The Umdhlebe Tree of Zululand

THE word "umdhlebe" does not, I think, appear in Döhne's "Zulu-Kaffir Dictionary." I presume it to be a derivative from the root *hlaba*, which Döhne interprets as denoting, among other things, the giving of pain. Some native tales of the tree will be found in part iv. of Bishop Callaway's "Religious System of the Amazulu," in which it is asserted that "there are several kinds, not one kind only of umdhlebe; some are small." I should be disposed to think the kernel of fact will be found to lie in native observation of the deleterious properties and weird aspects of certain *Euphorbiaceæ*. H. M. C.

Charlton, November 4

The Weather

THE past month has probably been one of the wettest on record. I have registered here 5·14 inches of rain during the month; only on seven days out of the thirty-one has the gauge shown less than 0·1; and on three days out of the seven rain has been recorded. J. M. FOUNTAIN

Hillingdon, Uxbridge, November 2

ON THE GRADUATION OF GALVANOMETERS FOR THE MEASUREMENT OF CURRENTS AND POTENTIALS IN ABSOLUTE MEASURE

THERE are several methods by which galvanometers may be graduated so as to measure currents and potentials in absolute measure, but they all involve, directly or indirectly, a comparison of the indications of the instrument to be graduated with those of a standard instrument, of which the constants are fully known for the place at which the comparison is made. There are various forms of such standard instruments, as, for example, the tangent galvanometer which Joule made, consisting of a single coil of large radius, and a small needle hung at its centre, or the Helmholtz modification of the same instrument with two large equal coils placed side by side at a distance apart equal to the radius of either; or some form of "dynamometer," or instrument in which the needle of the galvanometer is replaced by a movable coil, in which the whole or a known portion of the current in the fixed coil flows. The measurement consists essentially in determining the couple which must be exerted by the earth's magnetic force on the needle or suspended coil, in order to equilibrate that exerted by the current. But the former depends on the value, usually denoted by H, of the horizontal component of the earth's magnetic force, and it is necessary therefore, except when some such method as that of Kohlrausch, described below, is used, to know the value of that quantity in absolute units.

The value of H may be determined in various ways, and I shall here content myself with describing one or two of the most convenient in practice. The easiest method is by finding (1) the angle through which the needle of a magnetometer is deflected by a magnet placed in a given position at a given distance, (2) the period of vibration of the magnet when suspended horizontally in the earth's field, so as to be free to turn round a vertical axis. The first operation gives an equation involving the ratio of the magnetic moment of the magnet to the horizontal component H of the terrestrial magnetic force, the second an equation involving the product of the same two quantities. I shall describe this method somewhat in detail.

A very convenient form of magnetometer is that devised by Mr. J. T. Bottomley, and made by hanging within a closed chamber, by a silk fibre from 6 to 10 cms. long, one of the little mirrors with attached magnets used in Thomson's reflecting galvanometers. The fibre is carefully attached to the back of the mirror, so that the magnets hang horizontally and the front of the mirror is vertical. The closed chamber for the fibre and mirror is very readily made by cutting a narrow groove to within a short distance of each end, along a piece of mahogany about 10 cms. long. This groove is widened at one end to a circular space a little greater in diameter than the diameter of the mirror. The piece of wood is then fixed with that end down in a horizontal base-piece of wood furnished with three levelling screws. The groove is thus placed vertical; and the fibre carrying the mirror is suspended within it by passing the free end of the fibre through a small hole at the upper end of the groove, adjusting the length so that the mirror hangs within the circular space at the bottom, and fixing the fibre at the top with wax. When this has been done, the chamber is closed by covering the face of the piece of wood with a strip of glass, which may be either kept in its place by cement, or by proper fastenings which hold it tightly against the wood. By making the distance between the back and front of the circular space small, and its diameter very little greater than that of the mirror, the instrument can be made very nearly "dead beat," that is to say, the needle when deflected through any angle comes to rest at once, almost without oscillation about its position of equilibrium. A magnetometer can be thus constructed at a trifling cost, and it is much more accurate and convenient than the magnetometers furnished with long magnets frequently used for the determination of H; and as the poles of the needle may always in practice be taken at the centre of the mirror, the calculations of results are much simplified.

The instrument is set up with its glass front in the magnetic meridian, and levelled so that the mirror hangs freely inside its chamber. The foot of one of the levelling screws should rest in a small conical hollow cut in the table or platform, of another in a V-groove the axis of which is in line with the hollow, and the third on the plane surface of the table or platform. When thus set up the instrument is perfectly steady, and if disturbed can in an instant be replaced in exactly the same position. A beam of light passing through a slit, in which a thin vertical cross-wire is fixed, from a lamp placed in front of the magnetometer is reflected, as in Thomson's reflecting galvanometer, from the mirror to a scale attached to a lamp-stand, and facing the mirror. The lamp and scale are moved nearer to or farther from the mirror, until the position at which the image of the cross-wire of the slit is most distinct is obtained. It is convenient to make the horizontal distance of the mirror from the scale for this position if possible one metre. The lamp-stand should also have three levelling screws, for which the arrangement of conical hollow V groove and plane should be adopted. The scale should be straight, and placed with its length in the magnetic north and south line, and the lamp should be so placed that the incident and reflected rays of light are in an east and west vertical plane, and that the spot of light falls near the middle of the scale. To avoid errors due to variations of length in the scale, it should be glued to the wooden backing which carries it, not simply fastened with drawing pins as is often the case.

The magnetometer having been thus set up, four or five magnets, each about 10 cms. long and ·1 cm. thick, and tempered glass-hard, are made from steel wire. This is best done as follows. From ten to twenty pieces of steel wire, each perfectly straight and having its ends carefully filed so that they are at right angles to its length, are prepared. These are tied tightly into a bundle with a binding of iron wire and heated to redness in a bright fire. The bundle is then quickly removed from the fire, and plunged with its length vertical into cold water. The wires are thus tempered glass-hard without being seriously warped. They are then magnetised to saturation in a helix by a strong current of electricity. A horizontal magnetic east and west line passing through the mirror is now laid down on a convenient platform (made of wood put together without iron and extending on both sides of the magnetometer) by drawing a line through that point at right angles to the direction in which a long thin magnet hung by a single silk fibre there places itself. One of these magnets is placed, as shown in Fig. 1, with its length in that line, and at such a distance that a convenient deflection of the needle is produced. This deflection is noted and the deflecting magnet turned end for end, and the deflection again noted. Make in the same way a pair of observations with the magnet at the same distance on the opposite side of the magnetometer, and take the mean of all the observations. These deflections from zero ought to be as nearly as may be the same, and if the magnet is properly placed, they will exactly agree; but the effect of a slight error in placing the magnet will be nearly eliminated by taking the mean of all the deflections as the deflection of the magnet for that position. The exact distance in cms. of the centre of the deflecting magnet from the mirror is also noted. The same operation is gone through for each of the magnets, which are carefully kept apart from one another during the experiments. The results of each of these experiments give an equation involving the ratio of the magnetic moment of the magnet to the value of H. Thus if m denote the magnetic moment of the magnet, m' the magnetic moment of the needle, $2r$ the distance of the centre of the magnet from the centre of the needle, $2l$ the distance between the poles of the magnet which, for a uniformly magnetised magnet of the dimensions stated above is nearly enough equal to its length, and $2l'$ the distance between the poles of the needle, r, l, and l' being all measured in cms., we have for the repulsive force (denoted by F in Fig. 1) exerted on the blue[1] pole of the needle by the blue pole of the magnet, supposed nearest to the needle, as in Fig. 1, the value of $\frac{m}{2l} \cdot \frac{m'}{2l'} \cdot \frac{1}{(r-l)^2}$, since the value of l' is small compared with l. Similarly for the attraction exerted on the same pole of the needle by the red pole of the magnet, we have the expression $\frac{m}{2l} \cdot \frac{m'}{2l'} \cdot \frac{1}{(r+l)^2}$. Hence the total repulsive force exerted by the magnet on the blue pole of the needle is

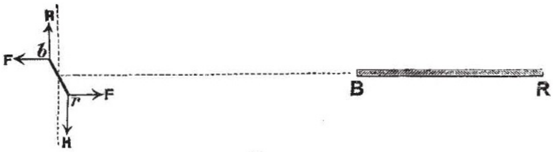

FIG. 1.

$$\frac{m m'}{4 l l'} \left\{ \frac{1}{(r-l)^2} - \frac{1}{(r+l)^2} \right\} \text{ or } m \frac{m'}{l'} \cdot \frac{r}{(r^2-l^2)^2}.$$

Proceeding in a precisely similar manner, we find that the magnet m exerts an attractive force equal to $m \frac{m'}{l'} \cdot \frac{r}{(r^2-l^2)^2}$ on the red pole of the magnet. The needle is therefore acted on by a couple which tends to turn it round the suspending fibre as an axis, and the amount of this couple, when the angle of deflection is θ, is plainly equal to $m m' \frac{2r}{(r^2 - l)^2} \cos \theta$. But for equilibrium this couple must be balanced by $m' H \sin \theta$; hence we have the equation :—

$$\frac{m}{H} = \frac{(r^2 - l^2)^2}{2r} . \tan \theta \quad . \quad . \quad . \quad . \quad (1)$$

The angle θ is to be measured thus :—The number of divisions of the scale which measures the deflection divided by the number of such divisions in the distance of the scale from the mirror, is, if the scale is placed as described above in the magnetic north and south line, equal to $\tan 2\theta$.

Instead of in the east and west horizontal line through the centre of the needle, the magnet may be placed, as represented in Fig. 2, with its length east and west, and its centre in the horizontal north and south line through the centre of the needle. If we take m, m', l, l', and r to have the same meaning as before, we have for the distance of either pole of the magnet from the needle, the expression $\sqrt{r^2 + l^2}$. Let us consider the force acting on one pole, say the red pole of the needle. The red pole of the magnet exerts on it a repulsive force, and the blue pole an attractive force. Each of these forces has the value $\frac{m}{2l} \cdot \frac{m'}{2l'} \cdot \frac{1}{r^2 + l^2}$. But the diagram shows that they are equivalent to a single force, F, in a line parallel to the magnet, tending to pull the red pole of the needle towards the left. The magnitude of this resultant force is plainly $2 \frac{m}{2l} \cdot \frac{m'}{2l'} \cdot \frac{l}{(r^2 + l^2)^{\frac{3}{2}}}$ or $\frac{m m'}{2 l' (r^2 + l^2)^{\frac{3}{2}}}$. In the same way it can be shown that the action of the magnet on the red pole of the needle is a force of the same amount tending to pull the blue pole of the needle towards the right. The needle is, therefore, subject to no force tending to produce motion of translation, but simply to a "couple" tending to produce rotation. The magnitude of this couple when the needle has been turned through an angle θ, is $\frac{m m'}{2 l'} \frac{2 l' \cos \theta}{(r^2 + l^2)^{\frac{3}{2}}}$, or $\frac{m m'}{(r^2 + l^2)^{\frac{3}{2}}} \cos \theta$. If there be equilibrium for the deflection θ, this couple must be balanced by that due to the earth's horizontal force, which, as before, has the value $m' H \sin \theta$. Hence equating these two couples we have—

$$\frac{m}{H} = (r^2 + l^2)^{\frac{3}{2}} \tan \theta . \quad . \quad . \quad . \quad . \quad (2)$$

Still another position of the deflecting magnet relatively to the needle may be found a convenient one to adopt. The magnet may be placed still in the east and west line, but with its centre vertically above the centre of the needle. The couple in this case also is given by the formula just found, in which the symbols have the same meaning as before.

The greatest care should be taken in all these experiments, as well as in those which follow, to make sure that there is no movable iron in the vicinity, and the instruments and magnets should be kept at a distance from any iron nails or bolts there may be in the tables on which they are placed.

We come now to the second operation, the determination of the period of oscillation of the deflecting magnet when under the influence of the earth's horizontal force alone. The magnet is hung in a horizontal position in a double loop formed at the lower end of a single fibre of unspun silk, attached by its upper end to the roof of a closed chamber. A box about 30 cms. high and 15 cms. wide, having one pair of opposite sides, the bottom and the roof made of wood, and the remaining two sides made of plates of glass, one of which can be slided out to give access to the inside of the chamber, answers very well. The fibre may be attached at the top to a horizontal wire which can be turned round from the outside so as to wind up or let down the fibre when necessary. The suspension-fibre is so placed that two vertical scratches, made along the glass sides of the box, are in the same plane with the magnet when the magnet is placed in its sling, and the box is turned round until the magnet is at right angles to the glass sides. A paper screen with a small hole in it is then set up at a little distance in such a position that the hole is in line with the magnet, and therefore in the same plane as the scratches. The magnetometer should be removed from its stand and this box and suspended needle put in its place. If the magnet be now

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[1] The convention according to which magnetic polarity of the same kind as that of the earth's northern regions is called blue, and magnetic polarity of the same kind as that of the earth's southern regions is called red, is here dopted. The letters B, R, b, r in the diagrams denote blue and red.

deflected from its position of equilibrium and then allowed to vibrate round a vertical axis, it will be seen through the small hole to pass and re-pass the nearer scratch, and an observer keeping his eye in the same plane as the scratches can easily tell without sensible error the instant when the magnet passes through the position of equilibrium. Or, a line may be drawn across the bottom of the box so as to join the two scratches, and the observer keeping his eye above the magnet and in the plane of the scratches notes the instant when the magnet going in the proper direction is just parallel to the horizontal line. The operator should deflect the magnet by bringing a small magnet near to it, taking care to keep the small deflecting magnet always as nearly as may be with its length in an east and west line passing through the centre of the suspended magnet. If this precaution be neglected the magnet may acquire a pendulum motion about the point of suspension, which will interfere with the vibratory motion in the horizontal plane. When the magnet has been properly deflected and left to itself, its range of motion should be allowed to diminish to about 3° on either side of the position of equilibrium before observation of its period is begun. When the amplitude has become sufficiently small, the person observing the magnet says sharply the word "Now," when the nearer pole of the magnet is seen to pass the plane of the scratches in either direction, and another observer notes the time on a watch having a seconds hand. With a good watch having a centre seconds hand moving round a dial divided into quarter-seconds, the instant of time can be determined with greater accuracy in this way than by means of any of the usual appliances for starting and stopping watches, or for registering on a dial the position of a seconds hand when a spring is pressed by the observer. The person observing the magnet again calls out "Now" when the magnet has just made ten complete to and fro vibrations, again after twenty complete vibrations, and, if the amplitude of vibration has not become two small, again after thirty; and the other observer at each instant notes the time by the watch. By a complete vibration is here meant the motion of the magnet from the instant when it passes through the position of equilibrium in either direction, until it next passes through the position of equilibrium going in the same direction. The observers then change places and repeat the same operations. In this way a very near approach to the true period is obtained by taking the mean of the results of a sufficient number of observations, and from this the value of the product of m and H can be calculated.

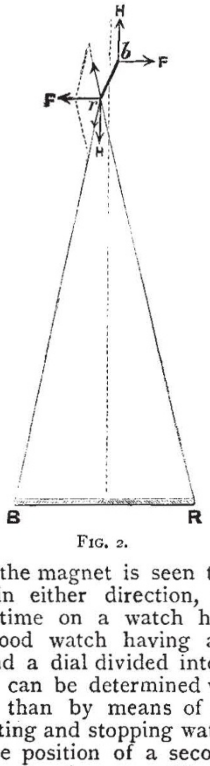


FIG. 2.

For a small angular deflection θ of the vibrating magnet from the position of the equilibrium the equation of motion is

$$\frac{d^2\theta}{dt^2} + \frac{mH}{\mu}\theta = 0,$$

where μ is the moment of inertia of the vibrating magnet round an axis through its centre at right angles to its length. The solution of this equation is

$$\theta = A \sin\left\{\sqrt{\frac{mH}{\mu}}\,t - B\right\}$$

and therefore for the period of oscillation T we have

$$T = 2\pi\sqrt{\frac{\mu}{mH}}.$$

Hence we have

$$mH = \frac{4\pi^2\mu}{T^2}$$

Now, since the thickness of the magnet is small compared with its length, if W be the mass of the magnet μ is $\frac{l^2}{3}W$, and therefore

$$mH = \frac{4\pi^2 l^2 W}{3T^2} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

combining this with the equation (1) already found we get for the arrangement shown in Fig. 1.

$$m^2 = \frac{2}{3} \cdot \frac{\pi^2 (r^2 - l^2)^2 W \tan\theta}{T^2 r} \quad . \quad . \quad (4)$$

and

$$H^2 = \frac{8}{3} \cdot \frac{\pi^2 l^2 r W}{T^2 (r^2 - l^2)^2 \tan\theta} \quad . \quad . \quad . \quad (5)$$

If either of the other two arrangements be chosen we have from equations (2) and (3)

$$m^2 = \frac{4}{3} \cdot \frac{\pi^2 l^2}{T^2} (r^2 + l^2)^{\frac{3}{2}}\, W \tan\theta \quad . \quad . \quad (6)$$

and

$$H^2 = \frac{4}{3} \cdot \frac{\pi^2 l^2 W}{(r^2 + l^2)^{\frac{3}{2}}\, T^2 \tan\theta} \quad . \quad . \quad . \quad (7)$$

Various corrections which are not here made are of course necessary in a very exact determination of H. The virtual length of the magnet, that is, the distance between its poles or "centres of gravity" of magnetic polarity, should be determined by experiment: and allowances should be made for the magnitude of the arc of vibration; the torsional rigidity of the suspension fibre of cocoon silk of the magnetometer in the deflection experiments, and of the suspension fibre of the magnet in the oscillation experiments; the frictional resistance of the air to the motion of the magnet; the virtual increase of inertia of the magnet due to motion of the air in the chamber; and the effect of induction in altering the moment of the magnet. The correction for an arc of oscillation of 6° is a diminution of the observed value of T of only $\frac{1}{80}$ per cent., and for an arc of 10° of $\frac{1}{20}$ per cent. Of the other corrections the last is no doubt the most important; but even its amount for a magnet of glass-hard steel, nearly saturated with magnetism, and in a field so feeble as that of the earth, must be very small.

The deflection-experiments are, as stated above, to be performed with several magnets, and when the period of oscillation of each of these has been determined, the magnetometer should be replaced on its stand, and the deflection experiments repeated, to make sure that the magnets have not changed in strength in the mean time. The length of each magnet is then to be accurately determined in centimetres, and its weight in grammes; and from these data and the results of the experiments, the values of m and of H can be found for each magnet by the formulas investigated above. Equation (5) is to be used in the calculation of H when the arrangements of magnetometer and deflecting magnet, shown in Fig. 1, is adopted, equation (7), when that shown in Fig. 2 is adopted.

The object of performing the experiments with several magnets, is to eliminate as far as possible, errors in the determination of weight and length. The mean of the values of *H*, found for the several magnets, is to be taken as the value of *H* at the place of the magnetometer. We have now to apply this value to the measurement of currents.

ANDREW GRAY

(*To be continued.*)

THE ITALIAN EXPLORATION OF THE MEDITERRANEAN

I BELIEVE it will interest the numerous readers of NATURE, especially those who have studied the important subject of the deep-sea fauna, or who are geologists, to learn that the further exploration of the Mediterranean this year, on the part of the Italian Government, has not been fruitless, although it has been short. I have just received a letter from Prof. Giglioli, of Florence, the purport of which I will, with his permission, now give:—

It seems that this summer the surveying-vessel, *Washington*, had to undertake a search (which proved unsuccessful) for some imaginary coral-banks in the shallow sea between Sicily and Africa, besides her usual hydrographical work, and that consequently very little time could be devoted to deep-sea exploration. However, Prof. Giglioli was allowed to accompany the hydrographer, Capt. Magnaghi, with the chance of taking any favourable opportunity that might occur. He thus got three deep-sea hauls: the first near Marittimo, in 718 metres, or about 389 fathoms; the second, half-way between Sicily and Sardinia (lat. 38° 38′ N., long. 10° 40′ E.), at a depth of 1583 metres, or about 857 fathoms, when a very rare and peculiar abyssal fish (*Paralepis cuvieri*), was obtained. That day (August 15) was also appropriated to hydrographical researches, and particularly to the successful trial of Capt. Magnaghi's new water-bottle, as well as to the marvellous work of his new currentometer, a most valuable discovery, by means of which the direction and force of sub-marine currents can be accurately determined at any depth. A large new trawl was used, and brought up a block of newly-formed limestone, which had been hardened with recent shells of Pteropods embedded in its mass. The third and last deep-sea dredging was made on September 1, between Tavolara in Sardinia, and Montecristo, in 904 metres, or about 490 fathoms, with indifferent results. He will send me the shells for examination. The Italian Ministry have promised him that a whole month next year will be allowed for deep-sea exploration.

J. GWYN JEFFREYS

WIRE GUNS[1]

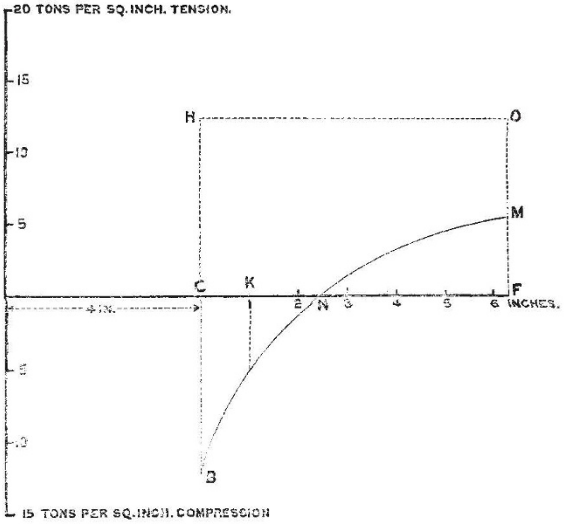
II.

IT has been necessary to dwell thus at length on the hoop method of construction in order to contrast it with the wire system, which we now proceed to describe.

A wire gun consists first of an internal tube, the function of which is to contain the rifling, and to transmit the internal pressure to the wire which is coiled upon it, and which gives the strength. This tube no doubt has a certain amount of strength of its own, but this is not its real function. The gun may be so designed and constructed that the tube is never in a state of tension. It may therefore be made, and possibly with advantage, of hard cast iron. In the 3 inch breech-loading gun made by the writer in 1860, the tube was of cast-iron $\frac{1}{2}$ inch thick, and this gun has been severely tested without injury. Hard cast-iron possesses many advantages, and amongst others that of great economy as compared with the steel tubes now generally used; but whatever be the material of the tube, its principal function is to contain the rifling and transmit the strain to the wires coiled around it.

Upon the inner tube is wound steel wire, square or rectangular in section. The tube is mounted in a machine similar to a lathe, and the wire is coiled upon one or more cylindrical drums, which are fixed horizontally on axes parallel to the tube and provided with proper apparatus for regulating the feed and tension. The tensions having been first calculated, the coiling begins from the breech-end where the end of the wire is made fast. When the muzzle end is reached the wire is coiled back again to the breech, and this process goes on till the whole of the coils are in place. The end of the wire is then made fast, and the gun, so far as strength to resist a bursting strain, which is called circumferential strength, is concerned, is complete.

Before proceeding to show how the longitudinal strength is provided for, it will be well to devote a little time to the substitution of coils of wire for the hoops above described, pointing out as we go along the superiority of the wire system. It has already been shown how important it is in the hoop system that the initial tensions of each hoop should be accurately calculated and applied. This is no less necessary with the wire coils, and it would at first appear that this must involve very intricate and tedious calculation. In the case of the gun represented in Diagram C, it was stated that the same strength which was given by 4 coils of steel, making with the tube a total thickness of $22\frac{3}{4}$ inches, might be obtained by $6\frac{3}{4}$ inches of wire, but supposing the wire to be $\frac{1}{10}$th inch square in section there would be required no less than 67 different coils and tensions, and as it is desirable to use even smaller wire for the first portion of the coils, there would probably be not less than 80 or 90 coils and the same number of tensions to be calculated. A formula has, however, been found which makes these calculations comparatively simple. In order to make this intelligible we must resort to another diagram, E, which represents the state of strain of the interior of a wire gun, or rather of the wire portion of it, on which alone we depend for circumferential strength. Assuming the wire to be very small, say $\frac{1}{16}$th of an inch square in section, the strains are represented very nearly by the curved line B N M. The coils between the inner circumference, *i.e.* the first coil, and the point N are all in compression, the maximum being at C; at N is the neutral point, when the wire is neither in compression nor tension; and from N to F all the coils are in tension, the maximum being at F.



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[1] Continued from p. 14