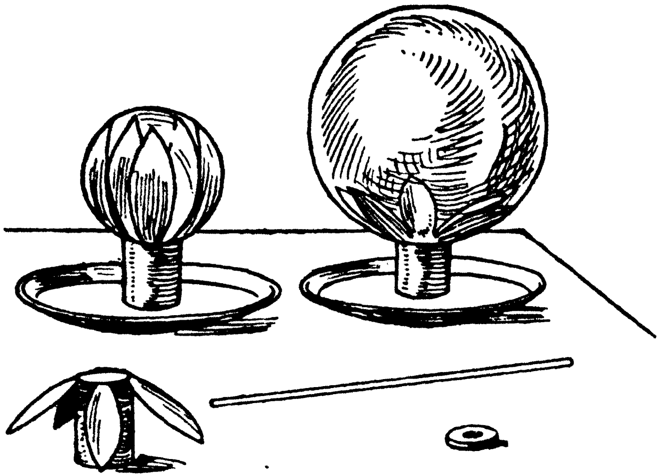
If you wish to prevent the bubble from contracting, it is sufficient to place your finger over the nozzle and prevent the air being driven out.



92. TWO BUBBLES COMBINING AS ONE.

It is a simple matter to make two separate bubbles combine into one. First blow bubbles on two funnels, one in the right hand and one in the left, placing a finger on each nozzle to prevent the bubbles contracting. Bring the edges of the wide openings of the funnels close together, so that the bubbles come into contact along a considerable portion of their surface. Suddenly this separating double surface will disappear, and a single bubble will be left, held by both funnels. The funnels may be moved into various relative positions, and the bubble will change shape correspondingly.

For example, set the funnels facing each other in the same horizontal line. The bubble, let us suppose, is of a bulging form, slightly more bulging below than above on account of the action of gravity. Draw the two funnels slowly away from each other. The bubble will gradually approach a cylindrical form, and ultimately, as the separation continues, an hour-glass shape. The same changes of shape will be produced by taking the finger off the nozzle of one or both of the funnels. The air will be driven out, and the bubble will contract from globular to cylindrical, and finally to hour-glass form. If, whether by separation of the funnels or by escape of the air, the process is carried too far, the bubble breaks into two hemispheres, one on each funnel.

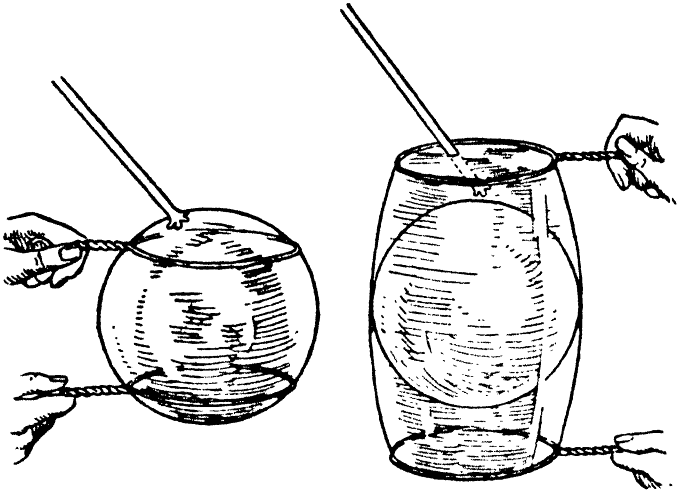


93. THE OPENING AND CLOSING FLOWER.

PREPARE as before the saucer and cork with the surrounding lake of soap solution.

Take a piece of silver paper and describe a circle on it of diameter about four inches. Also concentric with it describe a smaller circle exactly the size of the end of the cork. Then cut out a similitude of a five- or six-petalled flower, leaving the small circle intact, as shown in the figure. Place this flower on the cork, and wet the whole with the soap solution.

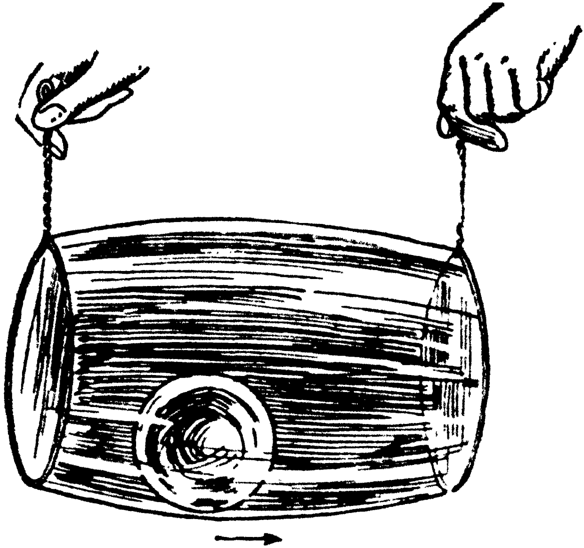
Blow a soap bubble, and bring it close to the centre of the paper. It will immediately adhere to it, and glide out along the petals, gradually raising them upwards until they are supported by a large bubble, as shown in the right-hand picture. To close the flower, introduce the tube within the bubble, and draw out some of the air by inspiration or suction. As the bubble diminishes in size the petals will be drawn nearer as in a closing flower.



94. THE SPHERE IN THE CYLINDER.

MAKE two equal-sized rings of iron wire by winding each piece round a bottle or other cylinder, and twisting the ends together to form a rigid handle. Wet them both in the soap solution, and, having blown a soap bubble, arrange it so that it may rest in contact with the two rings held parallel. By separating gently the two rings you can draw out the spherical bubble into a cylindrical form.

Ask a friend to take the tube, wet it in the solution, push it through the film which stretches across the upper ring, and blow very gently a second bubble inside the first. When this second bubble begins to press out the sides of the cylinder so as to make them bulge, stop blowing, and detach by a slight shake the bubble from the end of the tube. The approximately spherical bubble will rest within the barrel-shaped bubble. Separate the rings a little, and the contracting cylindrical bubble will deform the sphere into an elongated oval or egg shape. Make the rings approach one another, so that the cylinder becomes more bulging. If this process is continued till the sphere becomes free of the surrounding film, the internal bubble will drop down on the film across the bottom ring, and the two bubbles will collapse.

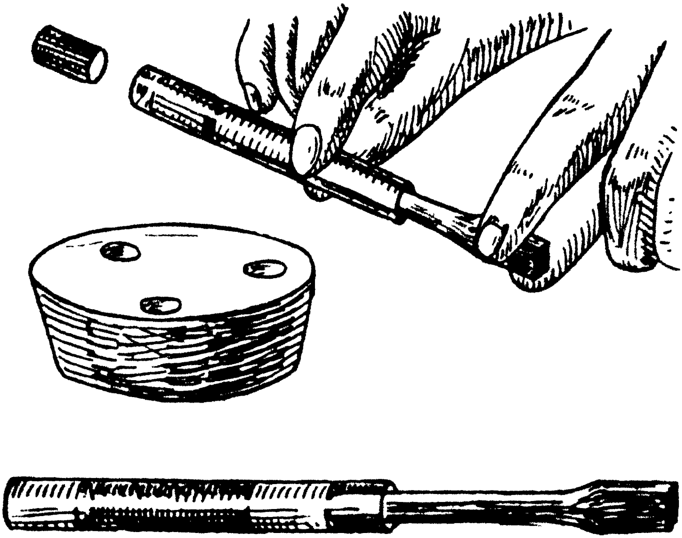


95. ONE BUBBLE ROLLING INSIDE ANOTHER.

As in the last experiment, form an approximately cylindrical bubble on the two rings, and get your friend to hold it in a horizontal direction. Insert the tube through the cylindrical surface, and blow a small bubble, which may be separated by a small sharp tap on the tube. It will fall gently on the concave surface without breaking it.

If now a slight inclination is given to the cylindrical bubble, the small sphere will roll down the slope inside the cylinder.

This experiment shows that bubbles in contact may maintain their surfaces distinct one from the other.



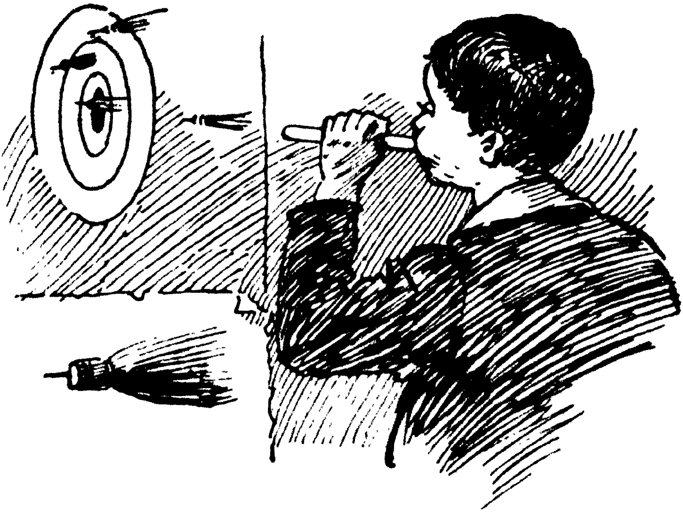
V. Elasticity.

96. THE POP-GUN.

This toy, which illustrates the compression and the spring of air, is made of a branch of elder emptied of the pith, and a round rod of wood acting as a piston in the cylinder so constructed. Two moistened plugs of packing, tow, oakum, etc., are fitted, the one at the mouth of the improvised gun, the other at the breech. The latter is pushed into the cylinder by means of the piston. This compresses the air entrapped between the two plugs, and as the air is more and more compressed the pressure increases proportionately, until the front plug is forced out with a sudden report due to the expanding air.

This apparatus is not very easy to make; for first you must find a suitable branch of elder, straight and uniform, and then you must extract the pith without splitting the wood.

A simpler form of air-gun may be made from the quill of a goose feather. This will provide a tube about three inches long; the piston may be a cylindrical penholder, or it may be constructed from a rectangular ruler by rounding off the one end so as to be thin enough to enter the quill tube. The projectiles must be innocent, sufficiently elastic and slightly moist. They are well supplied by the modest potato. Cut a potato in slices about the thickness of the finger, and then using the end of the quill as a punch or cheese-taster, cut out small cylinders of potato having exactly the diameter of the bore of the goose quill. With this miniature gun you may organize an amusing shooting match in the drawing-room, cutting out of a sheet of paper a circular hole to serve as target, and striving to shoot the potato bullet through this bull's eye.



97. THE PEA-SHOOTER, OR SHOOTING-TUBE.

PULL out of its containing tube the tuft of hairs of an ordinary paint-brush, and through this small bunch of hairs introduce a pin, whose point, after passing through the part of the brush which is tightly tied together, will project a short distance beyond the base of the hairs. This is the projectile.

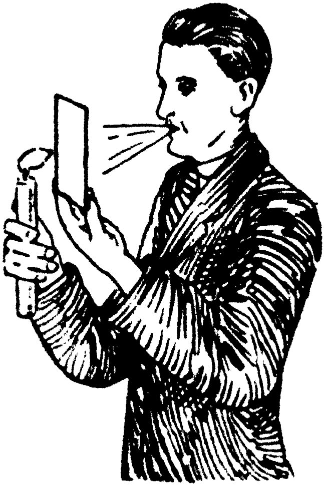
The shooting-tube may be made of a roll of paper gummed along the edge, or it may be a glass tube or reed of suitable bore. The uniformity of bore is not essential, and its size may vary within fairly wide limits.

Place the projectile at the far end, with the free ends of the hairs well within the tube, and the sharp point projecting outwards. Apply the mouth to the other end, and blow sharply. The first effect is to force the hairs against the walls of the tube, thereby gripping the projectile with a certain amount of friction, and closing the tube so that air pressure behind the projectile will increase. Very soon the pressure of the air overcomes the frictional constraint, and the projectile is driven forth with a velocity which may carry it as far as six yards. Good practice may be got by aiming at a cardboard target into which the sharp points of the projectiles will stick.

98. THE LEAPING COIN.

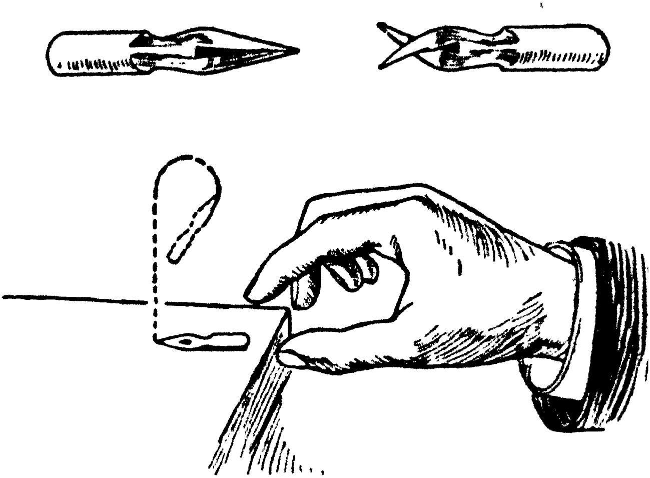
PLACE a threepenny piece on the table, and propose to a friend to lift it off without touching either it or the table.

To do this trick hold the hand half open two or three inches behind the coin; then, bringing the mouth well down to the table, blow sharply an inch in front of the coin. The air compressed suddenly by the blowing will penetrate beneath the threepenny and make it leap from the table into the hand. A few attempts will soon teach the operator the best relative distances. A sixpence is rather heavy for the success of the experiment.



99. THE AFFECTIONATE FLAME.

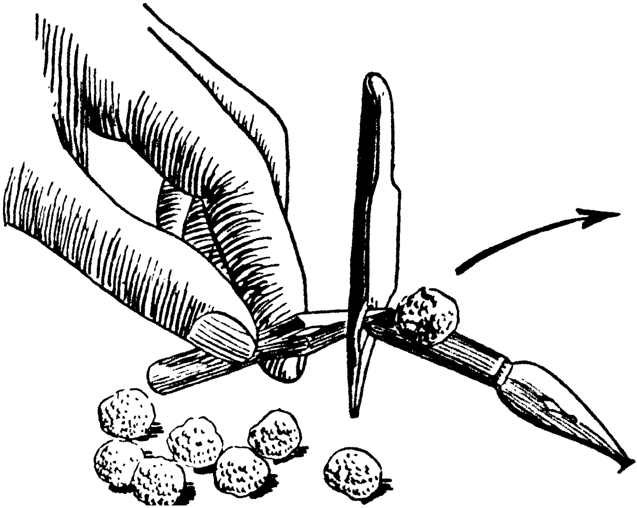
Blow upon a card or small screen interposed between you and a lighted candle. The candle will not be extinguished, since the blast of air is intercepted; but a curious effect will be observed. The candle flame will bend towards the screen as if it desired to reach your face. The reason is that the currents of air streaming past the edges of the screen, and so past the position occupied by the flame, produce a partial vacuum behind the screen, and an influx of air takes place from beyond the candle towards the screen, blowing the flame in the same direction.



100. THE JUMPING PEN.

Choose a metallic pen with its points fairly flat. Press the back of the points on the table until they become crossed, as in the upper right-hand figure. By an opposite pressure on your nail bring them back to the normal form.

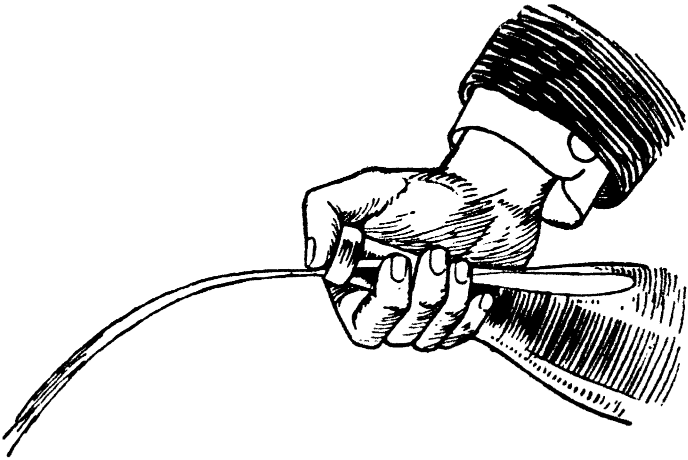
These preparations having been made beforehand, show the pen to your friends, and ask if it looks in any way remarkable. They will probably say no. Then announce that it has remarkable jumping powers when simply allowed to lie down on the table. Hold the pen close to the table with its point in the air, and then let it fall. The slight shock of falling will release the points from what is a position of instability, and one of them passing with a sudden jerk under the other will act like a recoiling spring, and project the pen upwards to a height of about twenty inches.



101. A MODERN CATAPULT.

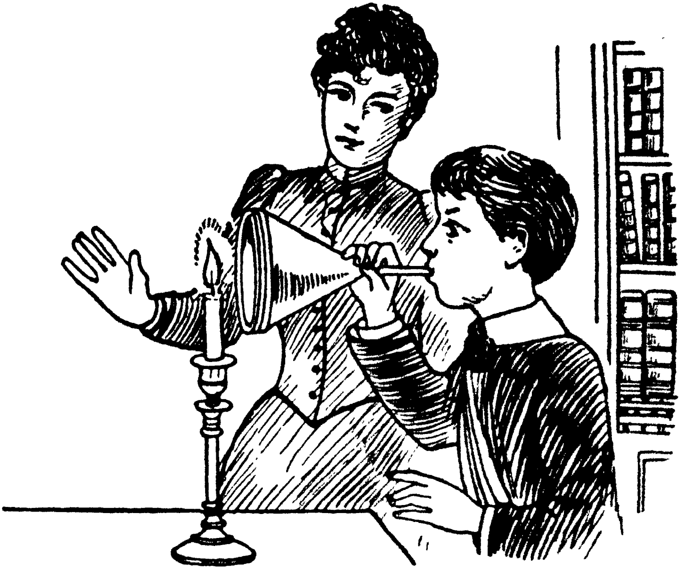
We may search in vain among the weapons stored in antiquarian museums for the catapult here depicted. More likely we shall find it at the desks of our schoolboys relieving the tediousness of hours of study by shooting small pellets of paper or bread at their more studious companions absorbed in their tasks. No noise, no smoke; impossible to tell whence the blow has come.

Three old pen nibs suffice for the manufacture of this instrument of projection. Fix two pen nibs upright in the table at a distance a little less than the length of one of them. Bend back the one in front, taking care, of course, not to break it, until it rests immediately in front of the slot in the other one, and fix it there by inserting the point of a third pen. Place on the bent pen one of the missiles, and then at the propitious moment draw back the third pen, so as to free the spring, and the bullet will be projected with sufficient force to carry it five or six yards.



102. THE SPRING OF AIR.

To demonstrate the "spring of air," as Robert Boyle, the discoverer of the law, called it, fill a bottle half full of water, holding the neck with the right hand in such a way that the thumb can be easily, when desired, slipped over the opening of the bottle. Blow into the bottle vigorously several times, carefully and rapidly closing the opening with the thumb immediately after each blow. The air entrapped between the water and the thumb will be at a higher pressure than the air outside. Hold the bottle so that the liquid comes up into contact with the thumb. Slip the thumb back slightly so as to form a small orifice, through which the water, driven out by the increased pressure, will be squirted out to a fair distance. The scene may be made more lively by directing the stream towards a good-natured member of the company, who will cheerfully receive the scattering spray as part of the humour of the situation.

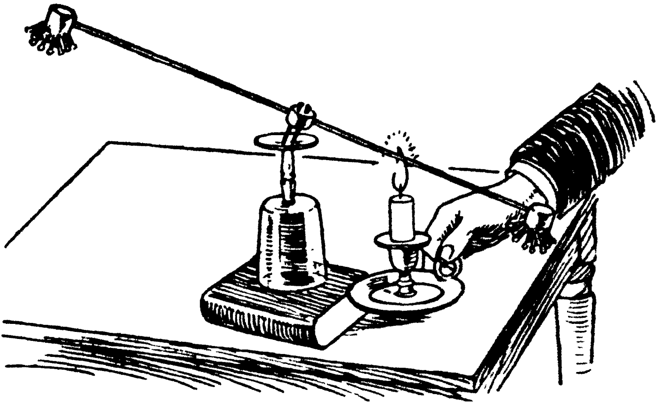


103. THE CANDLE AND THE FUNNEL.

An amusing game for a children's party is to offer a prize to the youngster who will extinguish a candle flame by blowing through a funnel or a wide trumpet-shaped cone of paper with a hole at the pointed end.

The novice naturally tries to blow straight at the flame through the funnel. But this will be ineffectual. There will be no concentration of the blast, which will spread out, and largely escape round the edge of the funnel.

If, however, the funnel is lowered till the upper rim is brought to a little above the level of the flame, the trick will be done; blow, and the flame will be put out.



VI. Heat.

104. EXPANSION OF SOLID RODS.

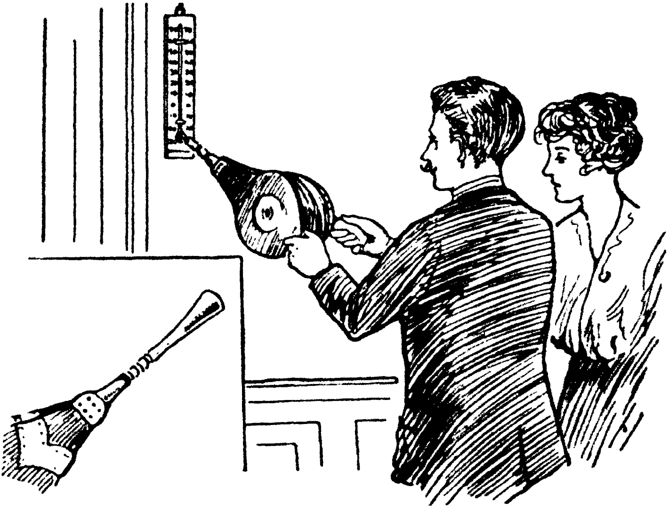
With one or two curious exceptions, all substances, whether solid, liquid, or gaseous, expand when heated. It is easy to show this in the case of liquids and gases; the ordinary thermometer is a familiar example. But owing to the smallness of the expansion of solids, it is not quite so easy to demonstrate the change in their case. The following apparatus may, however, be constructed with comparative ease.

Take a metal rod—a curtain-rod, for example—and pass it through a cylindrical cork parallel to the plane face. Slide the cork along to the middle of the rod, and insert on the lower face two pins, one on each side of the rod and perpendicular to its direction. The points of these pins, when placed on the bottom of an inverted tumbler, will form the pivot about which the rod will swing. To obtain a sufficient yet delicate balance, pass each end of the rod a short distance through another piece of cork, and adjust the balance by inserting nails in the two corks.

After the rod has been brought to a perfectly horizontal position, apply a flame to the one side, as shown in the figure. At once the balance will be destroyed, and the rod will swing down on the side where the flame is.

The reason is that the length of the rod on the heated side will be slightly increased, and the leverage or moment of the weight of the half rod and of the attached bodies will become greater.

The argument then is that, since the balance is destroyed and the beam comes down on a side to which there has been certainly no addition of matter, this descent can only be due to lengthening of the arm; hence the rod is expanded by heat.

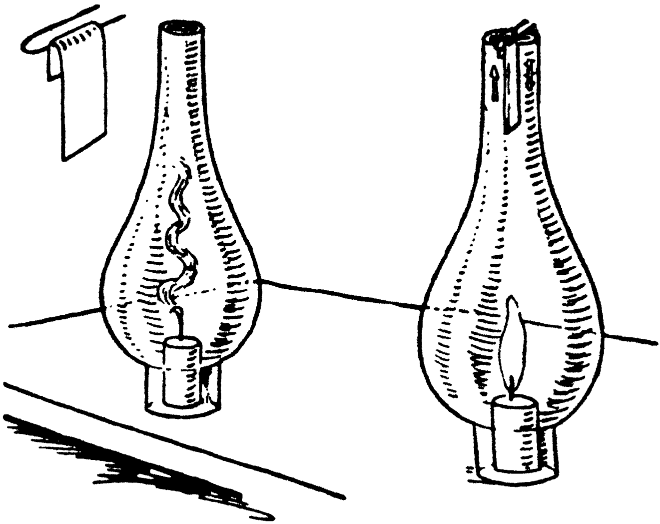


105. THE BELLOWS BLOWING HOT OR COLD.

THE blast of air from a pair of bellows bearing on the hand gives us the sensation of coolness which we may be apt to associate with the action of the bellows. The coolness, however, is due simply to the fact that the hand is at a higher temperature than the air.

But suppose we direct the blast against the bulb of a thermometer. Will the thermometer rise or fall? Guided by the false, uncorrected suggestion of our sensations, we might be disposed to say it will fall. But this is quite a mistake. When blown upon vigorously, the thermometer will rise several degrees.

And yet we may use the same bellows to form ice. Take a roll of blotting-paper, cut the one end into a fringe, and insert the other into the aperture of the bellows. Dip the fringe into ether or benzine or other volatile liquid, and begin to blow the apparatus. Very soon the blotting-paper will appear covered with a layer of hoar frost. This is due to the cooling effect of the evaporating ether made more active by the blast of the air, and this cooling produces the freezing of the moisture in the issuing stream of air.



106. THE CANDLE IN THE LAMP SHADE.

To protect a candle flame from the wind, a lamp shade is placed round it as it stands on the table. After a few seconds the flame gets faint, and finally goes out. This is due to the accumulation of the products of combustion in the lower part of the region occupied by the candle; the oxygen is used up, and the air becomes vitiated. How may this be prevented?

One obvious way is to provide openings below, say, by resting the shade on two matches, so as to create a draught of pure air entering below, and passing up to take the place of the heated gases escaping above.

But the same purpose may be effected in another way. Take a strip of cardboard of width equal to the diameter of the glass shade at its upper end, hook it round a wire (for example, a small hairpin), and insert it in the top of the shade so as to divide the space into two equal parts. The cardboard should hang down about two inches. When the shade is now placed round the candle, the flame will continue to burn with a clear light. This is due to the fact that fresh air descends down the one side of the card, while the vitiated air ascends up the other side, and by means of this steady circulation the conditions of combustion are maintained.

To make sure that no air sifts in below the glass, it might be set along with the candle on a plate containing a little water.

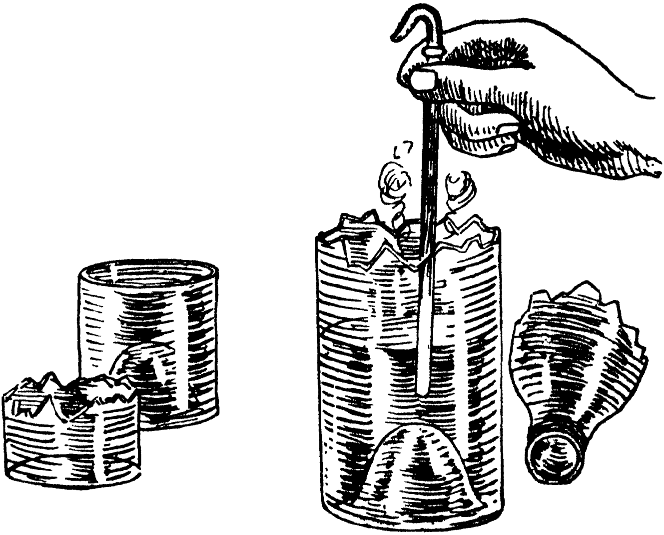
This experiment is a good illustration of the effect of heat in causing convection—that is, in producing currents of ascending hot air and descending cool air. The existence of these currents in the present case may be demonstrated by holding a lighted match first at the one and then at the other side of the cardboard.

107. PARTIAL VACUA PRODUCED BY HEAT.

As already pointed out, air and gases generally expand considerably with rise of temperature. If the vessel in which the air has been heated is hermetically closed and then allowed to cool, the air will contract to a lower pressure or smaller volume according to the conditions of the experiment. A partial vacuum is created, and curious effects may be produced.

For example, heat the contents of a carafe containing only air by dropping into it a lighted piece of paper, then close the mouth with a hard-boiled egg, from which the shell has been removed. As the air within cools, the pressure of the air will gradually force the egg through the opening of the carafe. The egg will be seen slowly elongating so as to become diminished in girth, and when it falls to the bottom a slight explosion will be heard, due to the sudden entrance of air at the atmospheric pressure.

Or we may put a little alcohol in the bottom of a bottle and set it alight by dropping in a lighted match. This will produce a considerable rarefaction of the contained air. If a ripe banana of suitable size, with the skin at the lower end opened out, is inserted into the mouth of the bottle the banana will gradually be pushed into the bottle, while the skin will be peeled off. In short, the banana peels itself.



108. THE BROKEN BOTTLE MADE SERVICEABLE.

THIS is how you could make some use of a broken bottle with jagged edges.

Fill what is left of the bottle with oil up to a level which falls short of the rough broken part. When everything is at rest, introduce into the oil the red end of a poker just taken from the fire. A crack will be heard, and you find that the bottle has been cut cleanly at the level of the liquid.

Thus a broken bottle may be transformed into a useful vessel; a broken wine-glass or tumbler into a new one of smaller size.

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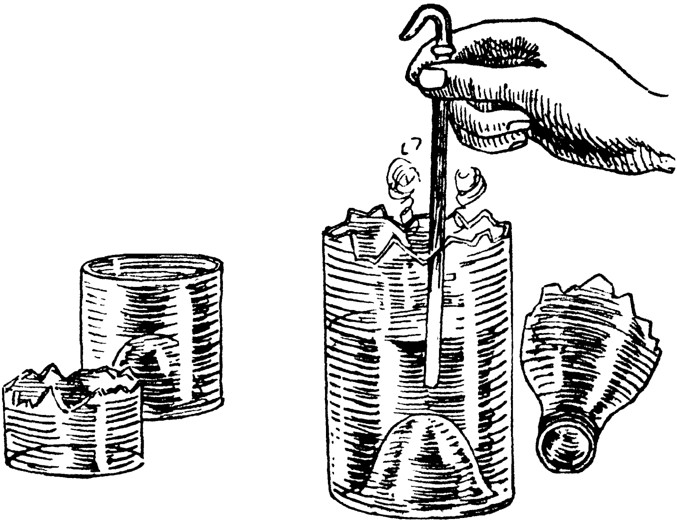

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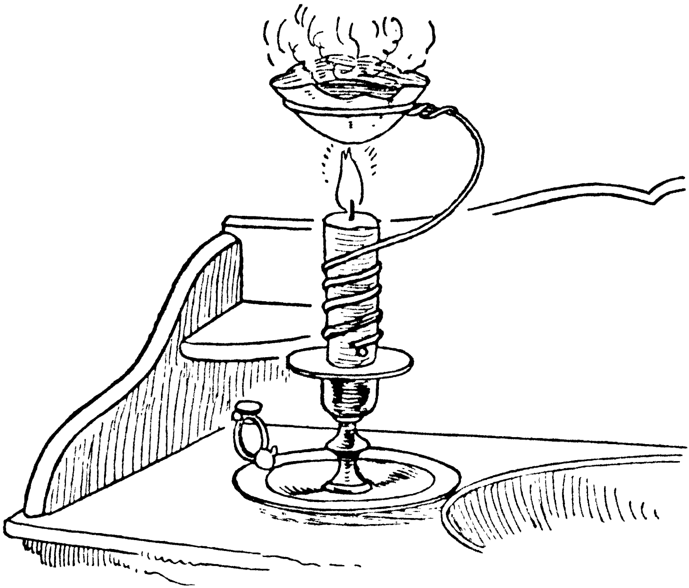
Thus a broken bottle may be transformed into a useful vessel; a broken wine-glass or tumbler into a new one of smaller size.

By repeating the experiment with successive lowerings of the level of the oil, we may produce a set of glass rings of equal or of varying thickness.

The effect depends upon the fact that glass is a poor conductor of heat. When one part is suddenly raised in temperature, the neighbouring parts remain practically unchanged in temperature. The heated part expands, and since the neighbouring parts remain unchanged in volume, a strain is produced where the parts join and a crack is caused.

It is always dangerous to heat a glass vessel by a flame. The heated part will expand, and crack away from the non-heated part. To guard against this danger there is always placed between the bottom of the glass vessel and the flame a sheet of wire gauze. This gauze being made of metal, conducts heat very much more easily than the glass, and carries the heat over the glass surface, which consequently becomes heated more uniformly.

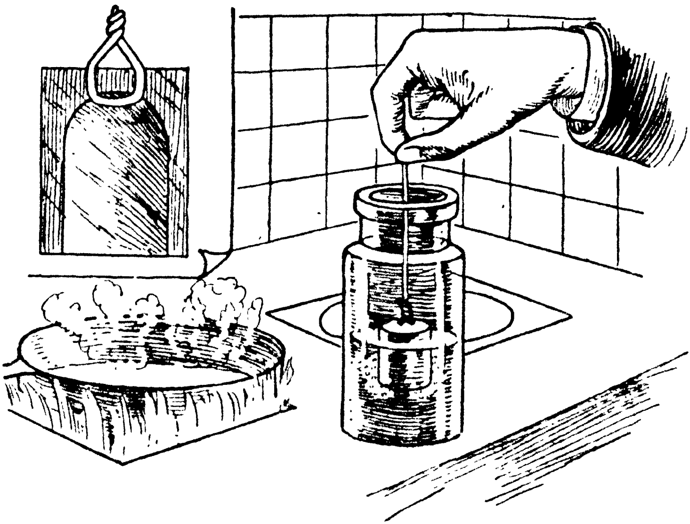


109. WATER BOILED WITH NEITHER FIRE NOR PAN.

TAKE a piece of fairly stout iron wire, and form the one end into a ring of some three inches diameter. Shape the other end into four or five turns of a helix of diameter equal to that of the candle which is to be used as the source of heat. This is best done by wrapping it round a wooden cylinder of about the same section as the candle. Arrange the connecting part of the wire so that when the helix slips over the candle the ring will be horizontal, and an inch or two above the wick. We have got our source of heat and retort stand.

The pan in which the water is to be boiled is simply a disk of stout paper, nearly twice the diameter of the ring. This is set over the ring, and pushed down so as to form a concave cup into which some water is poured. When the candle is lit underneath the flat paper pan the water contents will soon boil.

An even simpler way of boiling a little water is to put it in a funnel-shaped roll of paper, with the pointed end closed by a slight fold—what is known in Scotland as a "sweetie-poke"—and hold this over a gas or candle flame. The water prevents the heat of the flame from setting fire to the paper.



110. THE BOILING OF WATER.

To view the behaviour of water as it is heated to the boiling-point, it is best to have it in a glass vessel. This must not be heated directly, otherwise the glass will be apt to crack. It may be put on a piece of wire gauze and heated by a flame ; or it may be placed in a shallow dish with water in it, this shallow dish being heated by a fire or by gas ; or it may be set on sand lying in a flat pan, and heated below by flames. This last is the sand-bath, differing from the water-bath by the substitution of sand for water.

When ordinary water is heated, small bubbles are soon seen forming on the inner walls and rising through the liquid. These are bubbles of air originally dissolved in the water. Heat drives them forth.

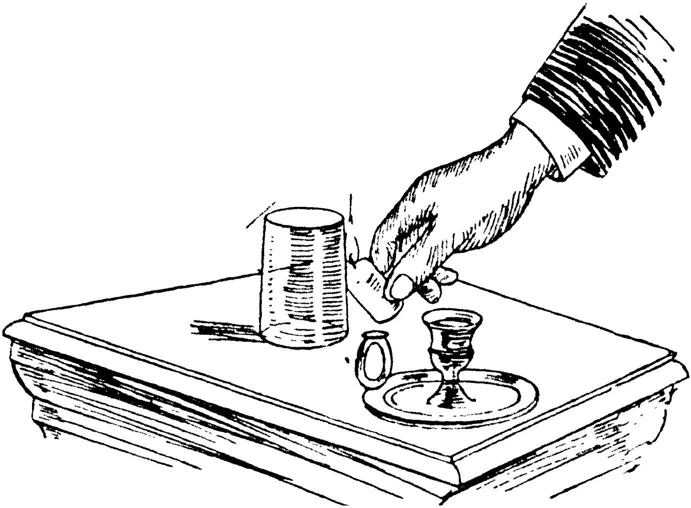
After a short time the air bubbles cease, but other bubbles begin to appear. These are bubbles of water vapour, which rise through the liquid and quickly condense again. The rapid formation and condensation of these bubbles of vapour produce the sound of "singing" which precedes the true boiling. Finally the bubbles, which grow larger and larger as the temperature increases, rise right through the whole mass of water and burst into the air above. The liquid is boiling. When the atmospheric pressure has its average normal value, water at the sea level boils at 100° centigrade or 212° Fahrenheit. We may show, as in Section 114, that under a less pressure water boils at a lower temperature than 100° C. Under greatly diminished pressure water may, indeed, be made to boil at its freezing-point.

The boiling-point is also affected by the presence of substances dissolved in the water. Strongly salted water requires to be raised well above the ordinary boiling-point before it gives off vapour freely. But the vapour which comes off has the temperature of 100° C.

The nature of the vessel has an influence on the boiling. It takes a longer time to boil water in a clean glass beaker or jar than in a copper vessel; it boils more quickly in a rough-walled pot than in a pan of polished metal. This is because the bubbles more readily form on the rough points to which air bubbles tend to cling. The presence of air between the walls and the liquid facilitates the disengagement of vapour.

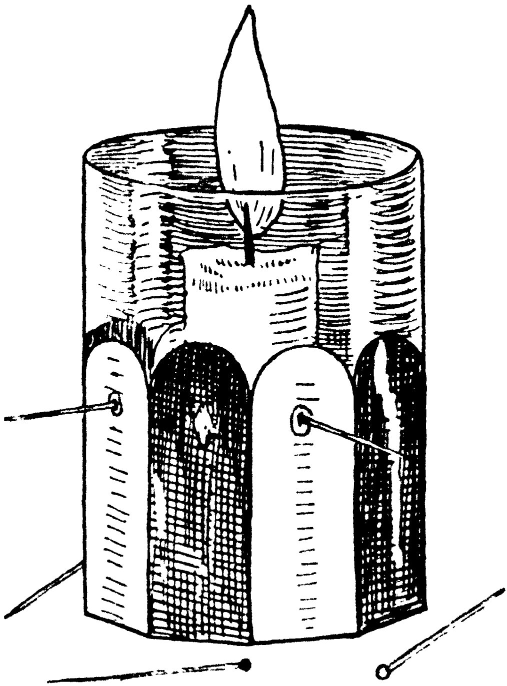
Having brought water to a state of brisk boiling, remove it from the flame. It will at once cease boiling visibly; yet its temperature will be about 101° or 102°. Throw in some iron filings, and immediately a lively ebullition begins. The air, carried in with the iron filings, starts the boiling again.

Hollow out a cork like a church bell, and lower it by means of a wire into water which has just been lifted boiling from the heating source. Brisk boiling at once begins again, the bubbles streaming from the edges of the cork bell and rising to the surface.



111. THE GLIDING TUMBLER.

Wet the rim of a tumbler, and then set it upside down on a slightly-inclined sheet of marble—for example, the top of a table two of whose feet have been slightly raised by wedges. The inclination must not be so great as to cause the tumbler to slip down the incline. While the tumbler is at rest bring a flame near its upper end, and at once it will begin to glide down the incline. The reason is that the heated air exerts a slightly greater pressure within the tumbler, relieving its weight sufficiently to make it rest not so much on the marble as on the layer of water under the rim. On this layer of water it glides down the plane.



112. ABSORPTION OF HEAT.

Why do we gladly wear white clothes in summer? Partly, no doubt, because of its freshness and brightness, but also because it has been recognized that they are cooler than dark-coloured clothes of the same texture and thickness. White surfaces absorb heat feebly—that is, heat radiating from the sun or other source.

Why, then, are polar bears naturally clothed in white? For the simple reason that white is a poor radiator as well as a feeble absorber. Consequently the animal warmth of the bear does not escape into the cold air so easily when the coat is white as when it is black.

These remarks illustrate what is known as the Law of Exchanges. Not only is the good radiator a good absorber and the poor radiator a poor absorber, but, in general, a body radiates exactly what it absorbs. Now, evidently a black surface is a good absorber; hence it ought to be a good radiator. On the other hand, a brightly-polished silver surface reflects the radiant energy falling on it, and therefore absorbs feebly. When hot it will radiate feebly.

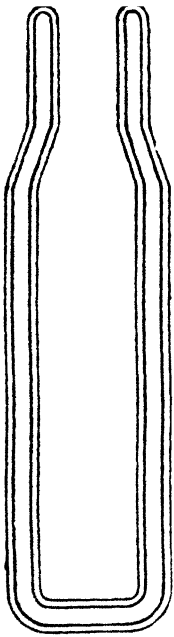
The following experiment may be taken as a verification of this law. Paint the interior of a cylindrical glass vessel with vertical bands alternately black and white—for example, with chalk mixed in water and with Indian ink. Suppose that there are eight compartments, four black and four white. Heat the head of a pin in a flame, and then plunge it into a candle so as to carry off with it a certain quantity of wax or paraffin. Take the glass vessel in the hand, and set the pin vertically upon the upper horizontal part in the middle of a white or black strip. When the wax or paraffin has cooled the pin will be left projecting at right angles to the glass surface. Do this for all the white and black compartments, and then place the vessel on its base with the pins projecting horizontally like spokes of a wheel.

Introduce into the centre of the vessel a lighted candle. The radiations from the candle flame will fall on the various strips, and after a short time the pins fixed outside the black strips will fall off, while those attached to the white strips will remain fixed for a somewhat longer time.

This shows that the glass with the blackened surface heats up more quickly than the glass which is painted white; and since the same amount of radiation falls on all the strips in the same time, it follows that more of it is absorbed by the black than by the white surface. Thus the glass beyond the black surface is raised to a higher temperature, sufficient to melt the wax which holds the pin in position.

113. TO RETARD THE RATE OF COOLING.

A HOT body exposed to the air cools mainly in two ways—either by radiation or by convection. In radiation the radiant energy passes outward through



the surrounding space just as light radiates from a bright object. When this radiant energy falls on a material surface it is partly absorbed and transformed into heat. In convection, on the other hand, the heat is given by contact to the air in the neighbourhood. This heated air expands and rises, giving place to colder air which flows in from all sides. This latter process depends on the presence of the air, and could be got rid of if the body were placed in a vacuum. In such a case the cooling would take place only by radiation.

We may retard the rate of cooling by putting round the hot body a poor conductor of heat, such as straw, or some woollen material, the outer exposed surface of which will not be at so high a temperature as that of the contained body. The surrounding air will not be heated so strongly, and convection of heat will go on at a slower rate. The radiation will also be diminished on account of the cooler outside surface.

It is not possible, however, absolutely to prevent cooling; for heat has an invincible power of diffusing itself from warmer to colder regions, and there is no substance absolutely impervious to heat.

Of all devices to prevent the cooling of a hot body or the heating of a cold body there is none so efficient as the double-walled vacuum flask invented by Sir James Dewar, familiar to all as the Thermos or Vacuum Flask. Dewar invented it for the purpose of storing cold liquid air, which would have rapidly risen in temperature and evaporated if placed in an ordinary vessel.

Take a vacuum bottle and an ordinary bottle of about the same size, and pour into them the same quantities of hot water from a boiling kettle. Cork them up, and leave them for half an hour. The water in the ordinary bottle will have cooled to a tepid state, whereas the water in the vacuum bottle will be still hot, and if poured out will scald the hand.

The experiment may be greatly improved by inserting a thermometer through a hole bored in the cork of each bottle and noting how the temperatures fall off as time goes on.

On what depends the great efficiency of the vacuum bottle? Simply because it is double-walled, with a vacuum between the outer and inner walls of the containing glass. (A vertical section of a vacuum flask is shown in the figure on page 252.) Before the air is pumped out from this region the outer glass wall is silvered on its inner surface, and the inner glass wall is silvered on its outer surface. The vacuum is then produced, and after the air has been almost entirely removed the small glass opening through which the air has been pumped out is fused and hermetically sealed.

Suppose now that the inside of the bottle is filled with hot coffee and corked. The inner glass wall will soon attain a temperature approximately equal to that of the liquid, and part of this heat will begin to be conducted slowly along the glass towards the corked end, finally passing out into the air. In this way, and practically in this way only, will a very gradual cooling take place.

The silver on the outer surface of the inner wall being raised nearly to the temperature of the liquid, becomes a somewhat feeble radiating surface; but the radiations take place through the vacuum, and are radiated back again by the silver on the inner surface of the outer wall. Consequently there is a very small loss of heat across the vacuum; and since the outer wall remains nearly at the temperature of the surrounding air, there is practically no loss on account of convection. Thus the conduction is small, the radiation is stopped, and the convection is reduced to a minimum. If the vacuum is not very good, convection of rarefied air will take place within the double-walled region, with transmission of heat to the outer wall, and the cooling will be a little more rapid. The flask will not act so efficiently.

114. THE WATER HAMMER: BOILING WATER BY COOLING.

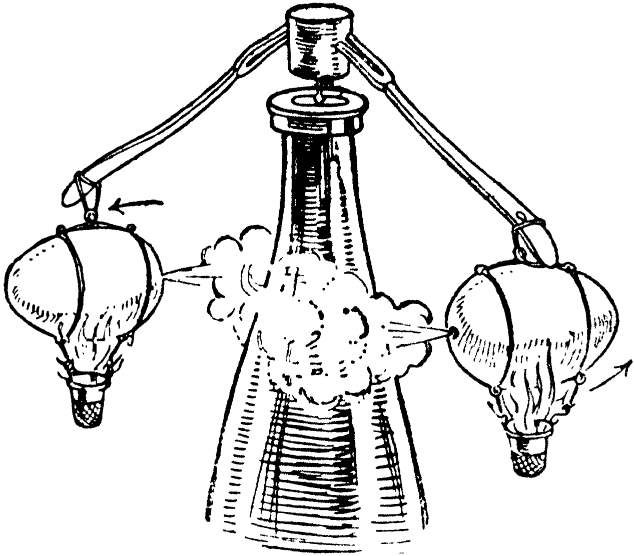
TAKE a small bottle with tight-fitting cork, fill it three-quarters full of water, and immerse it open in a pan containing salt water. When this salt water is brought to the boil, which occurs a few degrees above the boiling-point of fresh water, the water in the small bottle will soon be brought to its boiling-point also. Let this boil for some minutes until the vapour has driven out almost all the air, cork it quickly and remove it from the pan, making sure the joints by sealing round the cork with sealing-wax.

When the temperature has fallen sufficiently the vapour will condense partially into liquid, and a vacuum will be formed above the liquid in the bottle. Conditions are now favourable for producing the effect of the water hammer. Invert the bottle slowly, and then bring it back quickly to its upright position. A sudden noise will be heard as the water, free of air, and unhampered by the presence of air in the bottle, falls back into the bottom of the bottle.

Bring the bottle back again to the temperature of boiling by immersing it in the water-bath again. When removed it will soon cease to show ebullition. But if we bring towards the upper surface a piece of ice or cool the upper surface by allowing cold water to stream over it, the contained water will begin again to boil briskly. Even blowing on it through a hollow straw will produce the same effect. In these cases the vapour in contact with the part of the glass which is cooled is condensed, relieving the pressure for a moment, so that the pressure over the liquid has a lower value than that which corresponds to the temperature. Hence vapour bubbles out from the liquid till the pressure is restored again to the equilibrium value.

This latter experiment may be done more strikingly by means of a long-necked flask in which the water is briskly boiled for some minutes until all the air is driven out. Then gripping the long neck with a towel, quickly press home the cork, and lift the flask from over the flame. Invert it over a vessel of water, supporting the rounded part of the flask in a ring of a retort stand. After a short time all appearance of boiling will cease; but we may at once start it again by pouring cold water over the upturned bottom of the flask.

This experiment proves incidentally that water boils at a lower temperature under a lower pressure. On the top of high mountains, where the atmospheric pressure is considerably diminished, the boiling-point of water is so much reduced that cooking is made more difficult. For example, on the top of Mont Blanc water boils at 85° C. (or 185° Fahr.), instead of 100° C. (or 212° Fahr.).



115. BARKER'S MILL WITH STEAM.

THE principle of the Barker's Mill was explained in Section 54. Let us see how we may similarly employ escaping steam with apparatus constructed by materials ready to hand.

Pierce a small hole in one end of each of two eggs, and ask a friend who is fond of raw eggs to suck out the contents. Each egg must then be girdled with iron wire so as to provide a means by which it may be suspended from the handle of a fork, as shown in the figure. There are two girths of iron wire, prevented from slipping off by being connected by a short piece of wire bent into a ring at the middle. Attach hooks to the engirdling wires on the under surface of each egg, and to these hooks hang an inverted thimble, round the projecting rim of which a thin wire has been passed provided with two eyelets with which the hooks engage.

These two eggs will then have the appearance of dirigible balloons, the thimbles being the cars. The balloons must now be filled partially with water. This is done by heating the egg shells, so as to drive out some of the expanding air, and then plunge them in cold water. A certain quantity of water will pass into the interior.

Take now two forks, and insert the prongs slantingly into the opposite sides of a cork, whose base is pierced by a pin. The head of this pin resting on a coin placed over the mouth of a bottle will serve as the pivot about which the motion will take place. To the handle of each fork suspend one of the egg-shells by means of a wire passed through the ring on the top, the wire being wrapped once or twice round the fork for the sake of security, and the ends twisted together. The eggs must be placed so that the holes in the ends look in opposite directions. Place in the thimbles some cotton wool saturated with methylated spirit and suspend them below the shells. Adjust the balance by adding small shot to one of the thimbles. The apparatus is now ready for action. Light the spirit below the shells, and in a few minutes the water will begin to boil. The escaping steam, by its reaction on the suspended "balloons," will drive them round in the opposite direction, just as in the hydraulic Barker's Mill.

VII. SOUND.

116. VIBRATIONS OF A WINE-GLASS.

EVERY one knows how to make a wine-glass sing by partly filling it with water and running the moistened finger lightly round the rim. The note obtained will depend upon the thickness of the glass and the extent of surface set vibrating, and will therefore depend on the level of the contained water.

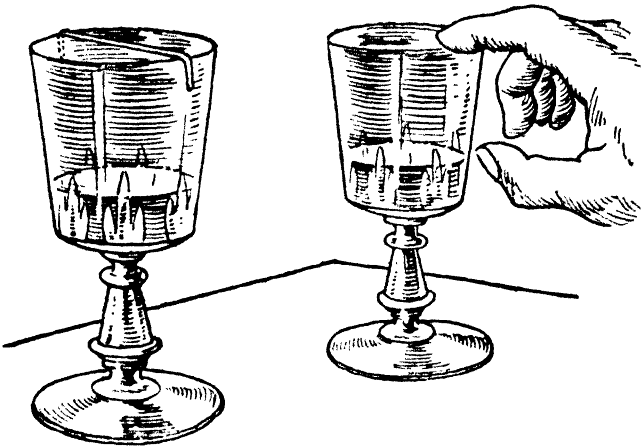
Fill the glass nearly full, and look closely at the water surface as the sound is being produced. It will be seen to be thrown into minute ripples close to the margin. As the finger moves round the rim it will be followed by wavelets on the water. If instead of running the finger right round the rim it is moved simply to and fro on one part, the sound will still continue; but a careful glance will show that the water is more violently agitated at certain parts than at other parts. The reason is that the glass vibrates in segments, forming what are called nodes and loops. The nodes are the places where there is no in-and-out vibration of the glass, and at any given instant these will be at the place where the finger is for the moment rubbing, at the place diametrically opposite, and at the intermediate places half-way between. Situated between these four nodes there will be four intermediate loops where the glass is moving in and out most violently.

As the finger runs round the rim the positions of the nodes and loops alter correspondingly. But if the vibration is maintained by to-and-fro rubbing at a particular place, the nodes will remain in much the same positions all the time, and the greatest agitation of the water surface will be where the loops are.

The distribution of nodes and loops may be shown in another way. Cut out of a piece of stiffish paper a symmetrical St. George's Cross sufficiently large to rest on the rim of the glass. Then double the ends down so that they may droop over the edge of the glass and prevent the cross from slipping off. The legs of the cross should be cut as thin as possible, much thinner than is shown in the illustration.

If the moistened finger is rubbed over the glass surface a little below one of the ends of the cross a sound will be produced, but the cross will remain unmoved. But shift the finger slightly away from the position of the end of the cross, and the cross will follow after so as to come, if possible, to the position of the nodes. The agitated glass throws the light paper from where the motion is greater to where it is less.

Another way of showing the different amounts of agitation of the vibrating glass is to cut thin strips of paper about an inch long, double them over, and set them astride like riders on the rim of the glass. If the finger moves to and fro at the distance of a quadrant from the position of the rider, a tremulous movement will be observed in the rider, and a slight to-and-fro motion along the rim; but if the finger is moved to a position about 45° from the rider, the rider, being now in the neighbourhood of a loop, will be thrown off. In these experiments the glass surface must be quite dry where the paper is touching it.



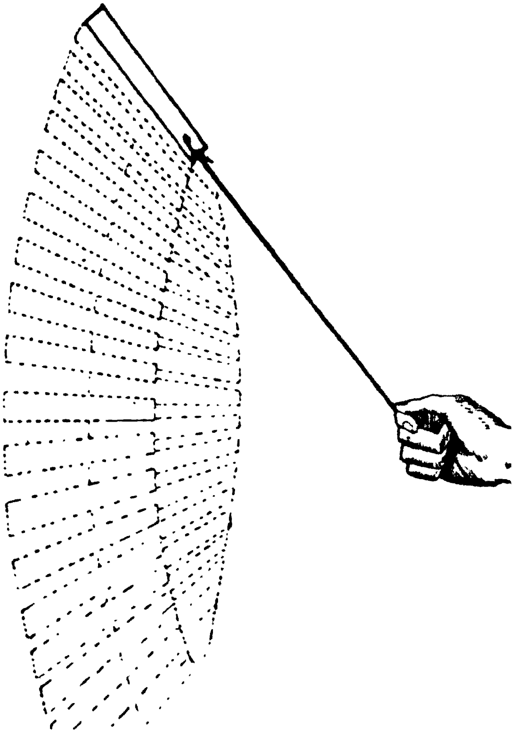
117. THE MUSICAL WIRE.

TAKE two similar glasses and fill them about one-quarter full of water. When struck like a bell or set in vibration by the moistened finger being run round the rim, they will probably give notes of slightly different pitch. By addition of a little more water to one of them the notes can be adjusted to the same pitch.

After having brought them thus to accurate tune the one with the other, lay a light thin wire, with the ends bent, across the one glass, and then sound the other by rubbing the rim with the moist finger.

Now the general principle of resonance tells us that one vibrating body in tune with another will be set sounding when the other is made to utter its note. Thus the glass bridged across by the wire will begin to vibrate in sympathy with the other, and the wire will dance in time with the music.

Another way of demonstrating the principle of resonance is to hold down any key on a piano, say the high treble G, and strike strongly the note one or two octaves lower, immediately releasing the key of the lower note so that it may be stifled by the damper. The higher note will be heard sounding although its string had not been struck. The higher note is produced by resonance, since the lower octave contains this higher note as part of its combined tone. In the same way a pianoforte string may be set vibrating by a singer sounding the same note in its vicinity.



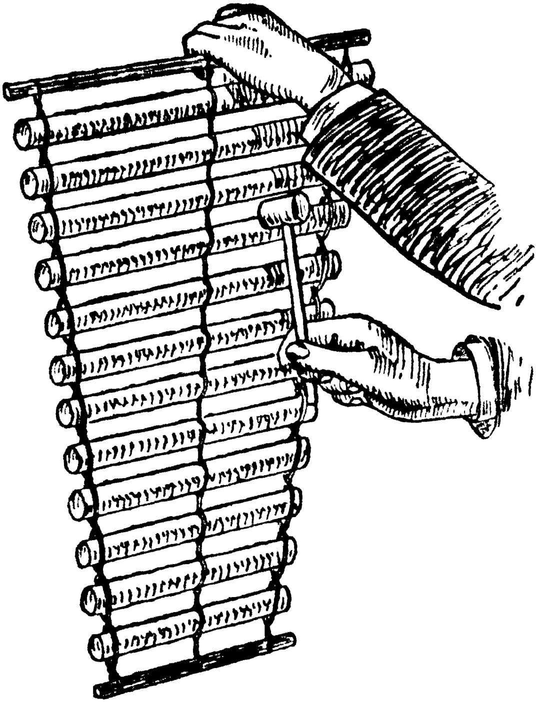
118. THE MOANING ROD.

THE apparatus for this experiment is a flat ruler or similarly shaped strip of wood with a hole near one end, through which a string is passed and tied securely. Seize the other end of the string, which should not be longer than two feet, and whirl the ruler round, slingwise, in a vertical circle. If the motion is not very rapid a curious fluttering will be heard. As the motion is sustained this fluttering will die away and come on again in successive alternations. Increase the rate of revolution, and the fluttering will become a low moaning, the pitch of which will rise with the rapidity of the motion. Here also, however, with steadily maintained whirling the sound of low pitch will alternate with intervals in which only a swishing sound will be heard —intervals, therefore, of comparative silence.

Meanwhile the hand will feel a rhythmic pull showing a varying tension in the string. Also when the moaning sound is heard the eye will see a series of successive images of the rod. This is due to the rod rotating round its long axis so that it presents itself to the eye, now broadside on, now edge on, in rapid alternation. The fact of the rotation is proved by simply stopping the motion, when the string will be found to be powerfully twisted.

Another curious feature of this phenomenon is that the rod and string refuse to move in a vertical plane. Instead they describe a conical surface.

When the operator is out of sight the moaning sound has a most weird effect upon the listener. It suggests gusts of wind, and yet it is not quite the same. Were it continuous it might be compared to the sound of an aeroplane propeller. When observed and listened to at the same time it gives interesting illustrations of important physical principles in optics, in sound, and in the dynamics of solids and fluids.



119. A "TUBOPHONE" OF CARDBOARD.

FROM a set of cardboard tubes of the same diameter we may construct a musical instrument on which simple tunes may be played.

When such a tube is sharply hit the air within it is thrown into vibrations, and a sound with a definite pitch is heard. The pitch is determined by the length of the tube, just as the pitch of a note produced by bowing any one string of a violin is determined by the length of the part of the string that is free to vibrate.

To obtain a set of tubes giving the notes of the ordinary diatonic scale, the lengths should be as the numbers—

$$1,\ \tfrac{8}{9},\ \tfrac{4}{5},\ \tfrac{3}{4},\ \tfrac{2}{3},\ \tfrac{3}{5},\ \tfrac{8}{15},\ \tfrac{1}{2},$$

corresponding to the notes,

C D E F G A B C'

or in sol-fa notation,

d r m f s l t d'

These ratios will be given by the following set of numbers—

90 80 72 $67\frac{1}{2}$ 60 54 48 45.

If, then, we begin with a tube 90 quarter inches long, the other lengths in quarter inches will be as the numbers just given. Or if we begin with a tube 18 inches long, the lengths in inches of the different tubes will be—

18, 16, 14·4, 13·5, 12, 10·8, 9·6, 9.

By making two other tubes of lengths 12·8 and 10·125 inches we get the notes which correspond to F sharp and B flat. We may also extend beyond the shortest length given above and obtain the octaves of D and E, with lengths 8 and 7·2 inches.

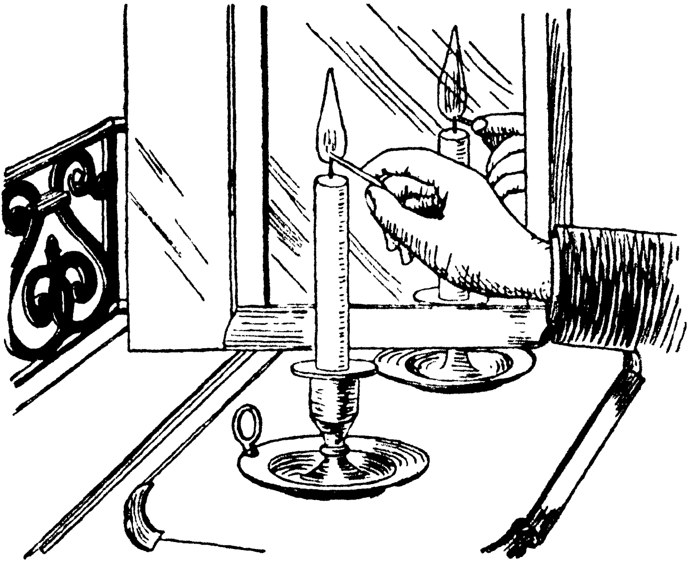
Lay these tubes in descending order of length on the table, and tie them together by means of two silk threads knotted successively round the middle sections of each tube. To keep the tubes parallel to one another tie their ends together by means of silk threads knotted between the tubes, as shown in the sketch. With the top and bottom tube fastened to two rods the instrument is complete and ready for use.

When the tubes are hanging free, and are struck with a cork hammer attached to a ruler or long pencil, each will sound its own note of definite pitch, and it is not difficult to play some simple melody on this tubophone.

With the end rods fastened to the backs of two chairs so that the instrument lies roughly horizontal, the performer may use two hammers, and play with greater rapidity and brilliancy.

Similar instruments may be made with solid rods of wood cut to the same relative lengths, or with metal or glass strips. In the latter case, however, the adjustment of the lengths must be made by ear rather than by calculated lengths.

As described by Livingstone in 1856, instruments constructed of wooden keys of different lengths were in use among the native tribes of South Africa.



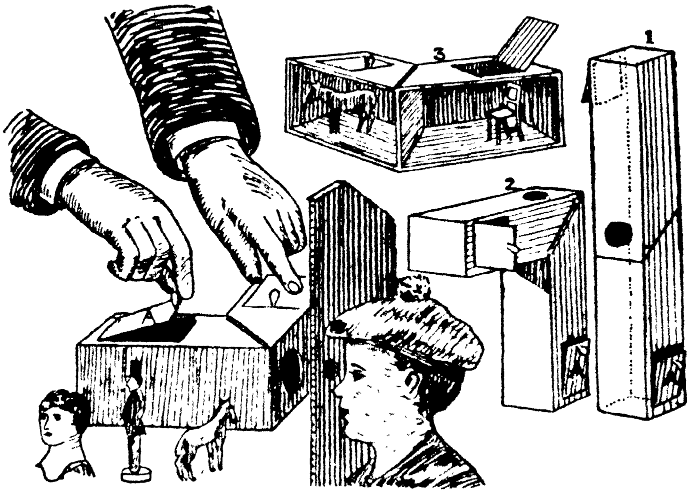
VIII. Optics.

120. REFLECTION OF LIGHT AT THE SURFACE OF TRANSPARENT BODIES.

Place two candlesticks symmetrically with regard to a vertical pane of glass—say, a casement window opening inwards into a room, so that each candle is at the same distance from the glass, whose position bisects at right angles the line joining them. Arrange in the candlesticks two candles of exactly the same height. An observer looking from one side should see the reflected image of the candle on the side next him coincide accurately with the candle on the far side. The proper adjustment is made by bringing about this coincidence.

Now say to a company all seated on one side of the pane of glass that you will light the candle on the farther side without going near it. Nothing is simpler. All that need be done is to light the candle on the nearer side; then immediately to all observers the farther candle will appear to be lighted also. The reflection of the flame of the lighted candle coincides accurately with the top of the candle beyond the pane of glass.

This is a very striking proof of the law that the image of an object reflected in a plane mirror is just as far behind the mirror as the object is in front, and every observer sees the image in the same position.



121. THE MAGIC BOX.

First make a cardboard box of square section, about two feet long and four inches to the side. Close the two ends, and cut out near the ends and on opposite sides of the box two square openings about three inches to the side, with lids large enough to cover the holes completely, and provided with cloth hinges. Cut the box into two equal halves by means of a section making 45° with the sides of the box. Turn the one half round until it forms an elbow joint with the other, both square openings being now on the upper side. Unite the two halves firmly along the oblique section with gummed strips of paper, taking care to leave a slot through which a piece of ordinary glass may be introduced, forming a transparent wall between the two halves. On what is now the vertical wall cut out a circular hole with its centre about two inches from the outer angle of the common oblique section.

The apparatus is now complete for optical mystification. Place in the two boxes different small toys—say, an ass in the one and a chair in the other, and ask a child to look through the circular aperture. By opening one or other of the trap-door windows and illuminating the toy in the corresponding box, you may make one or other visible at will. The one object when illuminated will be seen directly through the glass window fitting into the oblique section. When this box is darkened and the window of the other opened, the object in it will be seen by reflection from the glass, while the contents of the darkened chamber beyond will be invisible.

122. COLOURED SHADOWS.

FIRST provide yourself with a number of coloured glasses—red, blue, green, yellow, etc. Place a large book on end, and hang over it a sheet of white paper. Take two candles (different kinds of candles if possible, but that is not essential), set them in front of the sheet of paper, and adjust fairly close to the paper an upright pencil supported on a pedestal of cork.

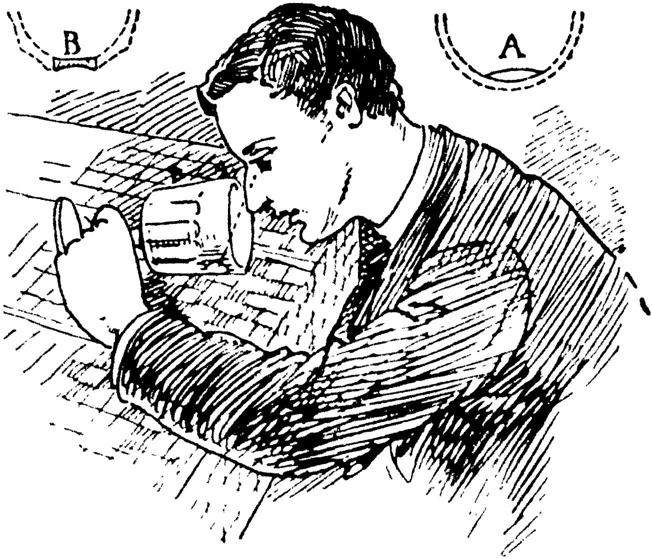
Each candle flame will cast a separate shadow of the pencil on the white sheet, and by moving the one candle to and fro we may rapidly arrange matters so that the two shadows overlap in a very dark part and the remaining parts of the shadows are of equal intensity of grayness. If the candles are of the same kind, this will happen when they are at the same distance from the shadows on the screen. If, however, the lights are originally of different brightness, the equality of shade of the shadows will be realized when the lights are at different distances. This gives a method for measuring the relative brightnesses of two sources of light, and constitutes what is called a photometer.

Now place in front of one of the flames a coloured glass—say the red glass. The shadow cast by the other light will, of course, be illuminated by the red light, and will, therefore, appear red; but at the same time the shadow cast by the red light, and which is, therefore, illuminated by the colourless flame, will appear a beautiful green. The effect when first seen is startling and extraordinary. For where does the green light come from? To get the best effect it will be necessary to move the red covered light nearer the white paper, or the uncovered flame farther away. An easy adjustment will, however, soon bring the two coloured shadows to appeal to the eye as of equal brightness.

Now remove the red glass and put the blue glass in its place. The two shadows will appear blue and yellow. Use the green glass instead, and the contrast colours will be green and red. In all cases the colour of the shadow which is cast by the coloured light is complementary to the colour of this light; that is to say, it would, if mingled with the original colour, produce white or colourless light.

The explanation of this beautiful phenomenon of contrast colours has not yet been fully given. It is largely physiological. There is no doubt that like effects are frequently seen in the sky. In front of a citron sky at sunset the hills appear a rich purple.

And the delicate greens and reds which frequently enrich the western sky at evening time are no doubt to some extent subjective—that is to say, the effect is partly within ourselves, and not wholly physical. It has been found, for example, that colour photography does not always reproduce the colours in a landscape as seen by the eye.



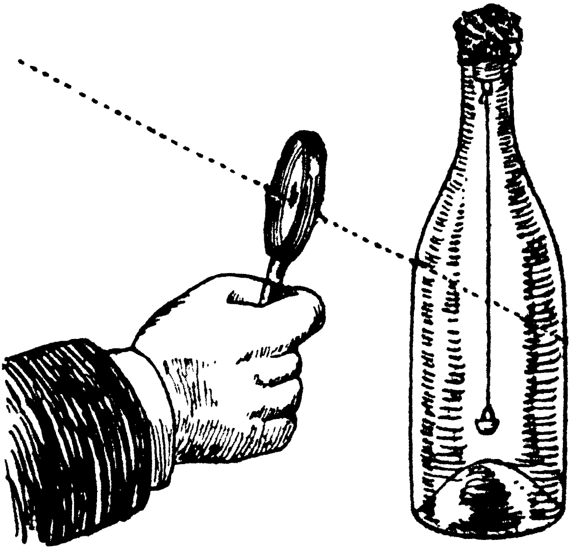
123. CONVEX AND CONCAVE LENSES.

TAKE a tumbler with concave strips cut out along the lower parts of the sides, pour a little water into it, and then, grasping it by the base, tilt it towards you until the drop of water lies on the upper uncut part, and look through the drop at the pattern on the tablecloth. The pattern will be seen enlarged, and it will be easy to count the threads. The drop of water acts as a magnifying glass in exactly the same manner as a convex lens of glass, and for the same reason. Rays from an object on the farther side falling on the lens are bent so as to be less divergent. They therefore enter the observer's eye as if from a more distant source. Hence all the points which make up the object are images at a farther distance, and are drawn apart, producing apparent magnification.

But now look at the pattern of the cloth through the cut part of the glass. This, as will appear from the drawing B, will behave as a concave lens, the kind of lens used by short-sighted people. The image of the pattern will be seen to be diminished, and the illusion suggests that it is much farther away. This is not the case, however. The rays from any point on the farther side falling on the concave lens are made more divergent, and enter the eye of the observer as if from a point nearer, and usually much nearer, the lens than is the object. The points which make up the object have their images, therefore, brought nearer and closer, hence the diminution in size.

With the advance of years a person with normal sight becomes unable to focus on his retina the light radiating from an object at a distance of a foot or even a yard. The light is too divergent. To reduce the divergence of the light from near objects he uses convex lenses, throwing the image to a greater distance, and so seeing it clearly. Such a person is said to be long-sighted, or presbyopic (*old eye*). This defect of sight comes on gradually with increasing age, which diminishes the power of accommodation of the eye.

On the other hand, there is the defect of short-sightedness or myopia (*shut-eye*), from the tendency of myopic persons to half close their eyes, thereby obtaining a better definition on the principle of the diaphragm in a photographic lens. Myopia is a defect of sight which is easily corrected by the use of the concave lens, which by increasing the divergence of the rays brings the image of all external nature within a few inches from the lens.



124. THE BURNING GLASS.

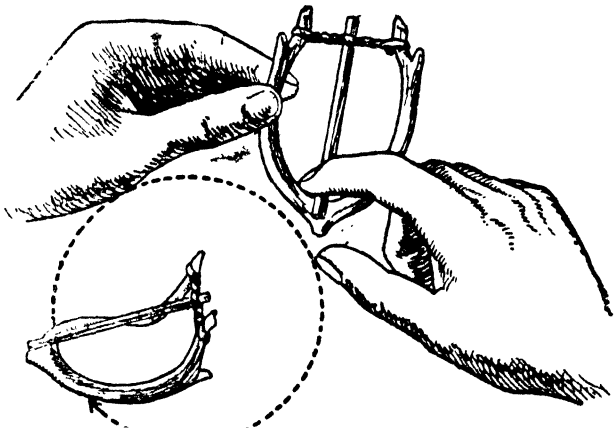
A CONVEX lens held in the rays of the sun will concentrate these rays to a bright focus, which is simply the image of the sun produced by the lens. When the hand is held so as to catch this small image, the heat will soon make itself felt, and the experimenter will ere long withdraw his hand or remove the lens. It is possible to set a piece of paper aflame by holding it for some time in the bright focus of a fairly powerful lens.

Show to your friends a corked bottle with nothing in it except a button hung at the end of a fine thread whose upper end is tied to a hook of wire inserted in the cork.

You offer to cut the thread without opening the bottle or touching the thread. To show that there is no deception you seal the cork and neck with sealing-wax.

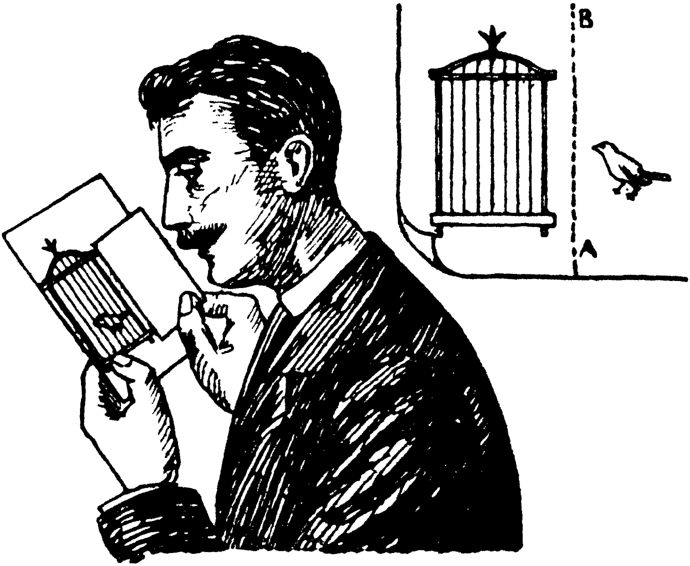
You then lift the bottle and carry it out of the room, and in a few minutes return with the thread cut and the button lying in the bottom of the bottle.

The method is shown in the drawing, and can be carried out only on a bright sunny day. For it simply consists in using a lens to concentrate the sun's rays steadily upon any point of the thread, and in a very short time the thread will be burned through. A black thread will act more efficiently than a white thread, since it absorbs the energy more quickly, and transforms it into heat.



125. AN OPTICAL ILLUSION: THE MERRYTHOUGHT OF A DUCK.

How, you ask, can the merrythought of a duck serve as an optical illusion? Wind a strong wire several times round the prongs of the merrythought, and twist the ends firmly together. Between the strands of wire which pass in front and those which pass behind insert a match, and give it a few turns so as to twist the wires. Draw back the match until its end rests on the part where the merrythought forks, and hold it there with the finger. Now suddenly let go, and the match will twirl round the wires and come to rest, bearing upon the merrythought on the other side of the fork. But this movement takes place so quickly that the eye cannot follow it, and the observer seems to see the end of the match pass through the solid part of the merrythought from the one side to the other, as if it had cut its way through the bone. This experiment may be repeated again and again; the illusion is always the same.

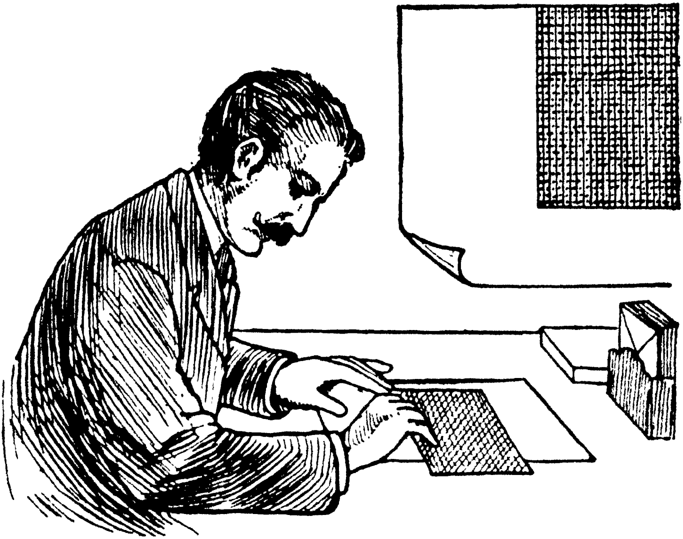


126. THE BIRD IN THE CAGE.

DRAW an empty cage on a sheet of paper, and a quarter of an inch distant draw a small bird.

Place a card between the two figures, holding it at right angles to the paper. Bring the face close up to the card, so that the one eye sees only the cage and the other eye sees the bird. After looking steadily at these objects for a few seconds the bird will be seen apparently to move gradually within the cage, until it occupies the place indicated by the image in the smaller drawing.

The experiment may be done with the small figure in the right-hand corner of the illustrative sketch. Place the card along the line AB, and the phenomenon will be produced.

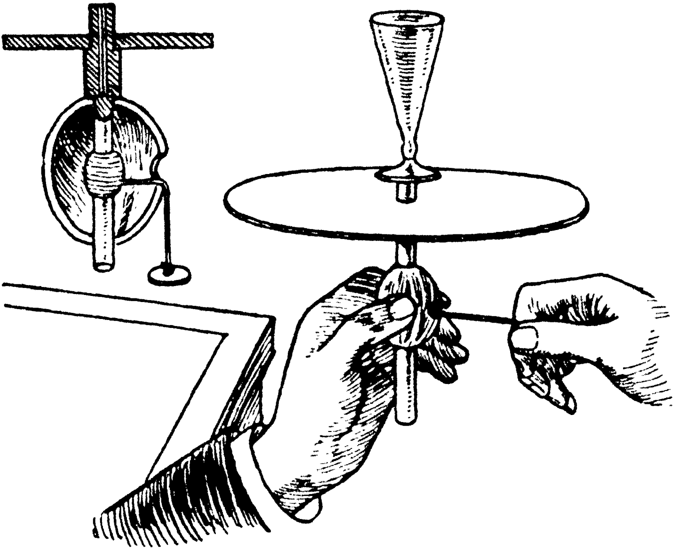


127. DIFFICULT READING MADE EASY.

Trace on transparent paper a series of fine parallel lines about twenty-five to the inch, and then a second series of similar lines crossing the first at right angles, and finally two other series inclined at 45° to the first. The grating will be so close that when placed over printed or written characters it will be impossible to read them through the ruled paper.

When all the company have vainly endeavoured to read through it, you announce that you will succeed where they have failed. Placing the ruled transparent paper over the printed page or letter, you read it fluently, to the admiration of all. All you have to do is to give to the transparent paper small, rapid, to-and-fro movements, as if you wished to rub the page into legibility: the characters will immediately appear quite distinct.

The same optical phenomenon is produced when, passing in a train at some little distance from a paling with gaps between the planks, we see what is going on behind the paling. The opaque and transparent parts follow so rapidly that the successive impressions on the eye remain superposed and practically simultaneous. There is a loss of brightness, but the details are distinctly seen.



128. THE PHANTOM FORMS.

MANY optical illusions are due to the persistence of luminous impressions on our retina. The most familiar example is the fiery ring which is seen when a glowing match is moved quickly in a circle. Before the impression produced by the light in one position has died away the impressions from the later positions crowd in upon the eye, and the sensation is one of continuity.

Another example is a singing gas flame. The flame sings because, in virtue of an instability in the pressure, it is jumping up and down with great rapidity. This may be shown by viewing the reflection of the flame in a rotating mirror. A piece of looking-glass held in the hand and moved with rapid oscillations about a vertical axis will show a succession of flames: a phenomenon which requires an alternation in the height of the flame, otherwise the successive images would run together as a continuous band of light.

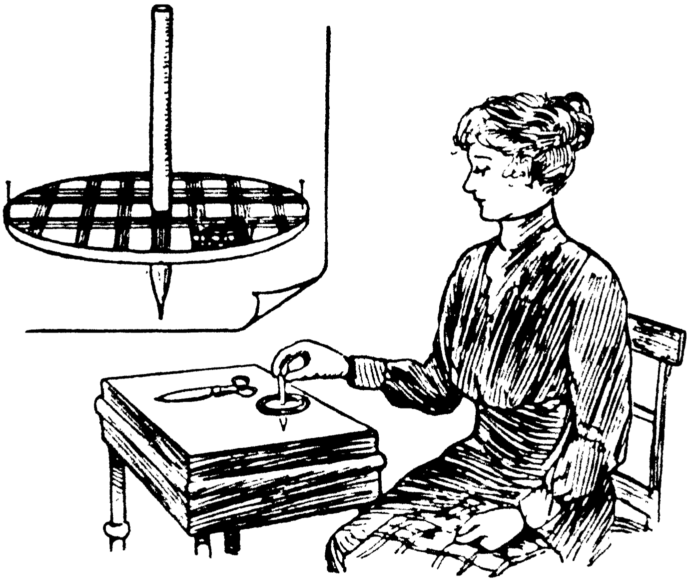
Falling raindrops appear to the eye as liquid filaments, and are so represented by artists in their landscapes; nevertheless they are small spheres.

Other striking examples may be obtained by constructing a simple apparatus for giving a rapid rotation about a vertical axis.

The figure on the left of the illustration shows how, by use of an empty nutshell and a penholder, a small hand-mill with vertical axis may be made. The part of the axis which passes through the nut is round and thin; the upper part is cut square-shape, so as to fit a square-cut hole in the centre of a cardboard disk which acts as flywheel. At the ends of the two halves of the nutshell small grooves must be cut. When the halves are firmly glued together these form holes through which the axis passes. A string is fixed to the axis and wrapped round it, coming out through a hole pierced in the side of the nut. By holding the nut in one hand and pulling the string with the other you may give a rapid rotation to the axis and wheel, and whatever else may be fixed to it.

By means of a red-hot wire burn out a hole in the top of the axis. Into this you may then introduce profiles of wire of various shapes. These profiles when set in rapid rotation suggest to the eye the semblances of transparent bodies of symmetrical shape—bottles, glasses, lamp shades, and the like.

Thaumatropes, zootropes, kinematographs are examples of the same kind of optical illusion.



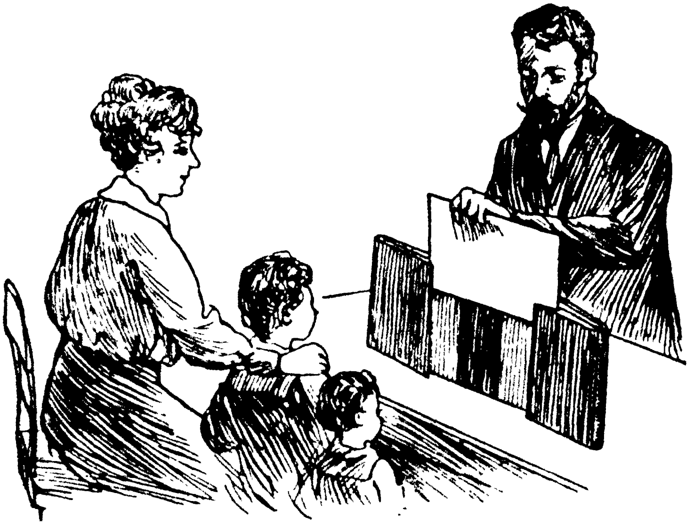
129. THE TOP AS A MATCHER OF TINTS.

LADIES who regard tops as mere playthings for children may nevertheless find them highly useful as a help in matching materials.

A simple and useful top may be made of a circular disk of cardboard, about four inches in diameter, with a pencil put through the centre and fixed with a little sealing-wax. The point of the pencil should be about an inch below the disk.

The problem, let us suppose, is to match a piece of cloth with an ornamental border, the two to be of the same general shade. Cut a circle out of the material of the same size as the disk of the top. Make a hole in the centre, and slip it over the pencil until the pattern lies on the disk, to which it may be fixed by two small pins. When the top is set spinning the pattern will disappear, and in its place will be a general shade or tint. Cut off a small square piece of the proposed border, and pin it to the edge of the disk so as to cover a small part of the material. When the top is now set spinning the border patch will appear as a circle surrounding the general tint of the pattern within. It will be a simple matter to tell whether the shades are the same.

Or the problem might be to match two differently-coloured pieces of material. The process will be the same, and the eye will be better able to judge by comparing the general resultant tints produced by the contiguous rotating parts than if these with their varied patterns simply lay side by side.



130. AFTER IMAGES.

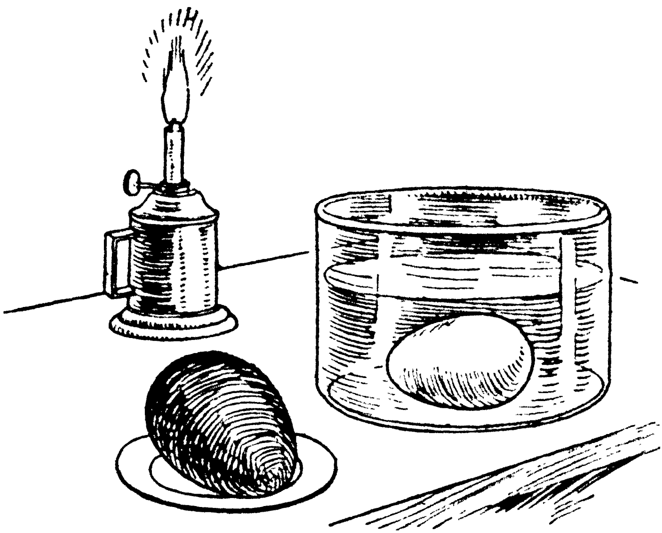
PAINT across a sheet of paper three bands of equal width but different colour—say, green to the right, black in the middle, and orange to the left. It may be conveniently supported, as shown in the picture, between the leaves of two books set on end.

Provide yourself also with a white sheet of cardboard slightly larger than the paper in front of which it is to be slipped when the time comes.

Place the coloured sheet in front of the company, and ask them to look fixedly at it for, say, half a minute. Then slip in front of it the white cardboard. In about ten seconds they will see on the white screen coloured bands appearing of the same width as those on the coloured sheet. But the colours will be different. Instead of green, black, and orange there will appear red, white, and blue, each being replaced by its complementary colour.

By modifying the design and colours of the original scheme you may produce as after images the flags of various nations. A black cross on a green ground will produce the white cross on the red ground of Switzerland or Denmark; white, violet, and green bands will furnish the flag of Belgium, black, yellow, and red; two white eagles on a violet ground will appear as the Russian black eagles on yellow ground; and so on.

The generally accepted explanation is that the eye gets fatigued under the stimulus of a given colour. When the eye then looks to a white surface the complementary part of the original colour —the two together make white or a neutral tint— will give the greater stimulus, since the eye has not been fatigued as regards this complementary colour.

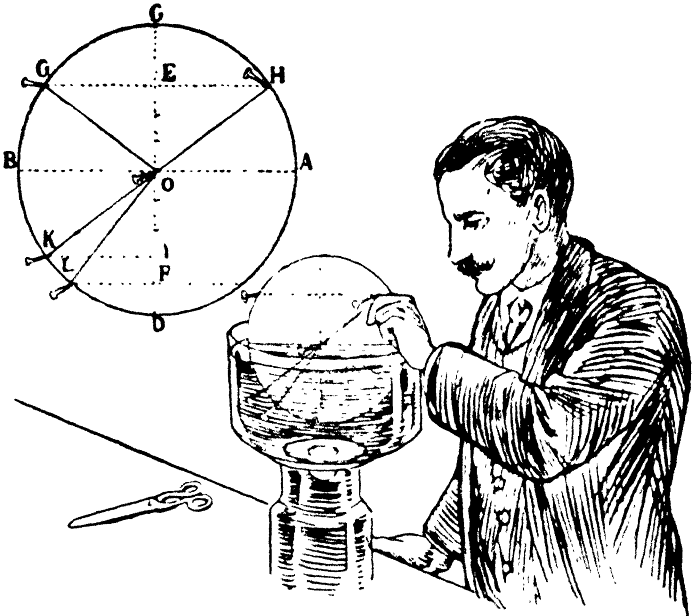


131. THE SILVERED EGG.

A SILVER spoon held over a candle flame will soon be covered with a layer of lamp-black. When plunged into a vessel of water it will assume again its bright appearance. Has the water washed it clean? That is the first suspicion. But draw it out again, and lo! it is black as ever. How is this curious effect explained?

The layer of lamp-black, being composed of extremely fine powder, is not wet by the water. The water surface which we believe to be in touch with the spoon is really backed by a film of air, and the light is reflected within the water internally from this surface, and is sent back to the eye as if from a solid mirror.

You may vary the experiment by blackening an egg in a smoky flame and then placing it in a dish covered with water. Present it to a friend, who to his astonishment will draw forth a black egg instead of one of silvery beauty.



132. REFLECTION AND REFRACTION OF LIGHT.

THE fundamental laws of the reflection and refraction of light may be verified by a simple piece of apparatus—to wit, a disk of cardboard and three pins. It is also necessary to have a large glass dish full of water.

The disk should be smaller than the section of the dish—say, six inches in diameter. Draw two diameters, BA and CD, at right angles to each other. Divide the radii OC and OF into six equal half-inch parts, and measure off OE equal to three of these, and OF equal to four. Draw GEH through E parallel to BA. Join G to O and also H to O, and prolong HO till it meets the circle again in K. Similarly, through F draw LF parallel to BA, and join OL. Place pins at G, H, K, and L, all perpendicular to the plane of the disk.

Now immerse half the disk in water. bringing the diameter BA to the water level.

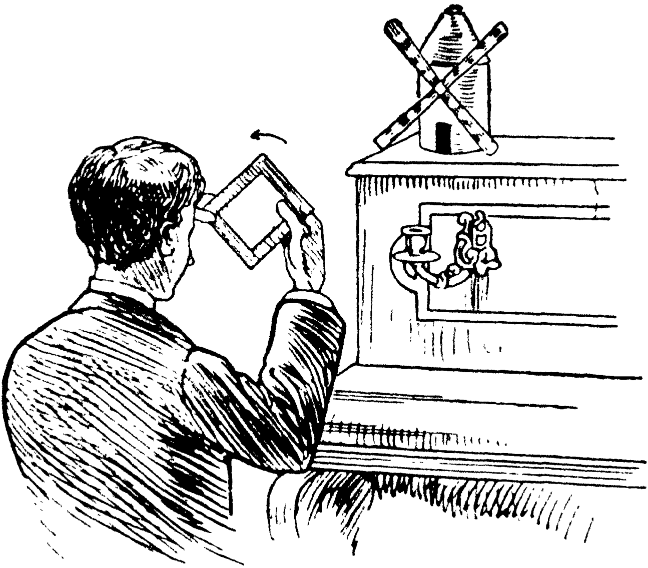
With the eye in any position you will see the reflection of the pin G at the position K, and the refracted image of the pin at L may also be seen. To show exactly where these two images are, place the eye behind the pin H, and look in the direction HO. No images will be seen in the water. The pin at H will obstruct the reflected rays from G and the refracted rays from L, which rays after reflection and refraction respectively emerge along the line OH.

Thus we verify—

1. The Law of Reflection—the reflected ray OH making with the normal CO the same angle as that made by the original ray, or $\angle GOE = \angle HOE$.

2. The Law of Refraction—the refracted ray making such an angle as to lift the image of L towards the surface by one-quarter of the original distance below the surface.

More generally, whatever be the angle LOD, the distance OI of the image below the surface is three-fourths of the distance OF of the object L below the surface. The image is somewhere in the line KO. This fact is usually stated in the words: The refractive index of water as compared with air is 4/3.



133. DON QUIXOTE'S DELUSION.

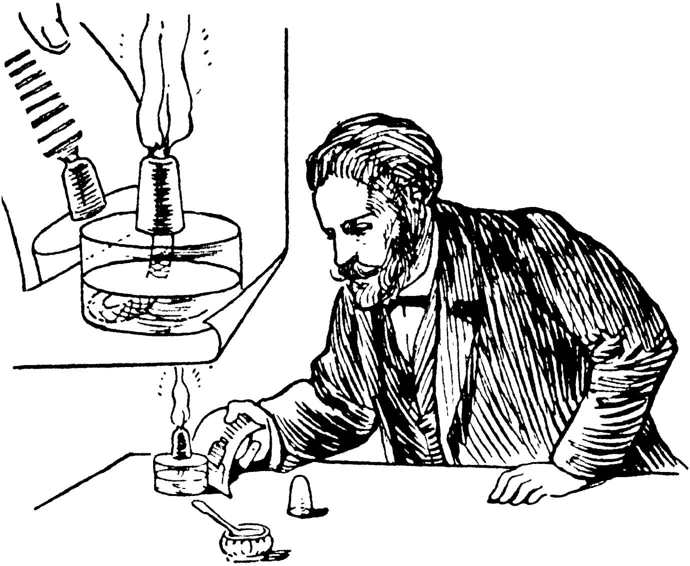
Look at a light at a little distance through a piece of fine silk gauze, and you will see the light extending out in four directions as a luminous cross of varied alternating tints. This is an example of what is known as Diffraction of Light.

Other examples are the coloured rings seen round the moon viewed through a transparent fleecy cloud; the coloured rings seen round the lights of a railway station when viewed through the moisture-bedimmed windows of a railway carriage on a cold night; the coloured fringes observed when a light is looked at through the eyelashes with the eyes half-closed.

The phenomenon depends on the light passing through a grating of thin solid bodies or through a cloud of minute particles. In the case of the bedimmed windows the moisture emanating from the lungs of those within the carriage condenses as minute dewlike drops on the cold window-pane, and the rays from the station lights are diffracted as they pass through this screen of minute drops. The size of the different coloured rings depends on the size of the intervening drops or particles: the smaller the drops, the greater the size of the diffraction rings.

A pretty variant of the experiment first described is to mount the silk gauze in a cardboard frame, and then construct a small toy mill composed of a cylinder of strong paper surmounted by a cone with the top cut off to allow the escape of the heated air from a candle placed within the mill. The candle should be of a height which will bring the flame to the level of a small square window cut out on the wall of the mill just above the door.

All the other lights being extinguished, the attention of the company is drawn to the illuminated window of the mill. But if this is a windmill, where are the sails ? In response to this query we place in the hands of the questioner the small frame with the silk gauze, and invite him to look through. At once the diffraction cross becomes visible, and by rotation of the frame can be made to appear as sails moving round one way or the other.



134. INTERFERENCE BANDS: THE FURROWED IMAGES.

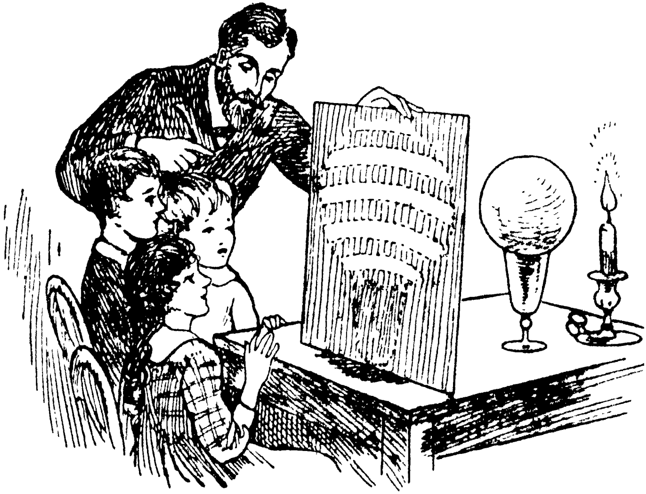
HERE is a curious mirror. The images seen in this mirror are crossed by dark bands, as if viewed through a ladder with close-set rungs. The experiment deals with what is known as the Interference of Light, and was first explained by Thomas Young, a famous English physician, in the early years of the nineteenth century.

The essential thing is a very thin sheet of transparent material, such as thin gelatine or thin-blown glass. By far the best material, however, is the mineral known as mica, which can be sliced along its cleavage planes into very thin sheets indeed. Mica windows are familiar in stoves and lanterns in which the changing temperature would be apt to crack glass.

To see the interference bands in their simplest form, it is best to use light of one colour—monochromatic light, as it is called. This is easily effected by using a spirit-lamp or other non-luminous flame in a room otherwise darkened, and sprinkling into it a little common salt. The metallic constituent of common salt is sodium, which burns with a yellow light. In this yellow light red objects appear dusky yellow, and blue objects black; the faces of the company assume a most unhealthy appearance, grotesque, indeed, in their pallidness.

Bring close to this monochromatic flame the thin mica sheet slightly curved outwards, and look down upon it. The reflected yellow flame will be seen crossed by dark parallel bands.

The explanation depends upon the fact that light is wave-motion, so that when two rays of light originally from the same source come together after separation, in certain positions the crests and troughs of the one ray coincide with the crests and troughs of the other, producing increased brightness; in other positions the crests and troughs of the one ray coincide respectively with the troughs and crests of the other, annihilating the wave-motion, and producing darkness. The two interfering rays are portions of the original ray—the one being reflected from the nearer surface of the mica, and the other from the lower surface. The latter is, therefore, retarded with respect to the former part by amounts which differ according to the thickness of the thin film, and the angle at which the original ray meets the surface.



135. NEWTON'S RINGS.

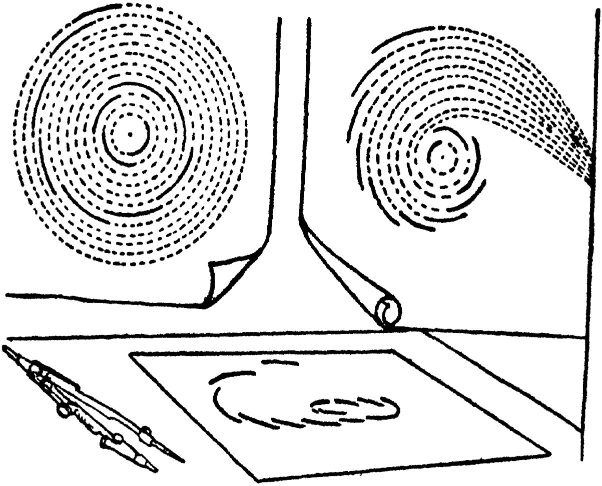
THE experiment of last section, although first fully explained by Thomas Young, was observed by Sir Isaac Newton, who devised a special apparatus for showing the phenomenon as a series of concentric rings of lights of different colour. When viewed in monochromatic light, Newton's rings appear as a set of numerous concentric rings of light and darkness.

The most familiar example of this phenomenon is given by a soap bubble, which, when thin enough, shows a beautiful scheme of colour, subject to striking changes owing to the continuous variations in the thinness of the film.

To show these colours by projection, set the soap bubble on the rim of a wine-glass coated with glycerine. On one side place an illuminated candle two or three feet distant, and on the other side at a few inches distance adjust a screen of white cardboard, or a sheet of thin paper mounted on a frame. The latter arrangement is preferable when the phenomenon is to be shown to a company seated on the farther side of the screen. After a few seconds the strips of colour will begin to appear. As the film thins off above the variety of tint will be most marked in that part. A careful inspection will show that the colours succeed one another in a definite order.

If, instead of a candle flame, we use the non-luminous flame of the spirit-lamp, and then make it yellow by adding common salt to it, the colour-scheme will be alternating layers of yellow and black.

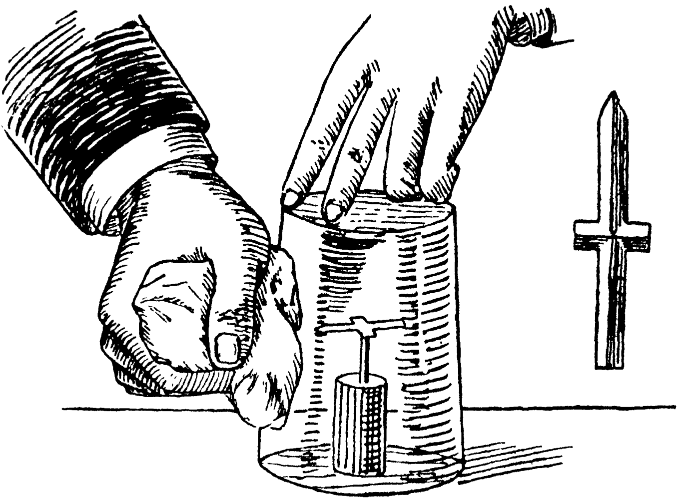
Another way of showing the same kind of effect is to form a flat film in a circular loop of wire, and reflect from this film the rays from a source of light. The reflected light is received on a screen, and is focussed by means of a lens placed between the light and the film.



136. THE CONVERGING ARCS.

DRAW with compasses a series of short arcs of concentric circles in such a way that each short arc in one circle ends close to where the short arc in the next circle begins, and so on till ten or a dozen arcs are drawn. These arcs will be arranged along a spiral; but to the eye they will seem to possess the further property indicated in the right-hand figure. If the observer imagines the arcs to be produced, they will seem to him to converge to a point.

This is an error of judgment, an optical illusion, which is immediately demonstrated by *completing* the circles to which the arcs belong. These circles will be concentric, and therefore the arcs when continued as circular arcs cannot meet or converge.



IX. Electricity and Magnetism.

137. THE ELECTRIFIED TUMBLER.

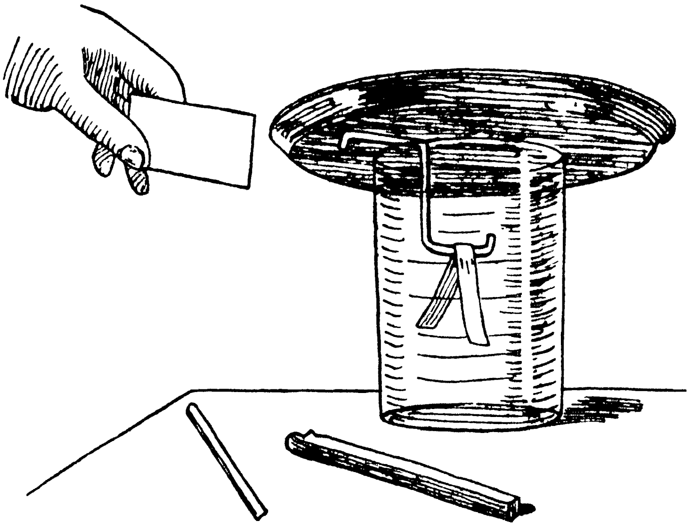
After a slight heating so as to make both surfaces thoroughly dry, rub a stick of sealing-wax with flannel, and bring it close over a collection of small snippets of paper lying on the table. The pieces of paper will at once rise up towards the sealing-wax, and some will adhere to it for a short time. The sealing-wax has been electrified by friction. The same may be shown with a rod of warm dry glass rubbed with silk.

A pretty variety of this experiment is the following. Cut out of a piece of stiffish paper folded fourfold an arrow having the form shown in the drawing, and balance it on the point of a needle, fixed vertically in a cork. The needle must not pierce the paper, but simply support it at the meeting of the folds. Cover the whole with a tumbler which has been previously heated before the fire.

Announce to the company that, without lifting the glass or touching the paper, you will make it turn to any of the company.

All that is needed is to rub with a piece of silk or wool the side of the tumbler facing the person who is to be honoured. The arrow will turn round and point towards the part rubbed.

By friction the glass has become electrified with what is conventionally called positive electricity. Just as in the case of the sealing-wax, the electrified glass attracts small bodies. But the initial action on the arrow is to electrify it by induction, making the nearer end negatively electrified and the farther end positively electrified. It is the nearer end which is attracted, and this is shown by the needle turning round and pointing towards the excited part of the glass.



138. THE ELECTROSCOPE.

Bend a piece of iron or brass wire in the form of a Z, with two right angles, as shown in the drawing. Lay the horizontal part on the rim of a tumbler thoroughly dried by heating, and place over it a small metal plate or dish. The vertical part of the wire must not touch the glass, and on the lower horizontal part a small doubled strip of silver or tinned paper hangs astride. Thin gold leaves would be preferable to the tinned paper, and the instrument used in lecture rooms and laboratories is usually constructed with gold leaves; hence the name, the Gold Leaf Electroscope.

Now electrify by rubbing appropriately either a rod of glass or a rod of sealing-wax, and bring it close to the edge of the metal plate. The two paper strips will at once repel each other and open out. This shows that they have become similarly electrified. Since the electricity on the paper strips has been produced there through the influence of, say, the rubbed sealing-wax, it must be the same kind of electricity as that on the sealing-wax. For the law is that like kinds repel and unlike kinds attract. Therefore we infer that the paper strips are meanwhile charged with negative electricity. Remove the sealing-wax and the strips will fall together again.

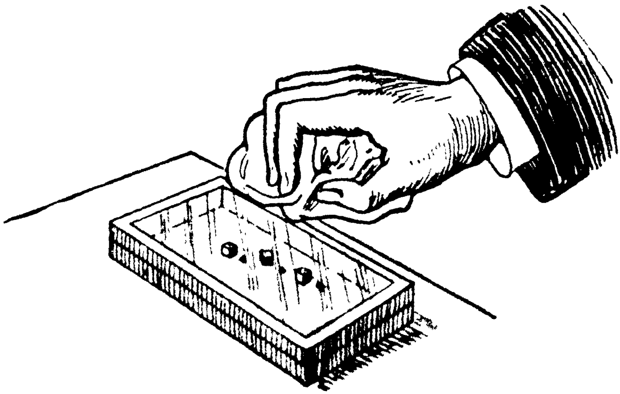
Exactly the same experiment may be repeated with the glass instead of the wax rod. In this case, however, the repelling paper strips will be charged with positive electricity, since the glass is positively electrified.

To show that the sealing-wax and glass are oppositely electrified, we proceed as follows. Begin, say, with the rubbed sealing-wax. Bring it close to the metal plate as before until the repelling paper strips are well apart. Keeping the wax rod steady in position, touch the metal plate with the finger. At once the paper strips fall together, losing their charge, which is repelled by the charged sealing-wax to earth. Take away the finger and remove the sealing-wax ; the paper strips will again repel each other and remain divergent. What has happened is that the positive charge held on the plate by the attraction of the negative charge on the sealing-wax when it was close in position to the plate becomes, when the sealing-wax is removed, free to repel itself all over the plate and wire and paper strips. Thus the whole conducting system is left positively electrified. If the sealing-wax be again approached it will draw up towards it the charge, and leave the paper strips less powerfully charged. They will, therefore, fall together, and come quite together if the wax be brought back to the position it had in the first part of the process.

But suppose now that we approach the rubbed glass to the plate. The paper strips will be further divergent, since the positive charge on the system of plate wire and paper strips will be repelled into the leaves in greater quantity.

Again remove the glass rod, and bring up the flannel with which the sealing-wax was originally electrified. The gold leaves will diverge, showing that the flannel is positively electrified just like the glass. Similarly, the silk used to electrify the glass will be found to be negatively electrified like the sealing-wax. When approached near the plate of the electroscope the paper strips will fall together.

In all cases it is found that when electrification is developed by rubbing two substances together—for example, dry paper and a brush—the one is positively electrified and the other is negatively electrified.



139. THE SWINGING DICE.

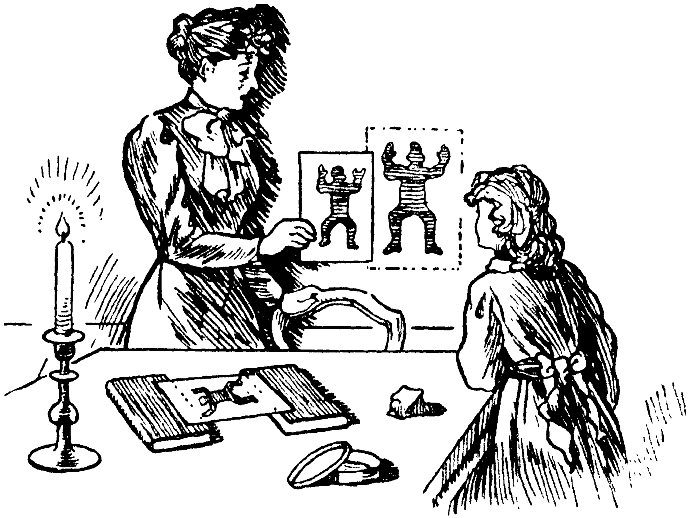
PLACE two books on the table at such a distance apart as to act as supports to a square of glass laid over them. Underneath the square scatter a few light bodies, such as small bits of cork or paper, feathers, pith balls, and the like.

Let us now electrify the glass by rubbing it with wool or silk well warmed before a fire. Immediately the light bodies will leap up towards the glass, fall back again to the table, make another leap up, and so on indefinitely. Or we may shape little puppets out of pith, and set them moving in a veritable dance.

Or the following amusing and baffling game may be played.

Cut out of elder pith three small cubes of the same size, and mark them like dice with pen and ink. Place them in a shallow box with a glass top.

When the glass has been electrified by friction the small cubes will spring up and fix themselves to the lower surface. Ask a friend to sum up the numbers on the dice. After a few moments, without having touched the box, you show him that he has counted badly—the sum of the points on the dice is not what he said. He adds them together again, and once more the dice change, and he is again convicted of careless counting. The explanation is that the face of each cube in contact with the glass loses gradually its power of cohesion. It falls away, remaining attached by one of the edges. Then the neighbouring face becomes attracted, and the cube oscillating about the edge fixes itself to the glass by another face. In this simple manner arises the changing of the points, at first so mysterious.



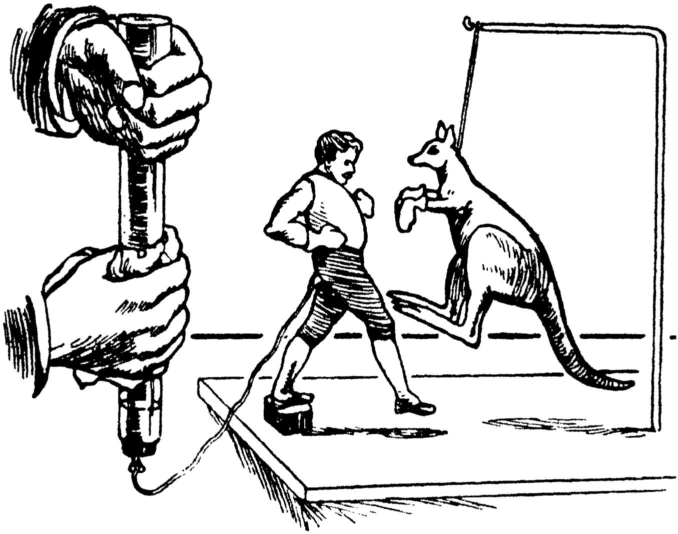
140. ELECTRIC SHADOWS.

As in the last article, support a glass plate on two books, each from half an inch to an inch thick. Prepare also a quantity of cork powder by filing a piece of cork with a fine file, and scatter the powder on the table under the glass plate.

Rub the plate with wool or silk, so as to electrify it, and immediately the powder will leap from the table and stick for some little time to the lower surface of the glass. As soon as the rubbing ceases the powder begins to fall away, and in a short time the plate will be quite clear.

Repeat the experiment with other plates of glass which appear in no way peculiar to the view of the company, but which have been specially prepared beforehand. On what is to be the lower surface of each there has been traced, by means of a brush dipped in glycerine, various figures more or less grotesque—clowns, dancing-bears, cats, dogs, and the like.

When any one of these apparently transparent plates is placed on the two books and electrified by friction, the cork powder will, as before, spring from the table, and fix itself to the glass surface. When the rubbing ceases the powder on the clean glass surface will fall away as before ; but wherever the glycerine is it will stick to the surface permanently. Lift up the plate, put it in front of a candle, and project the shadow on a screen.



141. THE BOXER AND THE KANGAROO.

A LIGHT pith ball suspended by a silk thread is frequently used in demonstrating the fundamental laws of electrical action. When a rod of sealing-wax or glass, electrified by friction, is brought near, the pith ball is violently attracted, and then after a few moments of contact strongly repelled.

An amusing development of this experiment is to cut out of visiting cards two small figures, one of a boxer and the other of any animal that may take the fancy. In the drawing a kangaroo has been chosen. These are made conducting surfaces by having pasted over their one side some silver paper.

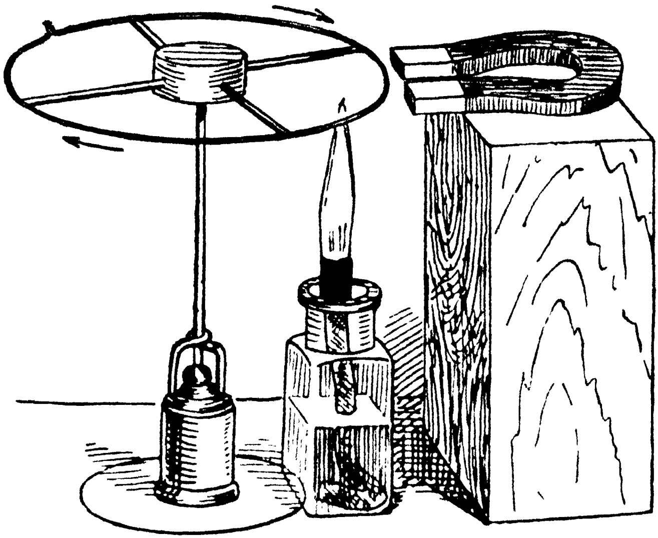
The back foot of the boxer is fixed to a piece of sealing-wax by means of a short bit of iron wire, the sealing-wax itself being fixed to the board. The boxer is, therefore, electrically insulated.

The kangaroo is suspended by a linen thread from a metal bracket fixed to the board.

A sufficient source of electricity may be made out of a cylindrical lamp shade, closed at its one end by a cork with a nail passing through its centre. This nail is connected with the boxer by a fine iron wire, care being taken that this wire is in touch with the silver paper covering one side of the boxer. The apparatus is now ready.

Place the insulated boxer a short distance from the suspended kangaroo, and rub the glass tube briskly with silk. This will electrify the glass positively, which, acting inductively on the conductor formed of nail, wire, and boxer, will electrify the boxer also positively. The kangaroo will at once be attracted until it strikes the boxer, and receives by contact so much of the positive charge. The man and animal, being now similarly electrified, will repel one another, and the kangaroo will swing away. The charge on the kangaroo will gradually be lost by conduction along the suspension. Attraction will again set in, and the infuriated animal will return to the attack, once more to be repelled.

It is always well to warm the glass before a fire, so as to dry it thoroughly.



142. ROTATION OF A RING BEFORE A MAGNET.

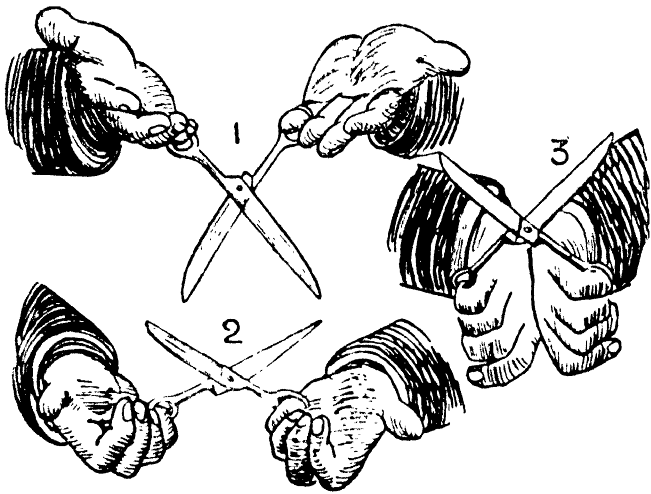
CONSTRUCT a light wheel whose hub is a cork disk with copper rods for spokes, and a thin iron wire for rim. The iron wire is kept in position by means of nicks cut in the ends of the spokes. A knitting-needle fixed in the centre of the cork perpendicular to the wheel will act as a vertical shaft supporting it.

The base on which this shaft is to rotate must now be made. This will consist of a cork cemented to a broad disk of cardboard, a slightly concave porcelain button fixed with sealing-wax to the top of the cork, and a glass bead surmounting the button. Through the bore of this glass bead the lower end of the shaft will pass, and rest pivoted on the button. To keep the shaft upright, twist a hairpin in such a manner that it will form at its centre a ring through which the knitting-needle will pass, and then push the ends of the hairpin vertically into the cork on each side of the button.

Place close to the rim of the wheel a horseshoe magnet supported horizontally at the proper height on a box or pile of books.

The apparatus is now ready, and the experiment consists in heating, by means of the flame of a spirit lamp or of a Bunsen gas burner, the wire rim a little to one side of the magnet. When this is being done the wheel will be observed to rotate slowly, as if the magnet repelled the hot part.

The explanation is that the red-hot part of the iron wire is non-magnetic, so that the magnetic pull of the magnet upon the rim of the wheel is no longer symmetrical. There is less pull on the quadrant which contains the heated part than on the quadrant which is unheated.



PART III.—RECREATIONS AND TRICKS.

143. THE THREATENING SCISSORS.

LET a pair of large scissors hang loosely from the little fingers of the two hands, each little finger being inserted in one of the handle-rings, with the palms of the hands uppermost, as shown in Fig. 1 of the drawing.

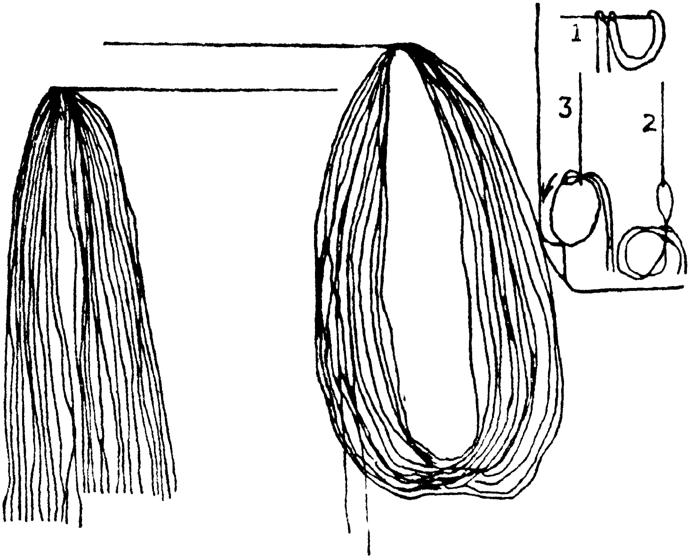
With a slight to-and-fro shake of the hands, cause the scissors to rotate first from you and then towards you, until the points are directed towards your breast, as shown in Fig. 2.

Finally bring your hands back to back, continuing the rotation of the scissors until they end by pointing straight at the spectator's face, as represented in Fig. 3.

At your first efforts you will be surprised to find that, in all probability, the scissors will not rise in the position indicated. When the hands are brought back to back you will probably find the scissors pointing downwards. At the first attempt almost every one will fail to make the scissors point upwards in the threatening position.

The condition for success is to see that the little fingers do not pass too far through the rings of the handle. Only the last phalanges of the little fingers should engage with the rings, as indicated in Fig. 2. If this condition is carefully realized the scissors will at the last turn point threateningly upwards.

When you have practised the action you will find great amusement in challenging your friends to do the same.



144. MULTIPLE THREADING OF A NEEDLE.

TAKE an ordinary egg-eyed sewing-needle of average size—say, No. 6—and a thin thread of sewing-cotton about two yards long. Thread the needle in the usual way, and have the ends of the thread the same length. About three inches below the head of the needle untwist each thread slightly, and pass the point of the needle between the strands, as shown in Fig. 1. Care should be taken not to leave extra twist on the threads, so that they remain apart without intertwisting. The needle has, therefore, pierced two eyelets in the thread.

Draw the needle eye and the thread which passes through it through the two eyelets on the threads, as shown in Fig. 2. Take now one of the threads between the eyelets and the head of the needle, and pull it steadily until it draws the eyelets and the other part of the thread through the eye of the needle. This is shown in Fig. 3. It will be seen that there are now three threads passing side by side through the eye of the needle. Continue the pulling through in the same direction, and in time the eyelets will again come up to the eye of the needle, and be pulled through with two other threads along with the three. This pulling through may be repeated again and again. Each time the eyelets pass through the needle eye two other strands are added to the threads which simultaneously pass through the eye. All this process can be carried out without looking at the needle or threads.

The operation may, therefore, be presented as a trick to a company. Prepare beforehand the eyelets up to the stage two. Then hiding with your finger the looped portion, show the thread passing through the needle eye, and then announce that, without looking, you will thread this needle with a large number of separate threads. Placing the hands below the edge of the table, proceed to the third stage, and go on until the passing through of the eyelets has been done some ten or twelve times. Then with a sharp knife or scissors, which may be supplied by one of the company, cut the loops as shown in the central figure in the illustration, and the result will be as represented in the left-hand figure.

145. THE TRIAL OF PATIENCE.

HERE is an amusing game very simply prepared. Make a ring of cardboard about the thickness and size of a shilling, and cut out a circular hole the size of a sixpence. Gum it to the centre of a plate, and challenge one of a company to get a ball set rolling in the plate to settle into the hole.

To give the plate just the necessary tilt so as to impart to the ball the momentum which will carry it over the edge of the cardboard ring and leave it in the hollow is no easy matter. It will try the skill, patience, and nerves of the novice.

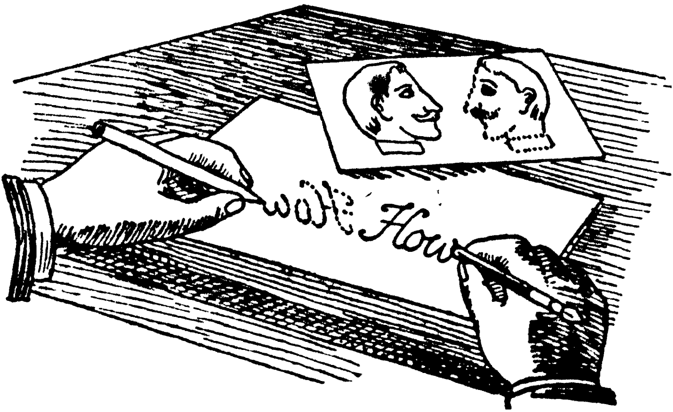
The true way to solve the problem is not to try and run the ball over the ridge, but to make use of the property of inertia. Allow the ball to come gently up against the outside of the circular ridge by slightly tilting the plate. Then suddenly lower the plate about an inch, raising it again quickly, and by a slight displacement bringing the centre of the ring under the ball. If done properly, the ball will drop into the centre and remain there. The reason is that the ball does not fall quite so quickly as the plate, on account of its inertia, and since it has no motion to right or left, it will settle into the centre of the ring without touching the raised rim.

146. TO CUT GLASS WITH SCISSORS.

A PANE of glass may be cut with ordinary scissors as easily as a sheet of cardboard.

The whole secret consists in plunging the glass, scissors, and hands in a bucket of water. The glass may then be cut in straight or curved lines without crack or fracture. The water kills the vibrations which would otherwise be produced in both scissors and glass. If the smallest portion of the scissors is allowed to come out of the water the experiment will be a failure.

Thin glass may also be cut by scissors if we first cover it with little strips of paper gummed all together and disposed in all senses. The paper strips have the same effect of killing the vibrations. The water method is, however, much simpler, and as certain of success.



147. LEFT-HANDED WRITING AND DRAWING.

It is a well-known physiological fact that the left hand acting alongside of the right hand will execute the same movements, but in the inverse sense.

By taking a pencil in each hand and drawing simultaneously with both, we can easily form a profile and its reflection in a plane mirror side by side.

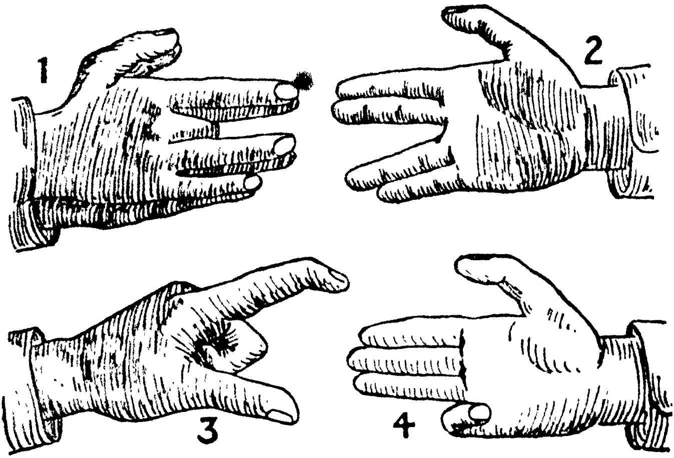
Butterflies and insects bilaterally symmetrical may be drawn with beautiful symmetry by tracing simultaneously the right-hand and left-hand halves by use of the right and left hands. This is specially effective on a blackboard, and surprises any who have not tried it.

Similarly with writing. If the right hand is made to write some words, the left hand working side by side will write exactly the same words, but in the inverse manner. The letters will be formed like their images in a mirror; the slopes will be in the opposite directions, and all the details characterizing the natural writing will appear in the left-hand copy. If the left-hand writing is on transparent paper it will be seen as natural writing when the paper is looked through from the other side; or the natural appearance will be seen if viewed in a mirror.

148. THE IMMOVABLE COIN.

PLACE a shilling in the centre of your outstretched hand, and challenge one of the company to remove it by brushing with a clothes brush. Offer it as a reward to any one who effects its removal by this means. So long as a true brushing movement is applied the coin will not move; the hairs of the brush simply slip over it.

The eager experimenter will be slow to believe it; but brush he never so long or so hard, the coin will defy his every effort.



149. FINGER GYMNASTICS.

INSTEAD of merely twirling our thumbs when we have nothing to do, we may exercise our fingers in a variety of ways.

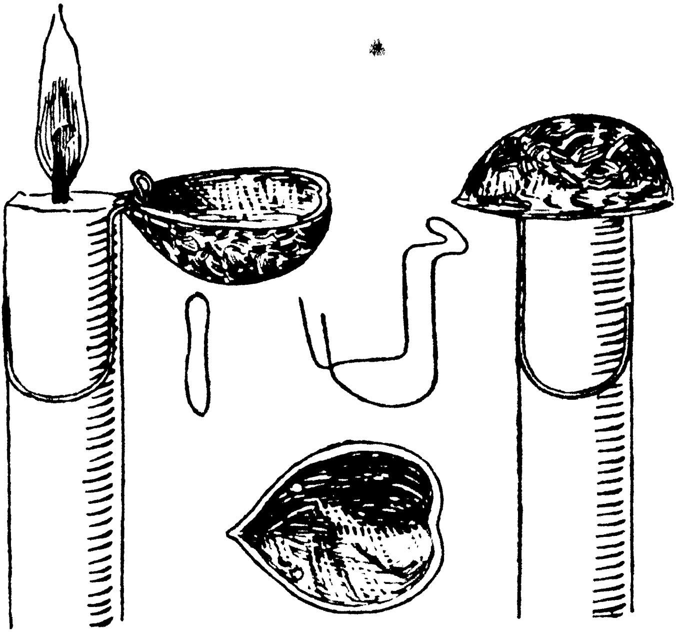
For example, bring the two hands together so that the tips of the corresponding fingers are in contact, with the exception of the middle fingers, which are bent down and brought into contact back to back along the second joint. In this position (see Fig. 1) it will be found easy to separate either the thumbs, or the forefingers, or the little fingers; but it will be quite impossible to separate the ring fingers when the others are kept in contact at their tips.

The second figure shows a position not easily attained by some until after a considerable amount of practice. In this case the fingers form two groups, the forefinger and middle finger being close together, and similarly the ring and little fingers, but the middle and ring fingers separated. A very good exercise is to bring all the fingers together from this position, and then separate them so that the middle and ring fingers are close together, and the others on each side separated. To pass from the one position to the other in rapid alternation is easy enough. But try to do the two hands together in such a way that when the right hand is in the position shown in Fig. 2 the left hand is in the other position ; and when the right hand changes to this other position the left hand simultaneously changes to the position of Fig. 2. This will be found a difficult exercise.

In Fig. 3 another difficult position is indicated—namely, to bend the last joint, and keep the finger otherwise perfectly straight.

To turn the little finger down as shown in Fig. 4 without bending in the slightest degree any of the other fingers, is also a difficult exercise. The ring finger tends to follow suit, although a far way behind.

Again place the two hands in front with the forefingers pointing at each other, the remaining fingers being closed. Now try to make the forefingers describe simultaneously in the opposite directions two vertical circles in parallel planes perpendicular to the line of the fingers. Having mastered this somewhat difficult movement, challenge your friends to do the same. It is surprising how many fail, even after numerous trials.



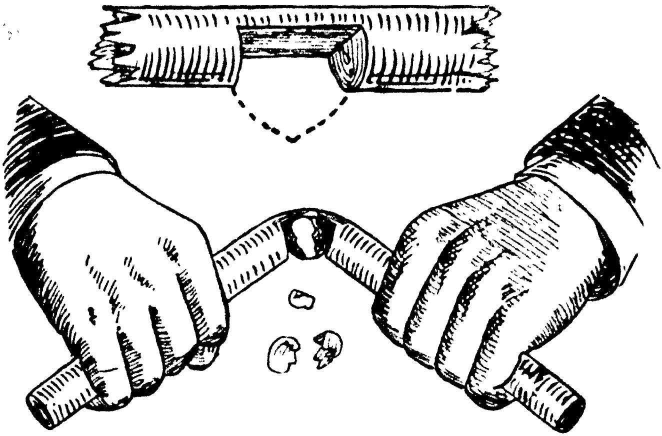
150. THE AUTOMATIC EXTINGUISHER.

When, owing to sleeplessness or eagerness, we lie in bed reading by the light of a candle, we not infrequently drop off to sleep and leave the candle burning itself uselessly away.

This inconvenience may be prevented by making an automatic extinguisher out of a walnut, a hair-pin, and a rubber ring.

Take the half of a walnut and, by means of a red-hot wire, bore two small holes on each side of the pointed part, and quite near the rim. Bend the hairpin into the looped form shown in the drawing. Pass the rubber ring through the two holes in the nut, and catch the ends round two short pegs of wood —for example, bits of a match. Introduce the head of the pin between the two rubber strips which pass across the nut near the pointed end, and twist the rubber by turning the wooden pegs round several times. The twist should be sufficient to bring the pin round into the interior of the nut when it is left free. The apparatus is now complete. The next step is to adjust it to the candle.

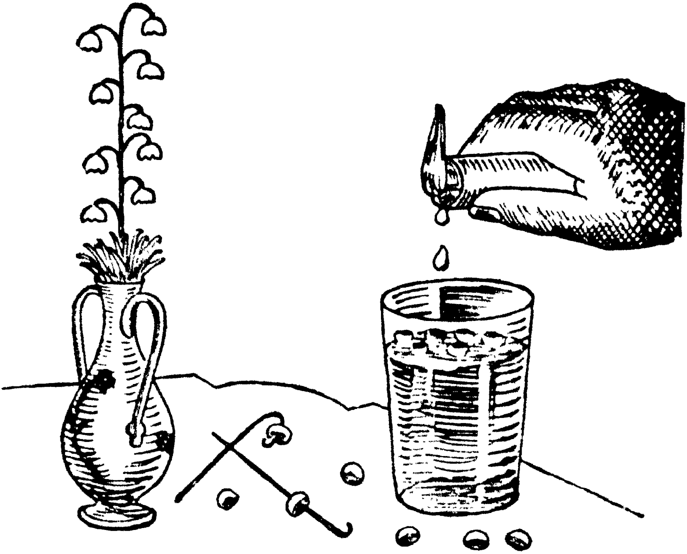
Pull the pin round until it is wholly on the outside of the nut, and fix the ends to the sides of the candle, adjusting the nut so as to have its rim lying horizontal, while the sharp point penetrates slightly into the candle at any chosen position below the wick. When, in course of time, the candle burns down to the level of the nut, the point of the nut can no longer find support in the side of the candle, and the rubber untwists and pulls the nut round until it rests on the top of the candle, extinguishing the lighted wick.



151. NUTCRACKERS.

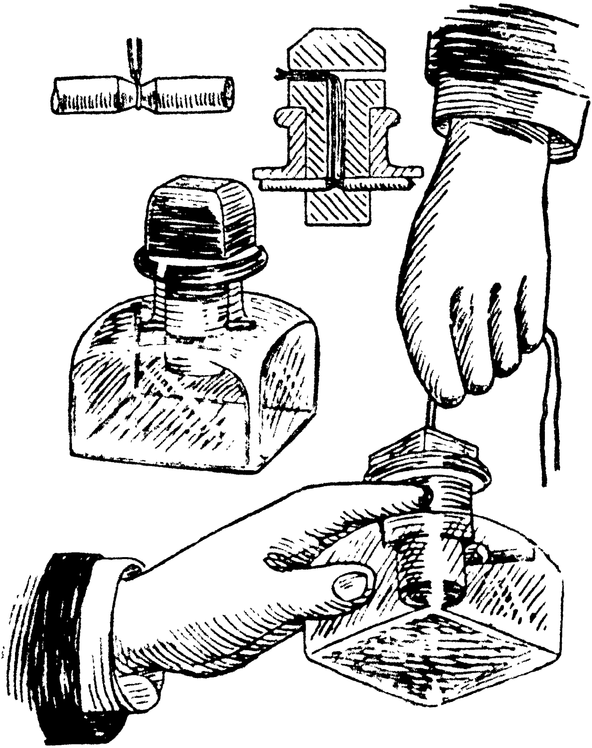
In cracking a nut under the heel or between two stones we risk bruising the kernel; in trying to break it with our teeth we may ourselves suffer in the contest; and as for manufactured nutcrackers, they are not always to hand.

We may, however, make quite a serviceable instrument out of the branch of a tree—the hazel tree itself, indeed. Cut in the branch a slot about the width of the finger, and well through the wood, leaving sufficient fibres to unite the two ends of the stick with a flexible bond. These ends are the handles of the nutcracker. Place the nut in the slot, and gripping the handles each in one hand, bend the branch so as to press hard upon the nut. The shell will crack, fall away, and leave the kernel uninjured within the slot.



152. CANDLE-WAX LILIES.

HOLD a lighted candle inclined over a glass of water so that the drops of melted wax may fall into the liquid. As soon as each drop reaches the surface it takes the form of a small cup floating on the surface. These drops have the size and form of the florets of a lily of the valley. Take a number of fine iron wires bent at the one end. Heat the other end of each wire, and pass it through the middle of the bell-shaped wax as it floats on the water. Pull this out and slip it along the wire until it comes to the bend at the end. Bend the wires to give the florets a droop, and bind them altogether, as shown in the figure. They will closely resemble the lily of the valley.



153. THE MYSTERIOUS BOTTLE.

To close a bottle with a stopper which cannot be removed without breakage. That is the problem. The stopper consists of a plug of wood with a large nail inserted crosswise in it just below the neck of the bottle. The question is, how did the nail get there?

The process is sufficiently simple, although it requires a pretty long explanation. Let us take the stages one by one.

The bottle must be flat-shaped, such as is frequently used for holding ink. The wooden stopper must be long enough to pass well below the lower part of the neck, when the enlarged portion rests on the top of the opening. The various stages in the construction are as follows.

1. Saw through the stopper close to the upper end, so as to remove a thin disk about a quarter of an inch thick. Lay it on one side in the meantime.

2. With the aid of a drill or a red-hot knitting-needle, bore a hole along the axis of the stopper, but not quite to the end. The hole should reach well below where the bottle widens out.

3. Near the lower end bore a transverse hole meeting the vertical bore, and passing through to the other side. The two channels, vertical and horizontal, will have the form of an inverted T.

4. Pass down the vertical hole a piece of thin flexible wire, and when the end has reached the horizontal hole, push it with a match into one of the horizontal channels, and draw it well out of the lateral hole.

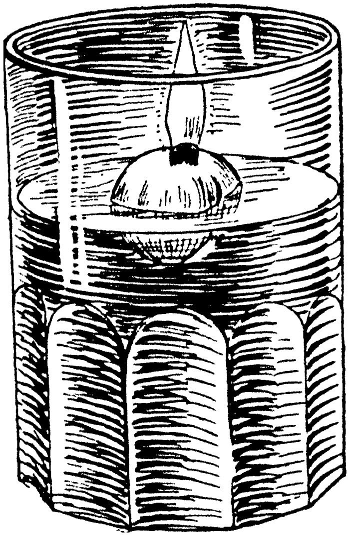
5. File a small notch in the middle of the nail, and attach to it the end of the wire. Gum the wire

and nail together along the one-half length, and leave them to dry.

6. Introduce now into the bottle first the nail suspended at the end of the wire, then the stopper. Invert the bottle, and draw out the other end of the wire until after some trials the point of the nail enters the hole through which the wire was originally led. Place the bottle upright, and pull steadily on the wire, which will little by little detach itself from the side of the nail, until the latter is drawn through the horizontal hole with the point of attachment of the wire at the foot of the vertical channel. The nail projects on both sides of the stopper, quite preventing its withdrawal.

7. To complete the mystification, cut away the upper end of the wire, and glue on the disk in its old position at the top of the stopper. Everything is now hidden except the nail, which appears as if it had been driven through the stopper by means of a hammer. To cover up all trace of how it was done, paint the top of the stopper so as to hide the join of the two pieces.

Ordinary cork could also be used, and it would then be unnecessary to saw off the top. It would suffice after all was finished to cover the top of the cork with wax, as is usual in sealing bottles.



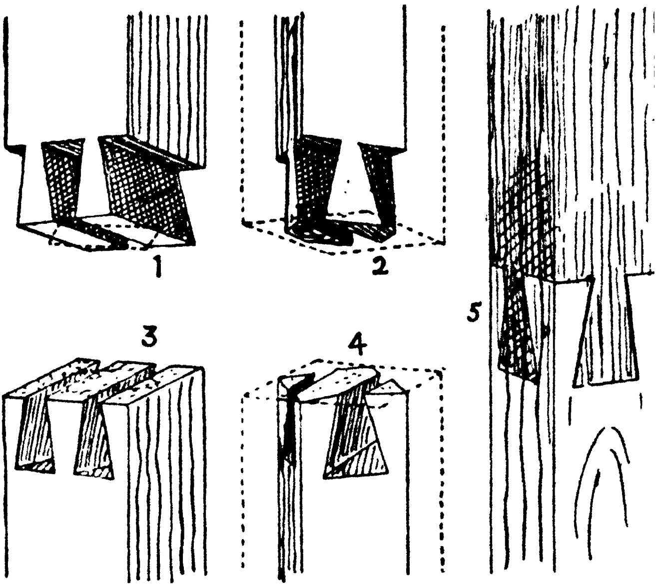
154. A NIGHT-LIGHT OF HORSE CHESTNUT.

When the horse chestnuts fall the girls and boys collect a fine harvest, and transform them into toys of all kinds. They thread them into chaplets and necklaces, and fashion the rinds into panniers and graceful baskets, or display their artistic taste by carving more or less grotesque figures to be coloured when dry.

A novel use is to make it serve as a night-light.

Soak the chestnut in a can of burning oil, after having riddled it all over with small holes by means of a sewing-needle. Scoop out a hole on one of the flatter sides, and place within it some cotton threads to serve as wick. Set it in a tumbler half full of water. If properly made it will float, and when the wick is lit will continue to supply light during the hours of the night.

The one great precaution is to make sure that it will float stably on the water. It is, therefore, best to choose a form which rests stably in a given position, and to make the hole on the part which naturally floats above water.



155. THE PARADOXICAL COUPLING.

Two pieces of wood of square section are dovetailed together by means of four tenons, so that each tenon is visible on one of the four faces. The appearance is shown in Fig. 5 of the illustration. The question is, how is it accomplished ? After careful inspection the great majority of people will be quite nonplussed as to how the two pieces could enter the one into the other.

The first idea which will occur to an observer is that the tenons form a cross, in which case the fitting would be an impossibility. Hence the conclusion is that the tenons do not form a cross. As a matter of fact, there are only two tenons cut obliquely to the faces and parallel to the diagonal of the square section. When this conception is clearly grasped there is no difficulty in seeing how the coupling might be done. It would require, however, a very skilful carpenter to cut out the tenons and the grooves so as to make the two pieces of wood fit accurately.

It demands, indeed, most delicate workmanship, and constitutes a masterpiece in carpentry.

But the result can be obtained without great difficulty in the following manner. Dovetail two pieces of wood by means of two parallel tenons, as shown in Fig. 1, which fit into the corresponding notches shown in Fig. 3. When the two pieces are joined, saw or plane away the four angles following the four sides of a square obtained by joining the middle points of the sides of the primitive square. This square is indicated by the dotted lines on the figures. In this way you obtain Fig. 5, the two pieces of wood being shown separately in Figs. 2 and 4, in which the dotted lines indicate the sections of the primitive pieces of wood. To make the dovetailing clearly visible, it is best to use two kinds of wood of different colour, such as deal and pear tree.

156. PAPER PUPPETS.

Let us cut out of cardboard or stout paper Sisters of Charity and their little pupils.

The necessary material consists of several large-sized calling cards, some fairly strong white paper, black, blue, and red pencils, and a pair of scissors.

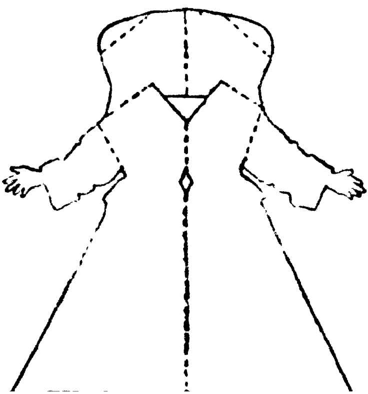


Fig. 1.

Fig. 2.

Bend in two along its middle line one of the cards; trace by means of transparent paper half of the model represented in Fig. 1, and lay it on one of the halves of the bent card; the bend of the card should coincide with the dotted line forming the axis of Fig. 1. Having traced the contour of the half-figure, cut the doubled card according to this contour, open it out, and Fig. 1 will be reproduced.

To transform the card into a Sister of Charity, bend it back again along the middle line; bring forward the two arms by bending them about the dotted lines; make the cap by means of two oblique folds. The form may be varied slightly, but care

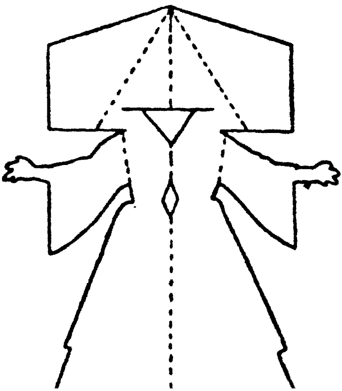


Fig. 3.

Fig. 4.

must be taken to have the cap well forward, so as to hide the place where the face would be. Colour the skirt and sleeves dark blue, leaving a white portion to represent the apron. Draw a rosary, a bunch of keys, and the like. The figure is now complete, and may be made to stand by slightly separating the two halves. The appearance is shown in Fig. 2.

Figs. 3 and 4 show figures differing from the other in small details; but each is constructed in the same way.

Figs. 5 and 6 show how in similar fashion the model of the little pupil may be produced. At first sight there seem to be four legs. But don't be alarmed. When the card is bent along the middle

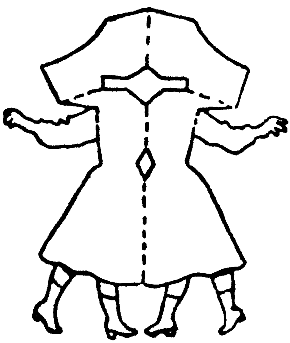


FIG. 5.

FIG. 6.

line we remove two of the legs, one from each side, taking care, however, that it is the front leg on the one side and the back leg on the other which are cut off. This leaves the model with two legs, one in front of the other, and on different sides. The figure will not stand erect without a little extra support, such as fixing the feet in slits on a flat cork. To give brilliancy we may colour the cap and dress as our fancy suggests.

The group of Fig. 9 represents four Sisters and four pupils dancing jingo-ring. The eight personages

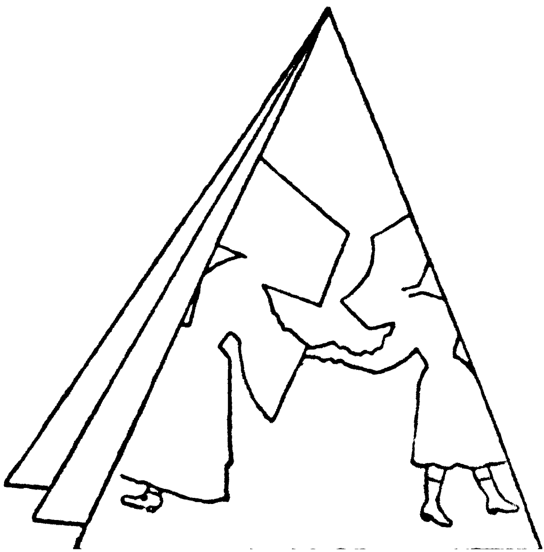


FIG. 7.

are cut out of one sheet of paper, prepared in the following manner.

The paper is folded once on a middle line. It becomes a twofold. By a second folding at right angles to the first, it becomes fourfold ; and finally by folding on the middle line of symmetry through the angle it becomes an eightfold.

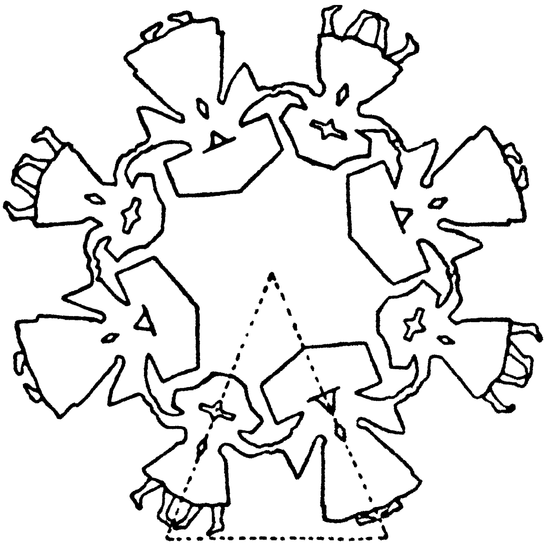


FIG. 8.

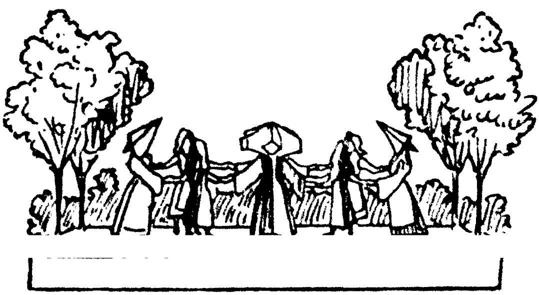


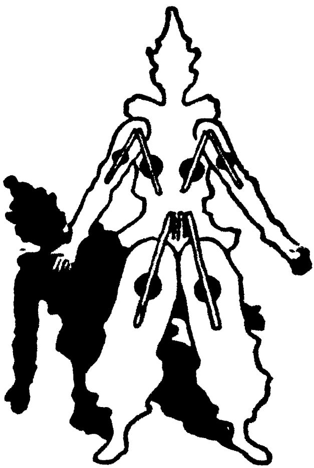
FIG. 9.

Trace on the upper face the half contour of the Sister of Charity and the little pupil hand in hand, as indicated in Fig. 7. Cut away all the paper around the contour of the two figures, so that when it is spread out flat it will appear like Fig. 8. Colour to taste each of the figures, taking great care not to tear the paper, especially at the join of the hands. Then bend each figure as already described, amputating the supplementary limbs, and set them down in standing position on a small platform fashioned like a lawn. Little sprigs of wood or matches covered with moss may be set round the margin, suggesting a country scene.

157. THE LIVELY PUPPETS.

A FEW old cards and ends of matches are all the requisites for the manufacture of a simple series of animated puppets.

Consider, for example, the construction of the



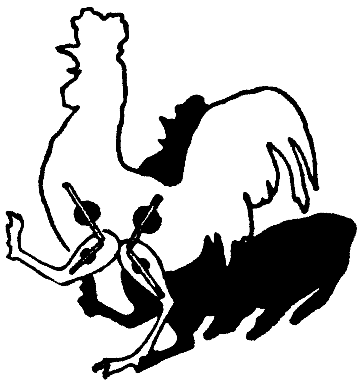
puppet you see figured on the page. First draw separately on cardboard the bust and head, then the two arms and the two legs, five pieces in all, and cut them carefully out with scissors or knife. Place the bust on the table, and set over it the four limbs in position.

Next mark the point about which each limb is to rotate, and through this point drive a pin.

Bend in two an ordinary match, so that the two branches are as near as possible to each other. The match will break across, but it must not be allowed

to break across completely. Certain fibres are still left to unite the two branches. Place the match thus bent on the figure, and by means of drops of sealing-wax fix the one branch to the limb and the other to the body, care being taken that the joint where the match is partially broken through is in contact with the pin. The four limbs having been joined up in similar fashion, the puppet is complete.

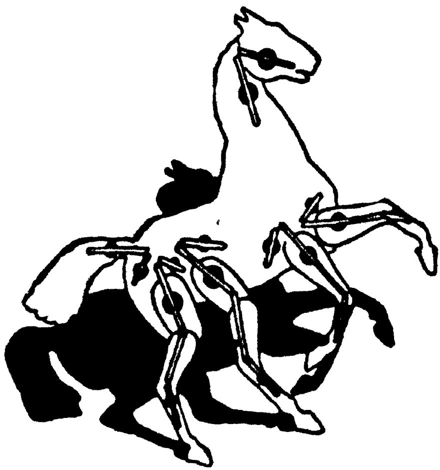
It is needful now to give it life. To this end place the side on which the matches are fixed into a plate containing a shallow layer of water. The bent fibres



of the wood which have not been broken absorb moisture, and tend to regain their originally straight condition. As a consequence the puppet will be seen to be animated by very amusing jerky movements. The legs will widen out and the arms will be raised just like a puppet worked by strings.

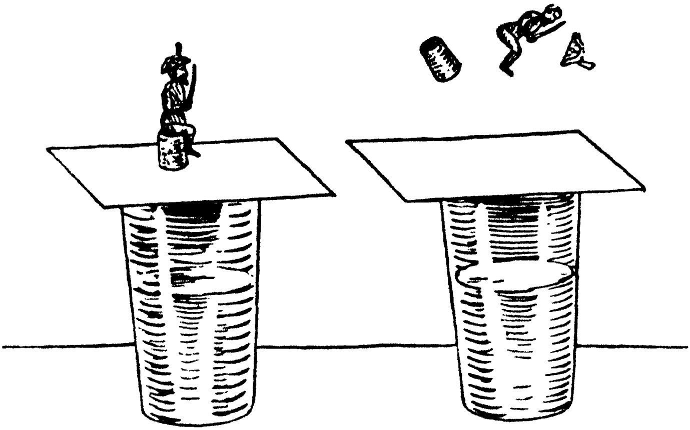
This is the principle, and it may be applied to the construction of many kinds of puppets, such as dancers, cocks and hens, and prancing horses.

The illustration of the last named shows that



there are special difficulties of construction, well worth the pains of surmounting.

The same movements will be obtained if the joints are moistened with a drop of water applied either with the finger or with a brush.



158. THE TREACHEROUS GLASS OF WATER.

PLACE over a tumbler three-quarters full of water a playing-card face downwards, and leave it for about half an hour. The moisture from the water will soak into the lower part of the card, making the lower surface expand. The card will assume a hollow shape above, and the sides will no longer rest closely on the rim of the tumbler.

Now carefully turn the card over and gently place on it a cork surmounted by a small paper figure of a veteran. After a short time the moisture will begin to collect on the new under surface of the card, what was originally the upper surface. At length the card will change to the opposite curvature. This will happen so suddenly that the cork and puppet will be projected upward from the momentarily unstable card.

159. THE SHUTTLECOCK PARACHUTES.

TAKE a strip of cardboard and draw on it the blade of a Turkish sabre about twice the size of the drawing shown in the upper left-hand corner of the illustration. Finish it below with a small circle, and then cut it out of the cardboard. This will serve as a model for reproducing an indefinite number made of very thin paper. Lay it on the paper, and trace the contour with a pencil, and then cut it out with a pair of scissors. The many figures so obtained may be coloured with crayons according to taste.

Weight each by gumming to the circle some wafers or flattened balls of soft bread. When thrown into the air as high as possible they will descend slowly with rotatory motion about the vertical. The swarm of shuttlecocks in all their varied tints will fall flutteringly to the floor, producing a lovely effect.

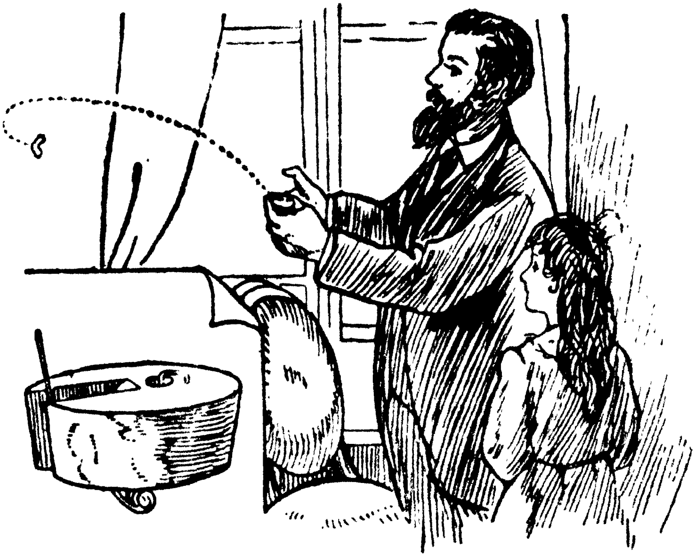
An even simpler form of parachute is got as follows :—

Take two strips of thin paper about six inches long and half an inch wide. Twist them together for about four inches of their length, and incline slightly to right and left the untwisted remainder, so as to resemble the letter Y.

If you allow this to fall from a window on a calm day it will be set spinning rapidly round the vertical axis, so rapidly, indeed, that the eye will not be able to distinguish the branching wings. This rotation is caused by the air pressing on the wings as they fall, and the resistance of the air greatly retards the fall, so that we have a veritable parachute.

In a room the parachutes may be dropped by the operator standing on a table or chair, so as to have as long a fall as possible before the floor is reached.

An added beauty, which will greatly delight children, is to have a number of parachutes made of differently coloured papers starting simultaneously from a height, and whirling down like a swarm of lovely butterflies.



160. THE BOOMERANG.

THE flight of a flat-shaped body through the air is usually very extraordinary. One of the most remarkable is the path described by the boomerang, invented by the Australasian native races, and used by them in warfare and in hunting.

Before making a miniature boomerang try the following simple experiment.

Cut a rectangular strip of paper two or three inches long and half an inch wide ; hold it between the thumb and forefinger with one long edge horizontal and the strip as a whole in the vertical plane, and then let it drop. Instead of falling straight down, it will begin to spin round its long axis and descend towards the floor in a slanting direction. A pretty variation is obtained by cutting the strip not accurately rectangular, but slightly tapering towards one end. The strip will spin round its long axis as before, but its path to the floor will be a helix or corkscrew, the narrower end of the strip pointing inwards.

When such a symmetrically-shaped piece of paper behaves in this way, it is not surprising that the behaviour of the boomerang is so much more extraordinary.

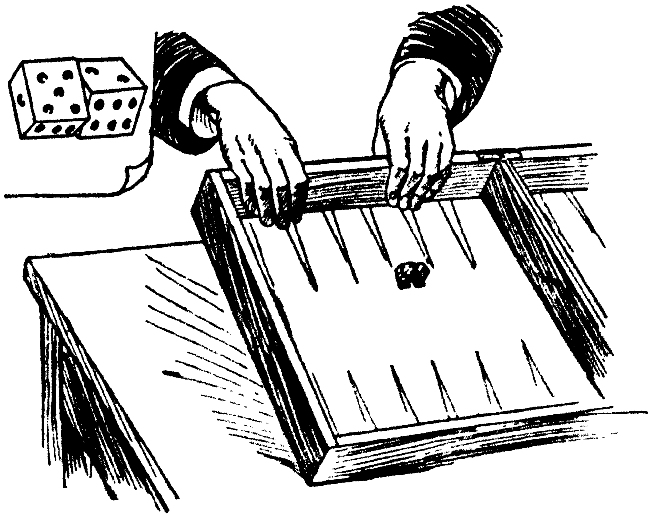
A toy boomerang may be made out of a small bit of cardboard by cutting it in an open elbow shape with branches slightly unequal and angles rounded. It might be compared to a crescent with one horn a little longer than the other. Place this projectile on the edge of a book, or balanced on the back of the hand with one of the branches projecting slightly. Holding the book somewhat inclined, give the small crescent of cardboard a sharp fillip so as to send it off in the plane it is lying in. This will give it at the same time a rapid rotation about an axis perpendicular to the plane of the cardboard. The boomerang will rise in its trajectory to a certain point, and then suddenly turn to right or left, reversing its direction of flight, and finally return towards the point of projection, falling usually near the feet of the operator.

In the hands of the adept the real boomerang may be made to come to earth behind the thrower. In all cases the missile rises to a considerable height in its forward flight, and then suddenly swoops back with accelerated speed as it falls towards the earth.

The swerving effect of the air on a rotating ball moving with considerable speed is familiar to all players of cricket, tennis, and golf. Why does a well-driven golf ball travel so far? On account of the underspin given to it by the club, which delivers its blow in a line passing under the centre of gravity. The "topped" ball has been struck along a line which passes through or above the centre of gravity, and, therefore, has no underspin, but may have a spin the wrong way. The "sliced" or "pulled" ball is sent off spinning about an axis inclined to the horizontal. There is, therefore, a small component spin about a vertical axis, and the ball swerves in the direction in which the front of it is moving round the centre.

The explanation of all these effects was given in 1672 by Sir Isaac Newton, who in a letter to Oldenburg writes: "I remembered that I had often seen a tennis-ball struck with an oblique racket describe such a curve line. For, a circular as well as a progressive motion being communicated to it by that stroke, its parts on that side where the motions conspire must press and beat the contiguous air more violently than on the other, and there excite a reluctancy and reaction of the air proportionally greater . . . and ought to feel the greater resistance . . . on that side where the motions conspire, and thence be continually bowed to the other."

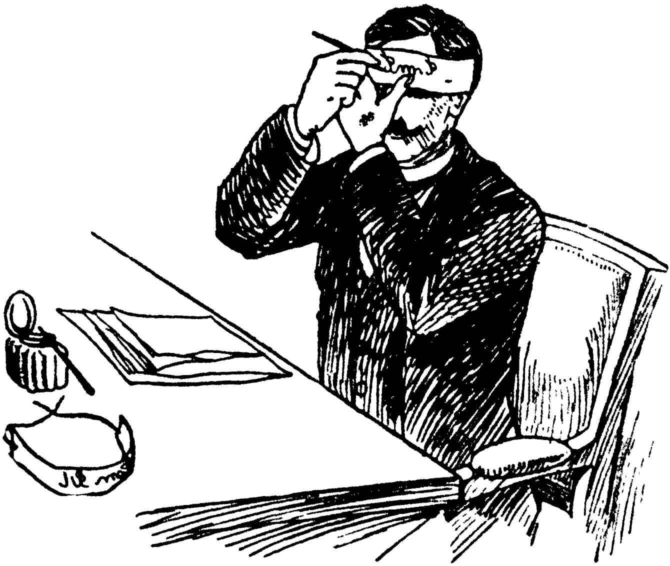
By a properly delivered stroke partly tangential along the lower surface of a light rubber balloon, the balloon may be made to rise almost vertically, and then, after looping its path backwards, descend forward obliquely to the floor.



161. THE ROLLING DICE.

To make two dice roll on an inclined plane, moisten one face of each of them with the tongue, and press them together so that the angles of one will project over the edges of the other. The two will stick together for a sufficient time to allow them to roll down the inclined backgammon board, as shown in the figure. The two will, in fact, behave like an octagon rotating round successive corners.

Having successfully impressed a small company with this experiment, you may further mystify them by challenging them to do it, taking care, of course, to pull the dice apart. Unless they know the trick they will not find the experiment an easy one to perform.



162. WRITING ON THE FOREHEAD.

Place a strip of paper over the forehead of one of the company, making it secure with a piece of string. Then, before he has time to reflect, put in his hand a pencil, and ask him to write any word on the strip—his own name, for example.

Nine times out of ten, to the great amusement of the others, he will begin to write the word backward from right to left, and to shape every individual letter as if he were a lithographer tracing the word on a lithographic stone.

The movement is instinctive, but the experiment will fail if the person who is to do the writing has the prudence to hesitate a moment and consider first which end of the paper he should begin on. But generally the writer will fall into the trap, and will hardly believe the evidence of his eyes when he is allowed afterwards to look upon his handiwork—the writing, so to speak, of King Dagobert.

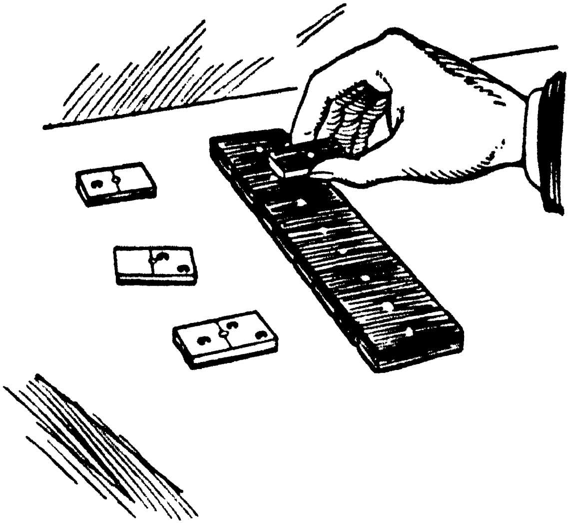
163. THE KNOTTED CORD.

tell us that a knot cannot exist in space of four dimensions. Just as a looped thread lying on a plane can be immediately unlooped by lifting it into the third dimension out of the plane, so a knot in three dimensions would become dissolved if we had access to a fourth dimension.

The following trick might be regarded as an appeal to the fourth dimension.

Lay a yard length of cord on the table, and propound the following problem: Take in each hand one end of the cord, and then, without loosening hold of the ends by either hand, tie a knot on the middle of the string.

After the company have, one by one, vainly endeavoured to effect the impossible, you come forward and sit down close beside the cord as it lies on the table. See that the cord lies in a suitable position, and, crossing your arms, look at it for a few moments as if concentrating your attention on the deep problem before you. Then leaning forward with arms still crossed, seize with the right hand the left-hand end of the cord, and with the left hand the right-hand end. Finally, uncrossing your arms, pull the string taut, and, behold, the deed is done!



164. CARD ARRANGEMENTS.

The following trick may be done either with dominoes or with playing-cards.

Take, in the first place, any twelve dominoes whose points make up the natural numbers 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and arrange them in the order 10, 3, 5, 1, 11, 12, 7, 2, 4, 6, 8, 9. Turn them back up, and invite one of the company to assist you by doing what he is told. As you spell the word *o-n-e* he removes the first from the top of the row to the bottom, then the second in turn, and then the third. As you pronounce the word *one* he turns up the fourth domino, and, lo, it is "one." This is then put aside. Then in the same way as you spell *t-w-o* he removes in succession the next three dominoes from top to bottom, and turns up the *two* when you say the word. This process is carried on to the end, and each domino appears as its number is called after it has been spelt.

With playing-cards you arrange the thirteen cards of one suit in the proper order, and holding them in the left hand with backs uppermost, as in dealing, you proceed in the same way to spell *o-n-e*, one, passing one card from top to bottom as you spell, and then turning up the next card when you say the number. As you proceed spelling, naming, and turning up, the cards fall out in the proper order up to *t-e-n*, ten. After this you spell *k-n-a-v-e*, knave; *q-u-e-e-n*, queen; and, lastly, the king remains in your left hand. Or you may prefer to spell *j-a-c-k*, jack, instead of knave, which requires, of course, a slightly different order; or you may simply finish up with knave, queen, king, without spelling the words.

Most people who perform this trick remember the initial order in which the cards must be arranged; but this is quite an unnecessary burdening of the memory. It is an extremely simple matter to construct the proper order by simply *working the process backwards*. Thus take the king in one hand, face down, and bring the queen above; spell mentally *q-u-e-e-n*, slipping the bottom card to the top at each letter; place the knave on the top, and slip the bottom card round five times; then place the ten in position, and transfer the three bottom cards to the top, since there are three letters in ten. Place the nine above, and transfer the four bottom cards to the top; and so on. The cards will then be in the following order, beginning from the top :—

3, 8, 7, 1, k, 6, 4, 2, q, j, t, 9, 5,

where *t* stands for ten, *j* for knave, *q* for queen, and *k* for king.

Instead of spelling out each number before it appears, we might arrange the cards so that a card of a given number came after counting from one up to that number, slipping the top card to the bottom at each numeration, and tabling the card when the full number was reached. For this case the order is, beginning from the top :—

1, 8, 2, 5, t, 3, j, q, 9, 4, 7, 6, k;

in which, however, jack, queen, king are simply tabled at the end without counting.

There is no limit to the making of arrangements of this kind. The whole pack of fifty-two cards could be arranged so that by telling off in the way described each complete suit would count out separately; or the aces might be brought first, then the twos, the threes, the fours, and so on in order.

165. THE TOWER OF HANOÏ.

THIS is commonly described in terms of piles of disks of diminishing size; but it may as easily be done with cards.

Take any convenient number of consecutive cards—say one to ten of a particular suit—and arrange them in order, with the highest number at the base. Lay the pile face up on the top of the jack, and place beside it separately on the table the king and queen. Jack, queen, and king simply serve as foundations on which to build the tower. The problem is to transfer the pile from the jack to either of the other bases, one card at a time only being transferred, and no card ever being under one of greater number. There is no difficulty getting the first four or five transferred, but as the number increases the process becomes somewhat complicated and greatly prolonged.

Suppose, for example, that 4, 3, 2, 1 are lying on the king, the others from 10 to 5 on the jack, as at the beginning. The problem is to remove the 5 from the jack to the queen and then pile on it the numbers 4, 3, 2, 1, one card being moved at a time, and no card being at any time under one of greater number. The process is this :—

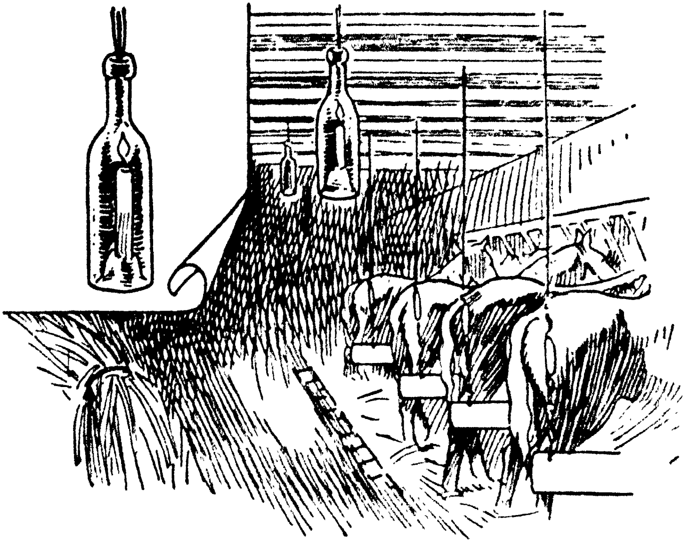
Place	5	on	Q	Place	4	on	5
,,	1	,,	6	,,	1	,,	4
,,	2	,,	5	,,	2	,,	K
,,	1	,,	2	,,	1	,,	2
,,	3	,,	6	,,	3	,,	4
,,	1	,,	4	,,	1	,,	6
,,	2	,,	3	,,	2	,,	3
,,	1	,,	2	,,	1	,,	2

The numbers 5, 4, 3, 2, 1 are now resting on queen. This process in passing from the 4-pile to the 5-pile involves sixteen separate transferences. To pass to the 6-pile requires thirty-two separate transferences, and so on. The general rule is that the whole number of separate transferences necessary to rebuild the pile on another base is $2^n - 1$, where n is the number in the pile. Thus, to pile 1 to 5 on a new base requires $2^5 - 1 = 31$; to pile 4, $2^4 - 1 = 15$, the difference 16 is the number of operations in passing from the 4-pile to the 5-pile. The whole pile of 10 can be rebuilt on another base in $2^{10} - 1 = 1023$ separate transferences according to the conditions laid down.

166. RUNNING THE FOX TO EARTH.

TAKE any odd number of playing-cards divisible by 3, and deal them out face up in three piles, asking one of the company to choose a card and say in which pile it is. Put the three piles together with the one named in the middle, and deal again, asking once more in what pile the chosen card now is. As before, with this pile in the middle, pick up the cards and deal a third time, asking still once again in what pile the chosen card is.

It is mathematically inevitable that the chosen card is in the very centre of the middle pile. It is, therefore, known to you, and you may produce the card by any more or less mysterious method that may be to your liking. As effective a way as any is to place the cards together with an apparently haphazard shuffling, so as to bring the chosen card to the top with face down. Then drawing it slightly out so as to project over the end, raise the pack a short distance above the table and let it drop. The air will catch the projecting part of the card and whirl it round above the falling pack so that it will alight face upwards.



167. A STABLE LANTERN.

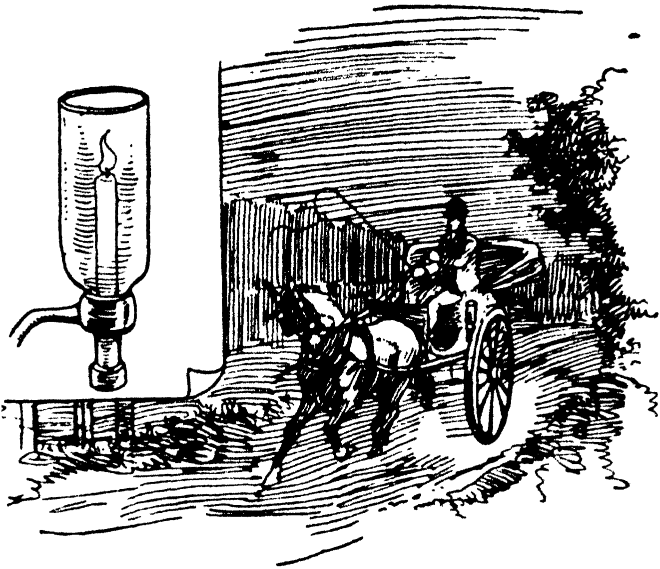
We are in the country; the stable lantern is broken, and we must find a substitute, be it but for one night, while waiting for the new lantern which ought to come to hand to-morrow.

Nothing is simpler; all we need is a bottle, preferably of colourless glass, with a high conical bottom.

Holding the bottle inverted, we knock out the small end of the cone by a few light blows with a pointed instrument, making an opening more or less regular.

Light a candle, and push it through the hole into the bottle, maintaining it there by a small wedge of wood, leaving a passage for the indraught of air.

Suspend the bottle by means of a string tied round the neck, and you have a temporary lantern made in less time than it takes to describe it.



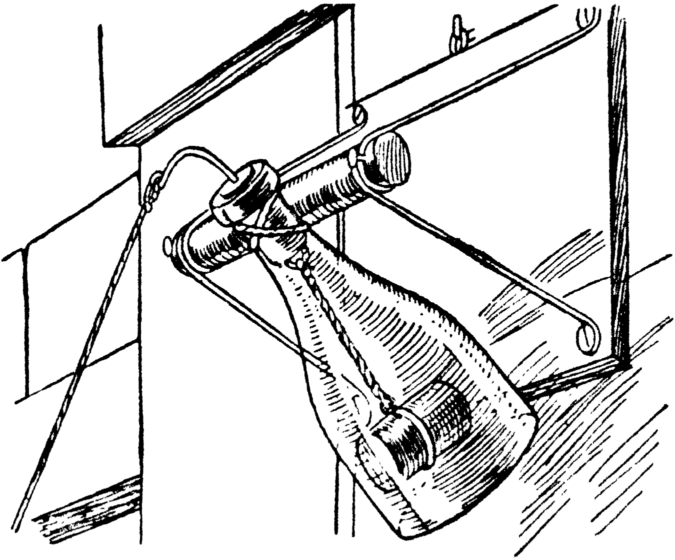
168. A CARRIAGE LAMP.

We have rigged up a bottle to serve as a stable lantern; we may similarly improvise a carriage lamp out of the same useful commodity.

As the night falls, you find yourself still far from home. The lamp has been forgotten, or it may have got cracked, and it is often difficult to procure another. But if lamp shops are scarce, inns and public houses are not. Enter the first you come to, and ask for a wide bottle. Having covered the bottom with water to the depth of half an inch, set the bottle on the hot stove or on hot embers.

As soon as the water begins to get hot the lower part of the bottle will crack off along the level of the water line. Invert the bottle, drop a candle into the neck and light it; and the lamp is made.

Place the neck in the sconce of the carriage, wedging it in with straw or paper for greater security, and pursue your way with an easy mind. The rules of the road will be satisfied.

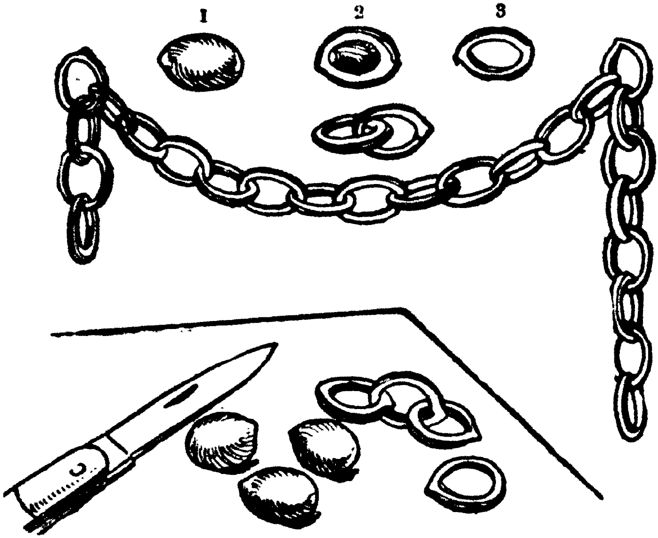


169. THE BOTTLE BELL.

We have seen how simply a bottle may be used for illuminating a stable or lighting a carriage. Before considering other uses of this domestic utensil, let us recall some of the ways in which a bottle may be cut neatly without recourse to the glazier's diamond. The best methods depend on variations of heat and cold. Heat a bottle along the line of section, and then suddenly cool it: the sudden dilatation and contraction of the glass cause it to crack along this line. The heating may be effected either by surrounding the bottle with cotton wick soaked in alcohol which is set aflame, or by a piece of twine well stretched and rubbed briskly to and fro along the surface, which becomes heated by friction; in both these cases the cooling is produced by pouring cold water into the heated part. In Section 108 will be found the description of the manner in which cutting is effected by plunging a red-hot poker into the oil, which fills the vessel to the required height; and, lastly, the method of the preceding section, in which the bottle containing cold water is set on the hot embers of a fire.

In addition to these there is the method in which a glowing piece of charcoal is drawn over the surface close to the scratch made on the glass by a file. We may by these means cut a bottle into a spiral as if it were made of a ribbon of glass rolled helically round a cylinder; in this form the bottle elongates when pulled out, demonstrating in an elegant manner the elasticity of

Whatever the means adopted for cutting the glass, a bottle deprived of its base can be used for various other purposes—such as a funnel; a bell jar for protecting young shoots in the garden; a table bell, the hammer being a metal ball suspended at the end of a thread; or a garden bell with wooden hammer arranged as in the figure. Such may not possess the great voice of Big Ben, but it will serve the purpose of our children when summoning their dolls to dinner.



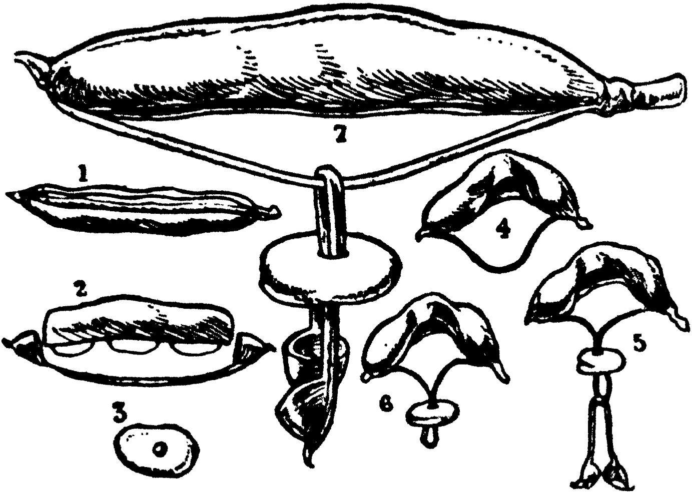
170. CHERRY-STONE CHAINS.

In the cherry season you may forge your cherry stones into links of a chain.

In the picture Fig. 1 shows the cherry stone well washed. With the point of a blade make small successive cuts on one side of the medial line. The stone is not so hard as it appears to be, and soon you will come to the enclosed fruit (Fig. 2). In the same way cut along the other side of the medial line; remove the almond, and smooth the sides and edges of the ring so obtained (Fig. 3).

Prepare a large number of similar rings, as nearly as possible of equal size, and then proceed to link them together. This is done by making a slit in a certain proportion of them by means of a sharp knife. The material is sufficiently elastic to allow the faces of the slit to be drawn apart so that a ring may be slipped in. The slit will close of itself, and will be visible only at near inspection. It is evident that a slit need be made only in every alternate link which is to go to the making of the chain, and there is no reason why two or more whole rings may not be linked into one which has been cleft.

The stones of other fruits may be similarly treated, and with a little ingenuity quite a variety of models may be manufactured. The operations need care and patience; but even if at the start some rings get broken, bear in mind that the material has cost nothing, and repeat, with the ancient Romans: "*Materiam superat opus.*"



171. THE BEAN TRICK.

"CHERRY ripe, cherry ripe, ripe I cry," says the old song. But the time of cherries is also the time of beans; and if you possess yourself of two pods, you can make up a trick which may puzzle your friends.

With the sharp point of a knife-blade make two cuts along the lower surface of the pod (Fig. 1) on each side of the cord of fibres which runs from end to end, taking care not to sever the ends of the cord (Fig. 4). Chisel away the inner surface of the cord so as to make it flexible, and empty the pod of the beans.

Make a hole in the middle of a bean (Fig. 3), large enough to allow the cord of fibres to pass through when doubled.

Take the second pod, and cut off the ends, keeping, however, the cord connection intact (Fig. 2).

These are the various pieces which are now to be combined.

Press the ends of the first pod towards each other, so as to allow the cord of fibres to sag (Fig. 4). Push the middle part of this cord, doubled, through the hole in the bean (Fig. 6), and then through the loop pass the cord of fibres of the second pod, the ends of which will then hang side by side, as in Fig. 5.

Draw the cord of fibres of the first pod back again through the hole in the bean, thereby pulling through the doubled middle part of the other cord, and the final result will be as in Fig. 7.

The trick now is: Remove the bean without tearing anything.

This will probably be difficult enough for any one who does not know how the whole was put together. To one who knows, the problem is immediately solved by simply reversing the process of construction.

Tricks with Strings.

Tricks with strings give much amusement, just as in the case of tricks with cards and legerdemain. Moreover, they demand no special cleverness with the hands, no particular preparation, and no apparatus. They are performed under the eyes of the spectator, and frequently with his assistance. The vast majority may be learned with ease.

In the accompanying illustrations the letters R and L represent the right and left hands of the performer or operator; r and l those of the spectator who has offered himself as the victim; *r* and *l* those of a second spectator when his services are required.

Let us commence with one of the simplest cord tricks.

172. THE SNARE.

KNOT together the two ends of a cord five or six feet long. Hold the knot in the hand, and lay the cord on the table in such a manner that the extremities *ab* and *xy* of the circuit cross one another at right angles after having formed two loops *m* and *n*. Ask one of the company to place his finger on the table within the cord, so as to prevent it being slipped off the table. In nine cases out of ten he will place his finger in the central square space X, being certain that the finger is within the circuit. But he will speedily discover his error when he sees the string being pulled away without hindrance.

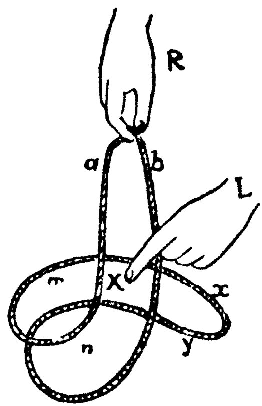


FIG. 1.

If you are asked to repeat the experiment, you will agree on condition that the finger be placed so as to allow you to remove the cord. Profiting by his former experience, your friend promptly places his finger once more in the square X. But now as the string is drawn away it catches on the finger, and is held tight.

The secret is that in preparing the string for the second experiment you turn the knot in your hand by an imperceptible movement. The result is that the two strands *a* and *b* cross before the central square is formed. In the first experiment they did

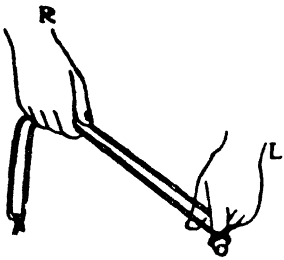


FIG. 2.

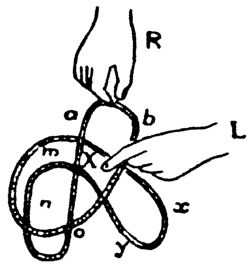
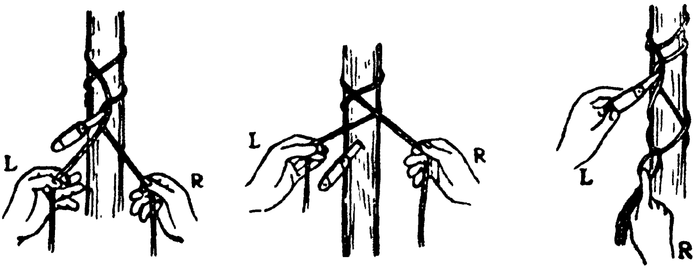


FIG. 3.

not cross. A comparison of Figs. 1 and 3 will show the slight difference in the way in which the cord lies on the table, and Fig. 2 indicates the manner in which, in the second case, the cord twists itself round the finger. A little practice will soon make perfect.



173. THE KNIFE IN THE TREE.

STAND in front of a tree or any other vertical post; encircle it with a cord, each end making a complete turn round the tree, so that ends originally in the right and left hands are still in the same hands at the end of the process. Insert the blade of an open knife just below the last crossing of the cords. Pass the right-hand cord round the right side of the knife, and seize it by the left hand, and simultaneously pass the left-hand cord round to the left side of the knife, and seize it with the right hand. Pass the two ends behind the tree, bring them round to the front, and unite them by a knot. While holding the knot remove the knife, and the whole piece of string will come towards you as if it had cut through the tree.

That this may be done properly, the secret to bear in mind is that it is always the same strand of cord which passes over the other. There will then be superposition of the strands, and no interlacing.

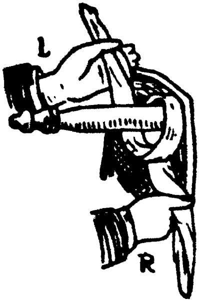


FIG. 1.

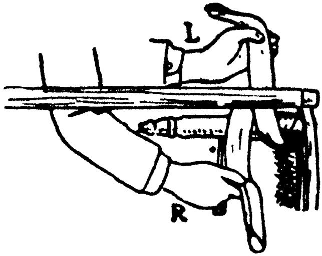


FIG. 2.

174. THE NAPKIN AND THE CHAIR.

THIS may be performed with a cord; but the experiment is more graceful with a table-napkin folded as a band.

Lay a chair back down on the table, and pass the napkin round one of the legs (Fig. 1). Bring above the leg the right-hand strand, and seize it with the left hand; also the left-hand strand, and seize it with the right hand. Ask one of the company to lay a cane over the leg of the chair and parallel to it (Fig. 2). Bring the strands above the cane, the left end in the left hand and the right in the right; pass the ends below the leg of the chair, and bring them

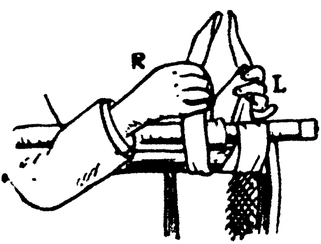


FIG. 3.

above once again (Fig. 3). Then tie them together. If the cane is now withdrawn, the napkin will come away as if by magic.

As in the preceding trick, the one thing to attend to is not to cross the strands. In the figures it will be seen that the right-hand end is always the farther away from the operator.

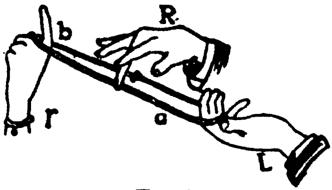


FIG. 1.

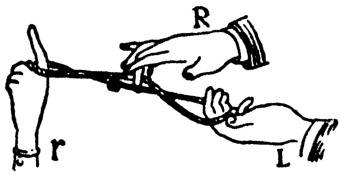


FIG. 2.

175. THE IMPALPABLE CORD.

KNOT together the ends of a stout cord about three feet long. Ask your friend to present the back of his hand to you and to raise the forefinger, over which you will pass one of the double ends, the other end being held in your left hand. Let *a* be the strand to the left of the operator and *b* the strand to the right. The problem is to remove the

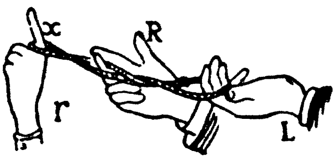


FIG. 3.

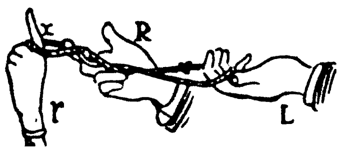


FIG. 4.

string from the upright finger without passing the loop over it.

To effect this, bring the middle finger (Fig. 1) of the right hand over the cord, and hook up the left-hand strand *a*, drawing it over *b*, as shown in Fig. 2. Turn the right hand palm facing upwards, and slip the finger up towards the loop *x*, where the upright finger of your friend holds it (Fig. 3). Insert the forefinger of the right hand into the loop x, and draw it a little towards you so as to enlarge the loop (Fig. 4). Turn the right hand over again so as to make the palm face downwards, and at the same time place the end of the middle finger on the point of your friend's upright finger (Fig. 5). Announce that the cord will pass between the two fingers without any one feeling it. Then slipping the forefinger of the right hand from the loop, and pulling the cord sharply with the left hand, you will see the cord slip out as if it cut through the two fingers. In reality it escapes round the side.

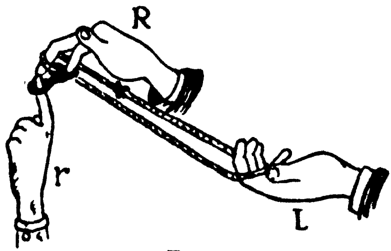


FIG. 5.

176. THE KEY SET FREE.

TAKE a cord about four feet long, knot the ends to make a closed circuit, and ask one of the company to keep the cord fairly stretched by passing the loops over his two thumbs. Lift the one loop momentarily off, and slip a key on to the double cord. The problem is to remove the key without altering the relative positions of the thumbs and the cord.

The process once learned is easily carried out, but it is not very easy to explain it by diagrams on paper. But let us try.

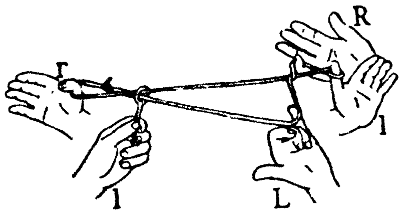


FIG. 1.

The experiment is more striking if a third party holds the key the whole time; but this is not essential.

The holder's hands are raised open in front, so that the thumbs are towards each other. The double cord is stretched tight enough to keep the two parts separate. These parts will be called *a* and *b* respectively, *a* being nearer to the holder and *b* farther away. Bring your hands, palms facing upwards, over the end which is held by the left hand of the holder. The little finger of your left hand hooks itself under the *a* string, and the little finger of the right hand under the *b* string, the right hand being the nearer to the left hand of the holder. Lift both hands slightly upwards, and pull them across, as shown in Fig. 1. Move the left hand towards the supporting thumb of the holder, and slip the string over the thumb. That leaves your left hand free. With the forefinger and thumb

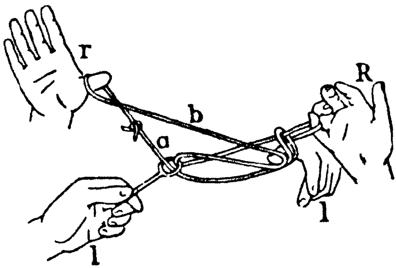


FIG. 2.

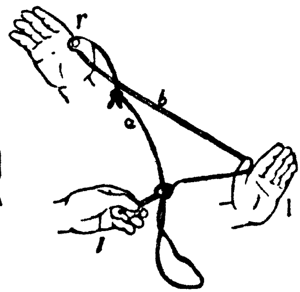
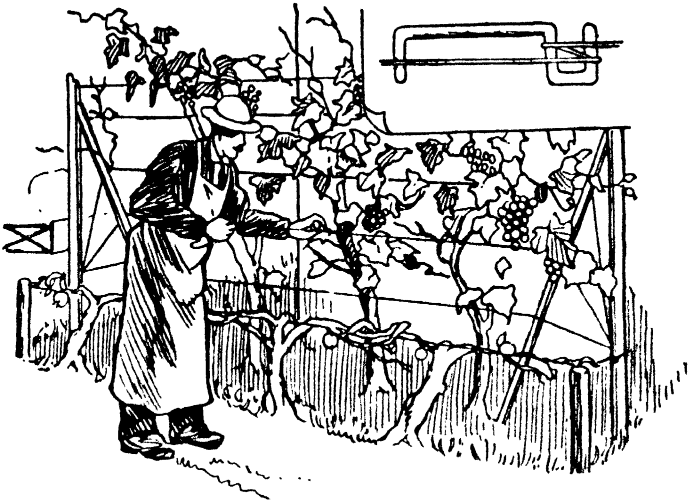


FIG. 3.

of this hand grip the string between the other thumb and the position of the key, and draw the loop over the thumb, on which already two loops have been passed, as indicated in Fig. 2. Slip the little finger of the right hand out of its small loop, and the key will fall to the ground, or be drawn easily off by the one who may be holding it.

It is the same principle, although somewhat simpler, on which a string may be made to appear to cut through a buttonhole or even across the neck of a child. In these cases the operator is the holder as well.

Put the double string through a buttonhole, and keep it stretched by the two thumbs. With the little finger of each hand catch up one of the strands passing towards the other hand. Draw the hands away from each other, still keeping the thumbs and little fingers in their appropriate loops. It will then be seen that the string held by one of the little fingers lies below the other. By a rapid movement let the neighbouring thumb slip out of its original loop and catch the loop held by the little finger. Release the little finger and pull the hands away from each other. The string straightens out as if it had cut through the buttonhole.



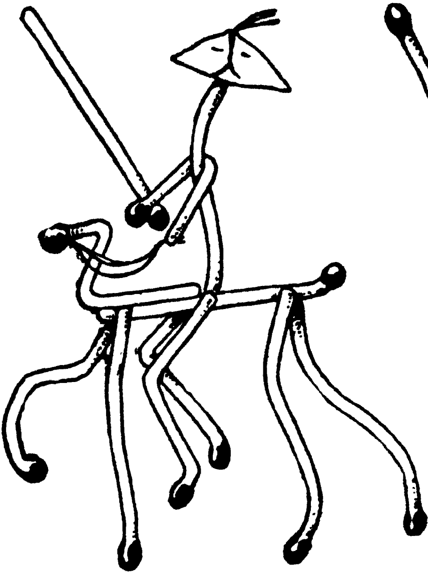
Useful Hints.

177. TIGHTENING IRON WIRE.

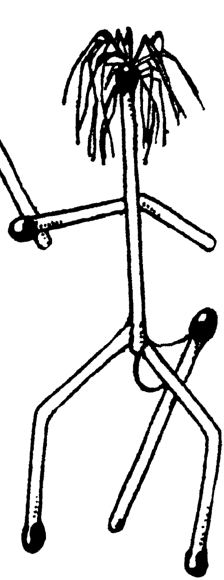
Amateur gardeners, and even professional gardeners, will be grateful for the following hint. It will supply them with a simple yet effective means of tightening wires which are liable to sag.

Cut from a stout iron wire short pieces of about three inches in length, and with a pair of pliers or pincers turn the one end at right angles, and double-curve the other into a U shape, as shown in the upper right-hand corner of the picture, the whole being in one plane. File also a small notch on the single hook, as indicated on the left of the drawing. This is the apparatus.

To apply it. Place the U-shaped end so as to enclose the wire, then, using the horizontal part as a lever, and raising it slightly to clear the wire, rotate it about a vertical axis. After one complete rotation the wire will be found looped on to the U part, and thereby tightened up. A second rotation will tighten it still more. When the tension in the wire is sufficient, adjust the short-hooked end until the wire rests in the notch.



THE GENERAL.



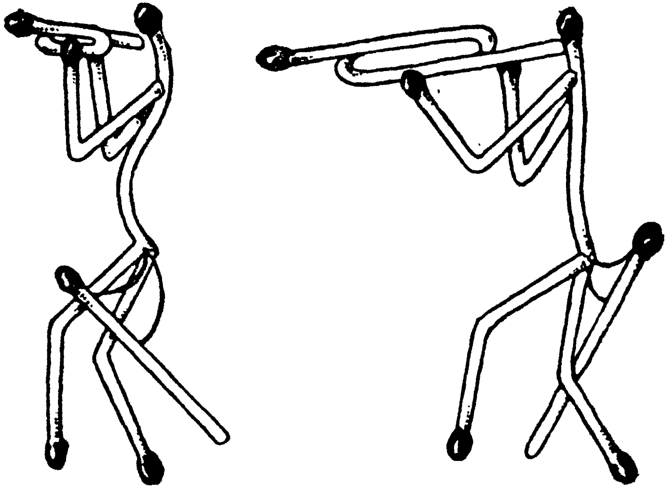
THE LIEUTENANT.

178. THE GALLERY OF VESTA FREAKS.

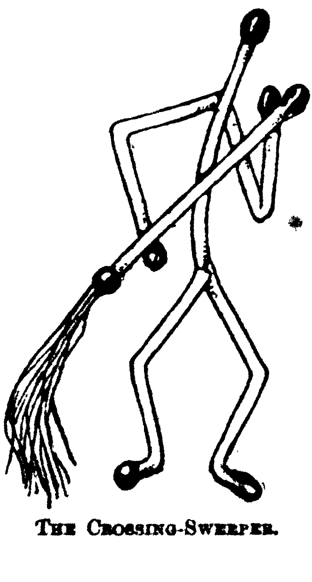
WE owe to the caricaturist Emile Cole the following amusing figures made of vestas. There is no difficulty reproducing them and adding to the number.

Heat slightly the non-phosphoric end of a vesta; apply it immediately to another vesta: the wax will cool and solidify, and solder the one to the other. This is the great secret.

In the gallery here presented we see at first a general mounted on his horse, then a lieutenant and two trumpeters.

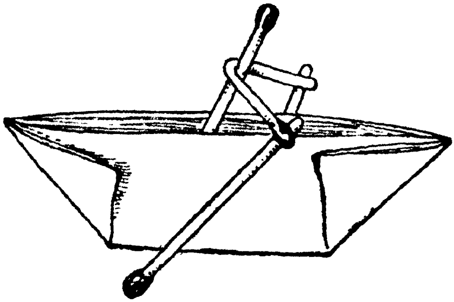


THE BUGLERS.



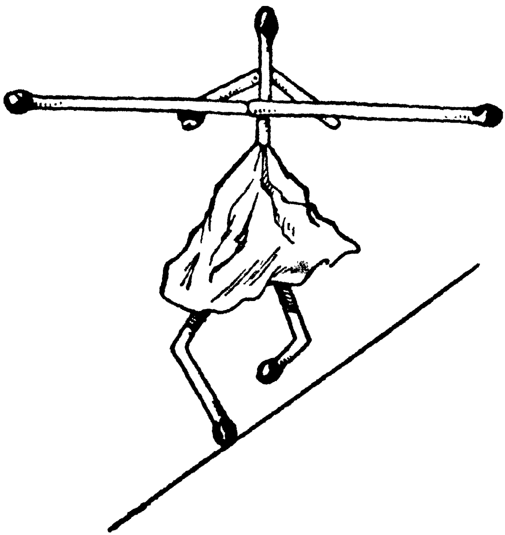
THE CROSSING-SWEEPER.

The plume of the lieutenant is a vesta rumpled between the fingers so that the wax falls away, and leaves the threads of wick separate. Similar threads serve to attach the swords of the lieutenant and the trumpeters. A vesta with the wick unravelled is the broom of the sweeper. A sheet of cigarette paper,

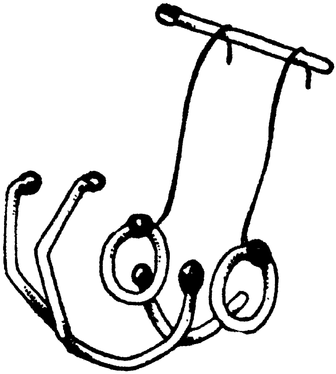


THE ROWER.

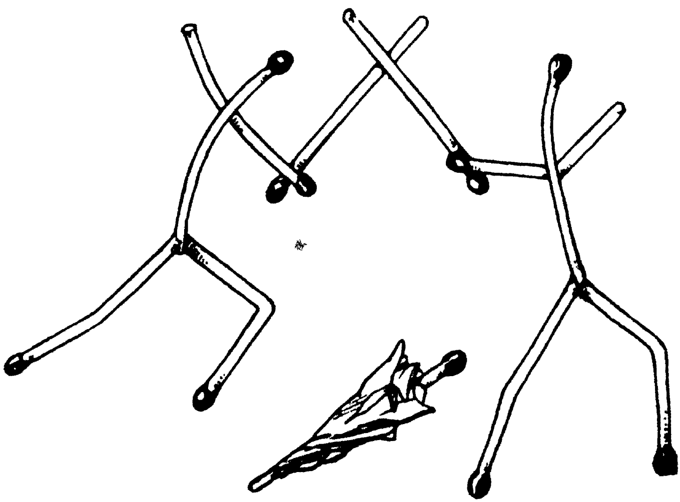
suitably folded, makes the boat of the rower. A similar sheet forms the attire of the tight-rope dancer.



THE TIGHT-ROPE DANCER.

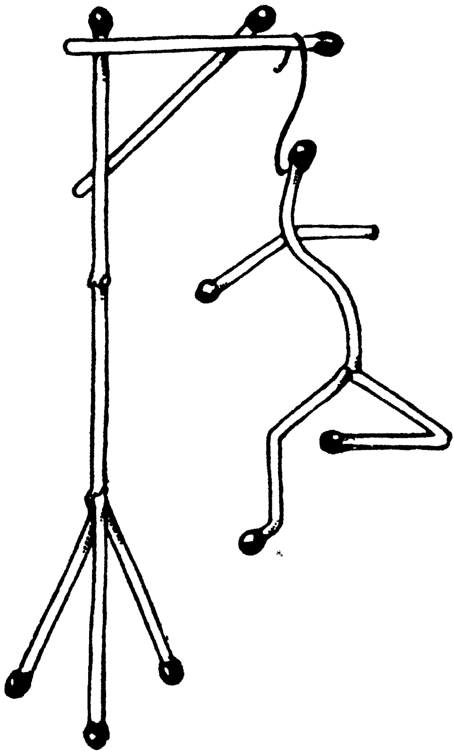


THE GYMNAST.



THE DUELLIST.

You will admire the suppleness of the athlete balancing on the rings, the ardour of the soldiers fighting a duel. Why do they fight? For the umbrella of the squad, which is lying at their feet! This is simply a vesta wrapped about by a sheet of cigarette paper.



Finally we gaze upon a criminal on the gallows coming to a sad

END.

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