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CONTENTS.

EXPORT TRADE.

There seems no reason to doubt the fact that American manufactured goods continue to enjoy the appreciation of foreign purchasers in as marked a degree as ever, although the increase of the home demand has checked the possibilities in the export field. Many a manufacturer has to consider gravely whether he shall develop his productive capacity up to the full limit of the business offering him, and the dictates of prudence often is that he should go a bit slow in putting his profits into fixed plant. One thing is certain, that a connection once made for export trade it is well to maintain it, and even to develop it, we think, at the risk of not filling every domestic order as well. Creating and meeting export demand is not the easiest thing, and there are many pushing for it from other countries, where the home consumption is not so brisk. Aside from its immediate benefit, export trade has also the advantage of affording the manufacturer an outlet when his home trade is dull.

Turning to the figures for July, we are glad to find that the total exportation of manufactures for the seven months reach $245,756,052, as against $236,093,429 in the same period last year. When we remember the decline in metal exports, due to the urgent demand for them at home, this total is very satisfactory, especially as it is now to be reinforced by the figures of the large crops with which America helps to feed the world.

RULES FOR RESUSCITATION.

Some years ago we first issued our rules for the resuscitation of persons suffering from accidental electric shocks. It has been a matter of profound gratification to us to know that the use of these rules has proved efficacious in a number of instances; while the many applications for copies, of which we are continually in receipt, evidences not alone an appreciation of their value, but the great extension in recent years of circuits and apparatus of high, killing potential. In the present issue, which as an export number enjoys a special circulation throughout all parts of the world where such apparatus is in use, we present our readers with the latest revision of these rules and suggestions, brought up to date by Dr. Goelet in the light of the best information, data and theory applying to electro-physiology and electrotherapeutics. In many instances we have found our readers place these rules on the walls of central stations, isolated plants and power houses, etc., and knowing this, we have now printed it on stout, heavy paper, whose color being distinctive and familiar will help in quick reference to the rules in the hour of emergency. Extra copies will be furnished gratis upon application.

CENTRAL STATION RATES.

The discussion on central-station rates at the Cincinnati Electric Light Convention served to bring out not only the live interest which that subject has at the present time for central-station managers, but also the great divergence of opinion existing as to what constitutes a rational system equitable both to the central station and to the consumer. To those who have followed the subject closely, it has been quite apparent that the present time marks a transition period in the matter of central-station rates somewhat similar to that in the early history of the art when the abomination of flat rates was dispossessed. The situation is undoubtedly largely due to the more systematic manner in which central stations are now being conducted—in other words, to the fact that the electric lighting industry is ridding itself of the crudities of the develop-

Rational Electromagnetic Units.

SIGNOR Giovanni Giorgi about two years ago brought before an Italian Congress of electrical engineers and physicists a system of rational electromagnetic units, which was referred to a committee for report. Recently this committee, which consisted of Prof. Roiti and four other prominent Italian scientists, recommended the adoption of the system. Signor Giorgi has made his system the subject of a paper communicated to the Physical Society of London, which paper we reproduce below.

It is now generally acknowledged that the system of electric and magnetic measures at present in use is open to an objection, insomuch as it includes an unnecessary factor 4π in the definition of the fundamental units of electric charge and magnetic pole.

We are indebted to Mr. Heaviside[1] for having first expounded the argument. He pointed out, as far back as 1882-83, that the origin of what may be called the "irrational" or "spherical" factor lies in the inverse-square formula, which was formerly adopted as fundamental. The equation for the intensity of field emanated from an electric or magnetic mass had in fact been written thus:

$$F = \frac{m}{l^2} = \frac{4\pi m}{S}$$

while, rationally it ought to be

$$F = \frac{m}{4\pi l^2} = \frac{m}{S}$$

where S is the area of the sphere on which the flux of induction at a distance l from the mass is spread.

From the first, or irrational, formula, the set of units in use has been deduced. Hence the origin of the spherical factor which runs throughout the whole system and appears everywhere in equations that have nothing to do with spherical or cylindrical bodies.
I qucte, for instance, the following cases:

(a)—Capacity of a plane condenser:

$$C = \frac{\kappa}{4\pi}\,\frac{S}{d}$$

(b)—Characteristic equation of magnetism:

$$u = 1 + 4\pi\kappa$$

(c)—Magnetic work, per unit volume of a medium:

$$dw = \frac{1}{4\pi}\,\mathfrak{H}\,d\mathfrak{B}$$

No doubt, the student who meets for the first time equations of this kind, is induced to think that 4π arises mysteriously from the most intimate nature of electromagnetic phenomena; so that if a day were to come when circles and spheres would be abolished from the world, we ought then to define π electromagnetically, and determine its value by measuring the energy of magnetization of a medium, or the capacity of a plane condenser.

These incongruities are removed when the system deduced from the inverse-square law is rationalized, by restoring the 4π to its right place. No doubt, the change is easy, so far as the presentation of the theory is concerned; there can be no divergence of opinion on the grounds which support it. But the difficulty arises as to the units to be employed for practical measurements. The electric and magnetic units already adopted and legalized throughout all civilized countries have been established in accordance with the spherical definition. What is to be done with them, in view of the results of the rationalistic principle?

Mr. Heaviside insisted upon the necessity of a general reform, and the adoption of a new volt, a new ampere, etc., all at variance with those at present employed. This is a good plan and grounded upon excellent reasons; but the opposition which is likely to be raised against its practical application cannot be ignored, and it is rightly believed that to insist upon a proposal like this would have the effect of delaying the adoption of the rational theory beyond any reasonable limit.

Two years ago Prof. Fessenden[2] and Prof. Fleming[3] advocated another plan, consisting of a partial change of units. Objection was raised against this reform, that it is not radical, and again it implies departures from the accepted systems. The question has been discussed further, but it still remains unsettled.

[1] See O. Heaviside, "Electrical Papers," (I) 199, 263; (II) 543; also "Electromagnetic Theory," (I) x, 116; (II) 275; in the latter references are given.

[2] See THE ELECTRICAL WORLD, Dec. 9, 1899.

[3] See THE ELECTRICIAN, Dec. 29, 1899; Jan. 5 and 12, 1900.

I propose here to show how, in my opinion, the question might be considered under another point of view, and then a solution derived, whereby the present practical systems of measures would be brought into agreement with the rationalistic theory, without either introducing new units or altering those already in use[4].

The principle from which the theory of the rationalization depends may be explained as follows:

When a quantity of electricity, or electric flux, dg, is displaced against an electromotive force e, the work performed is reckoned by

$$dw = e\,dq$$

or writing p for the activity of the electric current i, we have

$$p = ei$$

The magnetic analogue to electric displacement is magnetic flux, and the force acting on it is the magnetomotive force. Consequently the work performed when displacing a flux $d\phi$ against a magnetomotive force $\mathfrak{M}$, ought to be rationally expressed by:

$$dw = \mathfrak{M}\,d\varphi$$

or, if $g = \frac{d\varphi}{dt}$ is called *magnetic current*, we have its activity:

$$p = \mathfrak{M}\,g$$

The equations of activity, thus, define the rational units of *E. M. F.* and *M. M. F.* in terms of those of electric current and magnetic current, when the unit of energy is supposed given.

Now, on comparing our equations with those commonly written, we notice that the first one is unchanged, while the other, in the ordinary system, is written with a divisor 4π. Therein precisely lies the irrationality.

We see, however, at the same time that this irrationality affects but one side of the ordinary system. It appears that stress on this remark has not yet been laid by those who have hitherto written on the rationalization of units. I see in this the strongest argument in fvaor of the rational theory. For if spherical measures were preferable, the ordinary system ought to be likewise rejected, as not being entirely inclusive of them. These remarks explain also the scheme for a partial reform suggested by Prof. Fessenden.

The reason of the one-sided irrationality is that the usual formulas alluded to are those of the electromagnetic system—that is, deduced from the inverse-square law for magnetism; therefore, the spherical factor is limited to the magnetic equations only. These formulas do not agree with those deduced from the inverse-square law for electricity, or electrostatic formulas; therefore, it has not been possible to introduce the spherical measures both in electricity and magnetism at the same time. This is a reason why all systems grounded upon spherical measures are necessarily unsymmetrical. On the other hand, it is possible to build out a system wherein all measures are free from the 4π and mutually agree with each other; and then the strict symmetry between electric and magnetic formulas are restored.

The above arguments lead into a wider field of inquiry. It often happens that the advantages or disadvantages of a reform of "the usual units" are spoken about, without clearly stating what system of units is alluded to. Now, for practical calculations the units employed are those of the so-called practical set, which includes the volt, ohm, ampere, and similar ones. This set has not been extended to include several other electrical and magnetic units, nor any practical unit of length, mass, area and volume.

This is not an absolute system and may be considered as not bearing any fixed dependence from the theoretical formulas; therefore, the problem of the rationalization does not necessarily touch it.

All theoretical formulas are written with implicit reference to absolute or *C. G. S.* units. These, on account of their inconvenient size could not be adopted for the purpose of calculations, either in the industry or in laboratory practice, but the mathematical theory of electrical phenomena is usually expressed in terms of them. Now, it is to be remembered that the *C. G. S.* systems are in fact two, I mean, the "electrostatic" and the "electromagnetic." The conflict between them arises from the omission of a *physical factor*, viz., the electric or magnetic constant of free ether, just as the intrusion of the 4π arises from the omission of a *mathematical* factor in the formula of the inverse-square law.

These are, in fact, two irrational features which have simultaneously intruded themselves in the system. And I wish here to point

[4] The present paper is the theoretical development of a scheme which I ventured to lay down in a lecture at the meeting of the Associazione Elettrotecnica Italiana, held in October, 1901. See "Unita Razionali di Elettromagnetismo," in Atti Dell' Associazione Elettrotecnia Italiana, Vol. v, fasc. 6.

out that its rationalization implies that it must be ultimately recast. For, how can a system be called rational so long as the electrostatic and electromagnetic measures are kept distinct? Is it reasonable to correct by 4π the definitions of electric and magnetic mass, and still allow that they conflict together? Therefore, I think that the problem of the elimination of the spherical factor ought not to be distinguished from that of the unification between electrostatic and electromagnetic measures.

It may be remarked that, to attribute to either of the fundamental constant the value unity may at first sight appear a simplification; but the two assumptions cannot be introduced simultaneously[6], so that they necessarily lead to unsymmetry. And moreover, the simplification searched for has no other effect than to lead to a mistake. When either constant is measured by unity, it often happens that its existence is forgotten, and then confusion is made between quantities, such as magnetic force and induction, which are physically as distinct as might be *E. M. F.* and current in a circuit of a unit resistance.

There are therefore proper reasons for having both ether constants measured by other values than unity. But, when these assumptions are discarded, the inverse-square laws cease to bind to any particular choice of units, and we must look elsewhere for the scientific basis of a rational system.

We have already written the rational expressions for electric and magnetic activity. Suppose now that an electric and a magnetic circuit are *interlinked* together, so that the work developed by one is recovered by the other. In this case the activities are equal and opposite, so that

$$\pm e i = p = \mp \mathfrak{M} g$$

But these interlinked currents constitute an *electromagnetic loop*, to which the two circuital equations are applicable; these are:

$$e = \mp g \qquad \mathfrak{M} = \pm i$$

We have thus a set of four, or rather three equations, which contain explicitly the four concrete units of *E. M. F.*, *M. M.-F.*, electric current, magnetic current, together with that of activity.

These equations, instead of the inverse-square laws, are to be considered as fundamental in the electromagnetic science. They are necessary and sufficient for it. I may observe that by application of space differentiators it is easy to convert them into differential equations of the field, of the most general type, which includes the laws of propagation of electromagnetic disturbances and light waves. For our present purpose, however, the finite form is preferable.

On considering the cross-connections established by the circuit laws, we notice that the fundamental units needed are reduced to a common one for *E. M. F.* and magnetic current, and to another for *M. M. F.*, and electric current. Their product must reproduce the mechanical unit of activity; in the limits of this condition, their choice is entirely arbitrary.

No scientific reason of any kind may be assigned for preferring any particular choice to another. We are free to select any set of values which suits to practical convenience.

If the *watt* is assumed as unit of activity, we have two units ready made, the *volt* and the *ampere*, which satisfy the condition. Let us assume them as fundamental. This will be on the strict understanding that in the rationalized system they are introduced not as defined by theoretical relations, but in an empirical way. Thus the ampere will be the current which decomposes a stated quantity of silver nitrate; if asked the reason for it, we answer that theoretically all values are equally good, and we have adopted this particular one, because we found it already employed in electrical engineering.

Accordingly, we write down our fundamental set as follows:

Electromotive force=VOLT=Magnetic current.

Electric current=AMPERE=Magnetomotive force.

The product of these gives:

Electric activity=WATT=Magnetic activity,

reproducing in a double form the same mechanical unit.

From the fundamental set here assumed, a complete system of electric and magnetic units can be deduced. This system is rationalized. Therein, the relations between electric current, magnetic current and electromotive force stand as usually written. A change is introduced in the magnetomotive force, on account of the suppressed 4π. But no fresh unit is required for it; the rational measure of *M. M. F.* is simply in amperes. Practicians already employ it under the (improper) name of *ampere-turns*.

[6] Strictly speaking, this is not absolutely impossible; but it would require to reject Ampere's equality, which has practical reasons for its support.

In order to get rid of all other concrete units of electricity and magnetism, it is sufficient to combine together the volt, the ampere, and the second, in various forms, and interpret the results suitably.

The product of the ampere into the second is called *coulomb*. This gives:

Electric flux=COULOMB=Magnetomotive impulse,

and here the dualistic signification is illustrated when discharging a condenser into a ballistic galvanometer.

The product of the volt into the second, which has been called *weber* by the *B. A.*, gives likewise:

Electromotive impulse=WEBER=Magnetic flux,

and here the physical illustration is obtained when exploring a magnetic field by means of a secondary coil.

The ratio volt: ampere is the *ohm*, and the reciprocal ratio is sometimes called *mho*. In electrically or magnetically dissipative circuits, their interpretation is as follows:

Electric resistance=OHM=Magnetic conductance.

Electric conductance=MHO=Magnetic resistance,

and when dealing with alternating circuits, the *ohm* and *mho* are also the units for electric and magnetic reactance and impedance, susceptance and admittance. There are, of course, no magnetically dissipative bodies hitherto known, but apparent magnetic conductance (due to hysteresis), and reel magnetic susceptance and admittance are to be found in circuits subjected to alternating induction.

When a circuit is not dissipative, but electrically accumulative, the ration between quantity of electricity and *E. M. F.* is commonly called *capacity*, but the scientific name for it would be *electrostatic inductance;* the reciprocal quantity is *electrostatic reluctance.*

Their units of measure are the $farad = \frac{ampere \times second}{volt}$ and its reciprocal, for which no name has been coined. Looking from the magnetic side, the same quantities are exhibited as inertia and mobility, as follows:

Electrostatic inductance = FARAD = Magnetokinetic inertia.

$$Electrostatic\ reluctance = \frac{1}{FARAD} = Magnetokinetic\ mobility.$$

The electrostatic inductance and reluctance have been called *permittance and elastance* by Mr. Heaviside; these names appear, however, not to be entirely free from objection.

Any circuit made out of known bodies is magnetically accumulative. Therein, the ratio between the rational measures of magnetic flux and *M. M. F.*, is defined as *magnetostatic* or *magnetic inductance* (in the irrational system we have, instead of it, the *permeance;* it is advisable in order to avoid changes to continue to use this word in the signification now attached to it); its reciprocal is *magnetic reluctance.* Electrically, these quantities are exhibited as electrokinetic inertia and mobility. Under the electrical meaning, the rational unit *henry* has already been defined as $\frac{volt \times second}{ampere}$ so that we have but to acknowledge its magnetic signification. We have thus:

Electrokinetic inertia=HENRY=Magnetostatic inductance.

$$Electrokinetic\ mobility\ \frac{1}{HENRY} = Magnetostatic\ reluctance.$$

A caution must here be made, namely, that when simply "the inductance" of an electric circuit is mentioned, its magnetic, not electric, inductance has to be understood.

We conclude then, that the electric and magnetic concrete units in present practical use do not need to be altered, but only to be properly interpreted in order to fall into agreement with the formulas of the rational theory. Ten units are sufficient for the rational measure of all concrete quantities of electricity and magnetism, each one being taken in a double signification.

Now, as far as the relations of these quantities with each other and with energy and time are considered, the system is absolute. But in order to have it complete, it is necessary to introduce a set of specific units; and for this purpose a unit of length is required.

This is just the weak point of all systems employed up till now; for, as they always rest upon the unnecessary assumptions attached to the inverse square formulas, electric and mechanical units of reasonable size cannot consistently fit together. But if this chain is rejected, we are free to choose whatever units of length and mass we like, the only necessary link with the electric measures being that they reproduce the same unit of power.

For instance, the *meter* and *kilogram* are consistent with the

watt. If they are put together with the units hitherto enumerated, an absolute system meter-kilogram-second may be built up, which covers up electric, magnetic and mechanical measures in a perfectly consistent frame. This system consists entirely of units already in use; nevertheless it is strictly rationalized—that is, not only free from the 4π, but at the same time "electrostatic" and "electromagnetic." It is equally applicable for theoretical and practical calculations, thereby the *C. G. S.* system ceasing to be necessary.

The specific measures in an absolute system are defined by referring the concrete measures to the unit length, unit area, unit volume. Thus, whatever be the fundamental unit of length adopted, the specific units of electric force and electric induction, will be *volt per unit length,* and *coulomb per unit arc;* those for magnetic force and magnetic induction will be *ampere per unit length* and *weber per unit area;* and so on. Similarly the resistivity and conductivity of a body would be defined as the resistance and conductance of a cube of unit dimensions, and measured in *ohms into unit length* and *mho per unit, length.*. Finally, the definition of the electromagnetic constants of a medium is arrived at as follows:

The electrostatic constant or *electric inductivity* is the ratio between electric induction and force in a medium; it is to be measured in *farads per unit length,* the symbol κ being employed for it. Similarly, the magnetostatic constant or *magnetic inductivity* of a medium is the ratio between magnetic induction and force therein; this is to be measured in *Henries per unit, length.* I suggest to represent by the symbol λ the quantity thus defined.[7]

But the electric and magnetic inductivities of a substance can be also defined as the electric and magnetic inductance of a cube of unit dimensions. Thus, the electric inductance of a plane condenser, and the magnetic inductance of a straight core are given respectively by

$$C = \kappa \frac{S}{d} \qquad L = \frac{\lambda S}{d}$$

where, in both cases, S is the section, d the length or thickness of the induced body.

8. Stress must be laid on the fact that in the M—Kg—S system, none of the fundamental and derived units would have an absolute value.

Therefore, it is instructive to investigate by what numbers the two constants of the ether, κ_0 and λ_0 are measured in the units of this system. We get

$$\kappa_0 = 0.\ 000\ 000\ 000\ 008\ 842$$
$$\lambda_0 = 0.\ 000\ 001\ 256\ 637.$$

These values are not to be looked upon as an abnormal feature of the system; on the contrary, they express a physical truth. They instruct us that free ether has an exceedingly small susceptivity for electrostatic and for magnetic action, but far smaller for the first than the second one.

Either of these facts, or both, are likely to be obscured in the other systems of measures. We now understand why therein, to equate to unity either of the fundamental constant, has resulted in a set of derived units of abnormal values.

The small values of κ_0 and λ_0 are justified, if we consider their relation with the velocity of propagation of ethereal disturbances. Indeed, these values satisfy the equation:

$$(\kappa_0 \lambda_0)^{-\frac{1}{2}} = 3 \times 10^8$$

In view of the definite physical signification attached to κ_0 and λ_0 in the rational system, the direct interpretation of this result is not difficult.

Thus, rational units of electromagnetism do not any longer afford a method for calculating π, but only the speed of light.

I have mentioned Prof. Fessenden's proposal for the suppression of 4π. My own proposal is grounded on Prof. Fessenden's one. It has a point common with it, that is to alter the traditional value unity of the ether inductivity, and to shift 4π within it.

But Prof. Fessenden's object is simply to get rid of 4π in the formulas; therefore he assumes $\lambda_0 = 4\pi$, and that is sufficient for his purpose. I develop his suggestion still further, and get a scheme which physically is to be interpreted otherwise.

I wish not only to get rid of the 4π, but of a greater evil—that is, the distinction between practical and absolute system of units. In my system λ_0 is not a numeric, nor do I assume any special value for it; it is a physical quantity, having dimensions, and to be measured by experiment. I assume as fundamental the volt and the ampere, as arbitrarily chosen units, and not derived from mechanical units. When I put them in connection with any special unity of length, then I get λ_0 in henries per meter or in henries per inch. Practically this results as follows:

1st. I frame the practical units into an absolute system, and all other absolute systems are abolished.

2d. The practical electrical units may be related to the inch, as well as to the meter, without destroying the absolute feature of the system. This is, I think, an advantage.

3d. The fundamental units of the electric system are not specific, but electric ones. Thus in future, the so-called absolute determinations of the ohm will be interpreted as measurements of the ether inductivity.

I am of the opinion that to start from concrete units and quantities and then to derive specific ones from them will greatly simplify the understanding of the theory to students.

[7] In the rationalized system, inductivity is substituted for "permeability." The latter word, after Mr. Heaviside, may be preserved in its former signification; that is, in the meaning of relative inductivity. Thus, inductivity and inductance are physical quantities, while permeability and permeance are pure numbers; the latter are sometimes useful to consider. The symbol μ ought to be continued in use for permeability and λ for inductivity. This avoids confusion between irrational and rational equations. Likewise I use F and f for rational magnetic and magnetomotive forces, while H and h are used for the irrational ones. The letter λ agrees with L, magnetic inductance, just as μ with K, electric inductance.

American Electrical Machinery for a British Steam Railway.

The last of the main generators and engines intended to be installed in the power plant of the Mersey Tunnel Railway are about to be shipped from the Westinghouse Works, at East Pittsburg. These generators are of the railway type (1,200-kw, 650-volts, 90 r. p. m.), and are to be direct connected to vertical, cross-compound, Westinghouse-Corliss engines of 1,500-hp each. The power-house lighting and the electric light of all stations, sidings, etc., will be supplied from a separate generating plant comprising two compound-wound generators, each having a capacity of 200 kw at 650 volts, direct-connected to Westinghouse compound engines, and running at a speed of 250 r. p. m. The power generating plant will have an aggregate output of about 6,600 hp—6,000 hp for the railway proper, and 600 hp for lighting. The Westinghouse electro-pneumatic system of train control is to be used, and the cars will be equipped with Westinghouse high-speed air brakes. The rolling stock will consist of 60 cars, each about 60 feet in length. The trains will be formed of five cars each, the first and last cars of a train being motor cars, equipped with four 100-hp motors each.

The Mersey Railway connects Liverpool and Birkenhead, and passes under the river Mersey. The tunnel is double tracked. The route of the railway is about four miles and a half long, the total length of track, including sidings, being about 12 miles long. Its situation is unique, joining two such important business cities, between which the only competition in the transportation of passengers and freight is given by ferry boats on the river, and the traffic on the line is large. The number of passengers carried amounted to between seven and eight millions per year, even with the old steam locomotive system.

The railway is standard gauge, laid in accordance with heavy steam railway practice, the rails being of the ordinary English "bull-head" type, weighing 86 lbs. per yard. The line is to be fitted with the third-rail system, the conductor rail to be laid alongside and just outside of the running track. The running rails will not be used as the return electrical conductor, but a fourth rail is to be placed between them, solely for this purpose. This will entirely prevent any destruction of the track rails or buried pipes in the vicinity by electrolytic action. The third and fourth rails will be similar in size and in arrangement. They are to be of T-section, 60 feet in length, and to weigh 100 lbs. per yard. They will be effectively bonded and carried on stoneware insulators, spaced at intervals of seven or eight feet apart.

It is expected that the trains will run on a three-minute service. The tunnel and the seven stations of the system are to be electrically lighted throughout. The power generating station, the machinery and the track work are all being pushed rapidly to completion.