The Giorgi (M.K.S.Ω) System of Units

SEVERAL years ago, Prof. Giovanni Giorgi, professor of mathematical physics in the University of Palermo, proposed a new system of electrical units. At a meeting of a section of the Advisory Committee on Nomenclature of the International Electrochemical Commission in October last, a resolution was passed inviting national committees to express their opinions on the extension of the series of practical units at present employed in electrotechnics in the direction of Prof. Giorgi's system.

In this system there are four fundamental units; namely, the metre, kilogram, second and ohm.

Dealing first with mechanical units and their relation to the C.G.S. system, the changes are simple. We then have:

Length :	1 metre	=	10^2 C.G.S. units
Mass :	1 kilogram	=	10^3 ,, ,,
Time :	1 second	=	1 ,, ,,
Velocity :	1 m. per sec.	=	10^2 ,, ,,
Momentum :	1 kgm. at a vel. of 1 m. per sec.	=	10^5 ,, ,,
Force :	1 vis*	=	10^5 dynes
Energy :	1 vis acting through 1 metre	=	10^7 C.G.S. units
		=	1 Joule
Power :	= 10^7 C.G.S.	=	1 watt

When, however, we pass to electromagnetic questions, we are met with a difficulty. Maxwell attempted to express the measures of the various quantities occurring in terms of the three fundamental variables of mechanics—length, mass and time; and found that, without further assumptions, this was impossible.

The fundamental electrical quantities are four in number, and other quantities occurring can be expressed in terms of these†. We have the strength of an electric charge, ε, the strength of a magnetic pole, m, the permissivity of air, or a vacuum, K_0, the permeability of air, or a vacuum, μ_0. The measurements we make connecting these four quantities with our three mechanical units are three in number: namely, the force between two charges, the force between two poles, the force between a current element and a pole, or alternatively, the force between a current circuit and a magnet. Thus we have insufficient experimental results to express our four fundamental electrical quantities in terms of our mechanical units.

We are left, as is well known, with the result that the dimensions of $\sqrt{\mu_0 K_0}$ are those of the reciprocal of a velocity, and we can proceed no further without some additional assumption. We cannot say what are the dimensions of μ_0 and K_0 in terms of mass, length and time. We know, of course, that the velocity is that of the propagation of electromagnetic waves, but that does not add to our knowledge of the dimensions of μ_0 and K_0. An additional fundamental unit is required.

Maxwell's systems are based on one or other of two alternative assumptions: one—the electrostatic system—that K_0 is unity and therefore $\mu_0 = 1/V^2$, where V is the velocity of wave propagation; the other—the electromagnetic system—that μ_0 is unity and K_0 therefore equal to $1/V^2$. In the first, $K_0 = 1$ gives us the fourth fundamental quantity, while in the second $\mu_0 = 1$ takes its place as such.

These are not, however, the only possible assumptions. Any one of the quantities we wish to define might be assumed as a fundamental unit. It might, for example, be a quantity of electricity measured by its electrochemical effects, or in some other way independent of that already employed when measuring the force between two charges—this has been developed by Prof. W. Cramp in a letter to NATURE[1]—or a current of electricity measured in a similar manner. This was Prof. Giorgi's suggestion in some of his earlier papers.

In his later papers, he adopts the resistance of a certain bar of metal, and thus we have his M.K.S.R. system. Any suitable bar of metal might be taken; for example, the resistance between the ends of the standard metre. But it is universally agreed that any system of practical units must be the volt, ampere, ohm system, and this fixes the unit of resistance as 1 ohm. Prof. Giorgi therefore takes as his fourth fundamental unit a material bar having a resistance of 1 ohm, or more exactly 1 international ohm, and fixes on a column of mercury at a temperature of 0° C., 106·300 cm. in length, having a mass of 14·4521 gm. Thus, except for the 4π question, we arrive at the M.K.S.Ω. system.

The C.G.S. system is based on Coulomb's law of force between two electric charges written in the form

$$\text{Force} = \varepsilon\varepsilon^1/K_0 r^2$$

Prof. Giorgi prefers to use Heaviside's form

$$\text{Force} = \varepsilon\varepsilon^1/4\pi K_0 r^2$$

and thus eliminates the 4π in the expression for magnetomotive force.

On the C.G.S. system we have magnetomotive force $= 4\pi$ ampere-turns and the unit of magnetomotive force is $1/4\pi$ ampere-turn, whereas on the Heaviside system the unit is the ampere-turn.

The effect of this is to throw the 4π into the value of K_0. Thus we know that, in air, on the electrostatic system, when $r = 1$ cm. $= 10^{-2}$ metre and $\varepsilon = \varepsilon^1 = 1$ C.G.S. unit $= 10$ coulombs, then the force of repulsion is 1 dyne $= 10^{-5}$ vis.

$$\text{Hence } 10^{-5} = \frac{1}{4\pi K_0} \times \frac{10^2}{10^{-4}}$$

$$\text{and } K_0 = \frac{1}{4\pi} \times 10^{11};$$

* Vis is the name given by Prof. Giorgi in one of his papers to the unit of force.

† We might take other four quantities as fundamental, but this would not affect the argument.

or as Prof. Giorgi writes it

$$K_0 = \frac{1}{4\pi} \times 10^9 L,$$

where L stands for the unit of length, the metre.

In the above, for the sake of simplicity, Coulomb's laws have been assumed as the basis of the theory on which the system rests. This, however, is by no means necessary. In a very interesting article in the "Enciclopedia Italiana—Elettricita, Theoria della", to which Prof. Giorgi very kindly referred the present writer in reply to a request for information on some points of theory, he has in the most lucid manner "developed the three fundamental schemes, pre-Maxwellian, Maxwellian and electronic". Any of these can be taken as the starting point.

As Prof. Giorgi stated in a paper read before the Electrical Congress at St. Louis in 1904, neither the C.G.S. electrostatic nor the C.G.S. electromagnetic system is touched. Scientific workers will be free to use any one of these systems without modification, or substitute for them his absolute practical system.

To sum up, quoting again from the same paper: "In order to derive electric and magnetic units from mechanical units, a fourth fundamental unit is necessary. In the C.G.S. electrostatic and the C.G.S. electromagnetic systems, the fourth unit assumed is respectively the electrostatic or the electromagnetic constant of free ether, but this has many disadvantages. For the absolute practical system the fourth unit is the ohm." It would be more accurate to say the "international ohm, defined as the resistance of a certain column of mercury".

It should be noted, of course, that the two changes from the C.G.S. system suggested by Prof. Giorgi are quite independent.

Heaviside's suggestion as to the 4π could be introduced without adopting Prof. Giorgi's proposal to take the international ohm as the fourth independent unit. R. T. G.

[1] Nature, **130**, 368, Sept. 3, 1932.

The Inheritance of Acquired Habits

By Prof. E. W. MacBride, F.R.S.

For the last five years, experiments to test the heritability of acquired habit have been in progress in the Zoological Laboratory of the Imperial College of Science under my supervision; and an account of the work may be of interest to readers of Nature.

The first part of the results of these experiments has been published by the Royal Society: the second part is almost ready for publication. Miss Sladden, who carried out the work, began by rearing the young of *Salamandra maculosa* and the eggs of *Alytes obstetricans*, thus endeavouring to repeat Kammerer's work. It became evident, however, that we did not possess the equipment necessary to provide the conditions which would induce these animals to breed. We succeeded in confirming some of Kammerer's statements about the effect of the environment on the habits of one generation. Thus it is quite possible to induce *Alytes*, normally a land animal, to adopt an aquatic life; and in regard to *Salamandra* we were enabled to explain Herbst's failure to obtain Kammerer's results.

There are two distinct races of *Salamandra maculosa*, an eastern and a western. In the latter, which inhabits the Jura and the Vosges, the yellow pigment is arranged in two longitudinal bands on the back, over a general body colour of black. Miss Sladden has reared animals of this race from birth to an age of three years in boxes painted inside with bright yellow and also in boxes painted deep black inside. In neither case could we detect any alteration in the amount of yellow pigment as a result of the colour of the background. In the eastern race, however, which formed the subject of Kammerer's researches, the yellow pigment is arranged as a series of spots over a black background; and by experiments conducted by Mr. E. Boulenger, then curator of reptiles in the Zoological Gardens, and by myself, during the years 1919–1924, we were able to show that animals of this race exposed for long periods to a black environment do show definite reduction of the yellow pigment. But even if Miss Sladden had been successful in getting her animals to breed, the length of time involved would have been prohibitive, since the adult condition is only attained after four years' growth. Therefore we sought for a convenient experimental animal in which the generations succeeded each other more rapidly.

Some years ago (1912–1915), in conjunction with another pupil (Miss Jackson, afterwards Mrs. Meinertzhagen), I conducted experiments on breeding the stick-insect, *Carausius morosus*, and I found that this insect, whose normal food in England is privet, could be forced by starvation to feed upon ivy. I therefore suggested to Miss Sladden that she should test the development of this ivy-feeding habit. This insect offers great advantages when used as an experimental animal. It is parthenogenetic: males only appear in small numbers every five or six generations and when they do appear they are at once recognisable by their smaller size and different coloration. The parthenogenetic insect produces about 150 eggs a year which take about three months to develop: there is no metamorphosis and as there are no wings the nymph is morphologically similar to the adult.

The plan adopted was to isolate the just hatched young, keeping each one in a separate box. These boxes were made of metal: they were circular and had glass covers. In each box was placed a small piece of ivy leaf. At the end of two days