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THE CENTIMETRE GRAMME SECOND AND THE CENTIMETRE DYNE SECOND SYSTEMS OF UNITS AND A NEW GRAVITATIONAL EXPERIMENT.

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THE C. G. S. system of units was undoubtedly a great advance over previous systems, but it has at least one serious disadvantage. This is the employment of the gramme as one of the fundamental units. Mass is not a fundamental conception, and has no claim to be put in the same class as length and time. We can conceive of matter as distinct from mass just as easily as we can conceive of matter as distinct from electricity, and far more logically, for each unit of matter is always associated with the same quantity of electricity, while the amount of mass associated with the unit of matter, *i. e.*, the atom, is more than 200 times as great in the case of some kinds of atoms as in others.

There is, therefore, this theoretical objection. There is also a practical one. Any system of units must be logical, in that the dimensional formula for any quantity must be made up of such concepts only as are necessarily associated with that quantity. This is not the case with the C. G. S. system. The dimensional formula for quantity of electricity in the electrostatic system of units is $L^{\frac{3}{2}} T^{-1} M^{\frac{1}{2}}$, in which the conception of mass is brought in. Now, mass has no connection with electricity, so far as we know at present; if there were no such thing as mass we should still have electricity, and therefore the system of units which gives such a formula is defective.

There is a second practical reason. This is, that in the C. G. S. system of units it is much more difficult to see readily relations between different quantities, and to interpret them, than in a more theoretically perfect one, on account of the fact that the M in the formula of a force which has no necessary connection with matter may cancel out with an M which has a legitimate right to be there For instance, suppose that, in working out a problem, we get such a result as M/T, this may mean almost anything, *i. e.*, it may be the product of various things, and what these are is not readily apparent.

As a matter of convenience, the writer has used a system of units in which the dyne takes the place of the gramme, and has found that there is a considerable advantage.

In this system the unit of mass drops back into its rightful place, and is a dimension of the same sort as the unit of electricity or the unit of magnetism. Gravity is treated as a separate substance, distinct from matter, but residing in it in the same way as magnetism is supposed to reside in iron, and unit quantity of gravity is defined as that quantity which will attract equal quantity placed at unit distance with unit force. The atomic weight of an atom is its permeability to gravity, and corresponds to μ in magnetism. Lines of gravitational force are supposed to radiate from a body charged with gravity in the same way as from a body charged with electricity or magnetism.

Current of gravity is the quantity of gravity which passes between any two points in unit of time, and unit of gravitational potential causes unit current of mass through unit resistance.

To show the advantage of the C. D. S. system over the C. G. S. system, the following table is subjoined, which gives the principal dimensional formulæ in Electricity, Magnetism, Heat and Gravity in both systems:

C. D. S. Units.	Gravity.	Mag.	Elec. Stat.	Elec. Mag.	Heat.
Quantity	$\sqrt{FL}$	$\sqrt{FL}$	$\sqrt{FL}$	$\sqrt{FL^2/T}$	FL
Current	$\sqrt{FL/T}$	$\sqrt{FL/T}$	$\sqrt{FL/T}$	$\sqrt{FL^2/T^2}$	FL/T
Difference of Pot	$\sqrt{F}$	$\sqrt{F}$	$\sqrt{F}$	$\sqrt{FT/L}$	1
Resistance	T/L	T/L	T/L	L/T	T/FL
Capacity	L	L	L	L^3/T^2	FL

C. G. S. Units.	Gravity.	Mag.	Elec. Stat.	Elec. Mag.	Heat.
Quantity	M	$\sqrt{L^3}\sqrt{M/T}$	$\sqrt{L^3}\sqrt{M/T}$	$\sqrt{L}\sqrt{M}$	L^2M/T^2
Current	M/T	$\sqrt{L^3}\sqrt{M/T^2}$	$\sqrt{L^3}\sqrt{M/T^2}$	$\sqrt{L}\sqrt{M/T}$	L^2M/T^3
Difference of Pot.	L^2/T^2	$\sqrt{L}\sqrt{M/T}$	$\sqrt{L}\sqrt{M/T}$	$\sqrt{L^3}\sqrt{M/T^2}$	1
Resistance	L^2/TM	T/L	T/L	L/T	T^3L^2M
Capacity	MT^2/L^2	L	L	L^3/T^2	L^2M/T^2

Incidentally, it may be noted that the notation is more concise. This, however, is merely an accidental point, the main thing being that the C. D. S. system is "ethically" more correct, and that it does not distort ideas so much in the handling as the C. G. S. system does.

It will be found convenient to denote the different quantities by means of subscript letters. Thus, R_g, R_m, R_{es}, R_{em}, R_h represent gravitational, magnetic, electrostatic, electromagnetic, and heat resistances. So, also, W_g represents gravitational work, *i.e.*, $1/2mv^2$, W_{em} represents electrical work, or C^2R, W_h represents heat energy, being really only a particular case of W_g, in which the algebraic sum of the vectors representing the velocities is zero, and W_m represents magnetic work, or B × M.M.F. One or two remarks may be made in regard to these formulæ. There has been some doubt in regard to the correct dimensional formula for temperature. This has been caused by the incorrect assumption that k, the specific heat of a body, is a number. That this is not the case follows from the law of Dulong and Petit. According to this, the atomic heat of all the elements is the same. Therefore, the heat required to raise a cubic centimetre of any substance one degree C., *i. e.*, its specific heat, is equal to the heat required to raise the temperature of a single atom the same amount × the number of atoms in the cube. This last is a number, and the former depends upon the kinetic energy of the atom. As the dimensional formula for kinetic energy is the same as that for work, *i. e.*, LF. (in the C. D. S. system), the formula for temperature must equal FL÷FL., *i. e.*, unity.

We obtain the same result by considering the fact that Quantity of Heat × Heat Potential must equal Work, *i. e.*, LF × heat potential=LF. A current of Heat, then, is a cur-

rent of energy, in the form of kinetic energy. Temperature is heat potential, and specific heat is heat capacity. It is evident, therefore, that, like the gramme, the calorie must vanish from a rational system of units, and its place be taken by the erg and joule. Unit heat flux is one erg per second. Unit difference of heat potential is one degree C. (Theoretically, it should be the temperature to which one erg will raise unit mass of unit matter, *i. e.*, unit mass of hydrogen.)

Unit specific heat will be possessed by a body which requires one erg to raise one cubic c. m. one degree C.

The consideration of the gravitational formulæ gives us some ideas in regard to gravity, and suggests some experiments which have as yet not been tried. The resistance of mass to motion, or inertia, varies directly as the acceleration, and as the mass. It is independent of place or the actual distance passed over in attaining the velocity. The energy possessed by a body in motion is proportioned to the integral of the various accelerations received by it, squared; *i. e.*, it varies as the velocity squared.

We have an exact analogy to this in the case of motion of matter in a frictionless fluid. Suppose a ball placed in a fluid, such as water, which we will suppose to be frictionless. Then, on moving the ball, we may conceive of a vacuum being formed behind the ball, and that this vacuum will be proportional to the square of the velocity with which we move the ball through the water. The water is, of course, supposed to have inertia, otherwise the vacuum would not form. So long as the velocity with which the ball is moving is constant, no work is done, and there is, therefore, no resistance to the motion, and it will continue in motion forever, unless opposed by some force. Suppose, however, that the ball meets with an obstacle which tends to stop it, then the vacuum will tend to close up, and the water will push the ball ahead, till an amount of work has thus been done equal to that done in making the vacuum originally. Such a behavior corresponds exactly with the behavior of matter moving in the ether.

This theory, however, demands a reconception of the ether, for it is generally taken that the ether possesses no inertia. On closer examination, however, it will be seen that the difference is only apparent. In all the cases where we have had opportunity for measuring any inertia of the ether, a finite quantity only of the ether has been in motion. In the case of an electric circuit, for instance, the only ether in motion is that definite amount corresponding to the current produced. It is, of course, well known at the present time that electrical energy is not transmitted along the wire, but through the dielectric, but this does not affect the statement made that the only inertia effect which could be perceived would be that due to the motion of a definite amount of ether. Therefore, as no inertia effect has ever been found in connection with the motion of the ether in an electric circuit, we are justified in saying that the inertia of the ether is negligable in such a case. But we are not justified in saying that the inertia is negligable in the case where an infinite amount of ether is in motion, as would be the case, according to this theory, when a solid is moved through space, for an infinite amount of the infinitely small may be appreciable.

If, however, we take the two fluid theory of electricity, which, as Dr. Lodge has shown, is forced upon us by the consideration of many phenomena, and consider an electric current as the shearing past each other of two dissimilar parts, which together make up the ether, then there need be no such modification of our views, for, since in any case of electric flow there are always equal quantities of plus and minus electricity, and we may suppose the moments of inertia equal and opposite, no inertia effect could, of course, ever be observed in an electric circuit. When, however, the ether is moving as a whole, the inertia effects would be added instead of subtracted, and we would have, as shown above, all the phenomena of gravitational inertia.

It is, of course, not necessary for a body to have mass in order to display inertia effects, for its resistance to motion may be due to a "counter-motive" force, as in a circuit having self-induction; consequently there is no difficulty in accounting, in various ways, for the ether showing an inertia effect.

To take up the theory, for it is more than a mere imagining, having been worked out mathematically with some fullness in several directions; from Fizeau's experiment (confirmed by Michaelson and others), we know that when matter moves it drags with it a certain amount of the ether, but that a certain part remains behind, flowing through the matter. If this ether has any inertia (using the word in its broad sense), then there will be an effect similar to that which occurs when a sieve is moved through water. A vacuum, or a spot of less density, or of less rigidity will be formed behind the body. The size of this spot will vary as the velocity, and if the velocity is doubled the spot will be doubled, and four times as much work will be done in making it. And this no matter what the time in which the spot (which we will call the vacuum, provisionally) is formed, or where in space it is formed. On taking away the driving force the ether will close up on the body again, and push it on, till the vacuum exists no longer, and consequently all the work done in forming it is given up again. As the ether is supposed to have no friction, mere motion of the vacuum from one spot in space to another will necessitate no work and consequently we have Newton's law, that a body tends to continue in its state, whether of moving with a given velocity, or at rest.

This is the part of the theory which deals with inertia, and the experiment referred to above is as follows: Set a body in motion, under the action of a constant force, then remove the force, and examine the body at the time when the force is removed. If the ether has inertia, then at the instant when the accelerating force is removed there will be an abnormal reduction in speed for an exceedingly small time. This will be followed by an abnormal acceleration, also acting for a very small time, and of such dimensions that after the lapse of a very small time, the velocity of the body will be the same as if neither the retardation nor the acceleration had existed. If the time during which these effects take place be not too small, it will be observable on a chronograph, and will give a trace as follows:

The dotted line shows the trace if the effect had not taken place, the other the trace if the effect does occur. It will be seen that they only differ for an exceedingly small portion of time, and it is doubtful if the experiment would succeed, even if the effect existed. It has, however, I believe, never been looked for.

If this be the true theory of inertia, then the theory of gravitation is as follows: If we take a rod of any solid substance, and press down one atom, which we will call A, it pulls down the atom next it, which we will call B, because, though the atom B is moving, it merely oscillates about a fixed point, and is always within reach of the influence of A. This property is what we call rigidity, and it is this which enables a solid to stand a shearing stress.

If the solid is melted it is called a fluid, and is commonly supposed to be unable to withstand a shearing stress. This is due to the following circumstance: Let us press down A. If B did not move, then B would have to follow A, if it were not that in a fluid the atoms no longer oscillate about a fixed point, but change their positions relatively to one another. The atom B moves at ordinary temperatures at a velocity of somewhere near 100,000 centimetres per second. The distance between any two atoms is somewhere in the neighborhood of 1/100,000,000th of a cm. Consequently in the 1/1,000,000,000,000,000th of a second, the atom B will have passed without the radius of attraction of A. Consequently we see that for any forces which are impressed in a greater time than 10^{-13} second, the fluid will have no rigidity. But if the force is applied in less time, we have no reason for supposing that the fluid will not resist shearing, or that a water tuning fork could not be constructed at the centre of the earth. For, if we accept the electrostatic theory of cohesion, the force which A exerts on B when A is pulled down travels at the rate of more than 10^{10} c. m. per second. As B will have to move say 10^{-8} c. m. to get out of the way of the pull from A, we see that if an impulse is given in less than 10^{-18}th of a second, B will be pulled down, and the fluid will resist a shear. And it is this force which acts to join the atoms together which gives rise to the phenomenon of surface tension. Consequently we see that if the ether has rigidity, whether it be a solid or a fluid, it must have surface tension.

Let us take the case of two bubbles of air in water. There is a surface tension at the junction of the air and water, and it may be shown that the effect of this is to bring the two bubbles together. A similar result would follow if the two bubbles had their places taken by two drops of water hotter than the rest of the water. Or if the drops were made up of a number of concentric shells, the density of each shell being greater than that of the shell next inside it, the equivalent of such a shell would be produced by sticking the prongs of two tuning forks into the water, for at those places where the velocity of a prong was greatest the density of the water in unit volume would be least, and the forks would be attracted. So if we suppose the atom to be, say, a Thomson vortex ring, and that this vortex ring, in virtue of its rotation, renders the ether next it less dense, or less rigid, it would attract any other atom similarly constituted in the same manner as we know two atoms do. And this attraction would be always the same in quantity, no matter what the temperature or surroundings, so long as the atom was the same, *i. e.*, its weight would be constant. And if another atom produced a different degree of density or rigidity near it, its weight would be different and constant.

Thus we see that if the ether has inertia (or some "counter motive force" opposes its motion), then matter must have inertia, and if the ether has rigidity, and atoms produce a difference in the cohesion of the ether near them, then all atoms will attract each other in proportion to the change they produce in the rigidity of the ether near them.

There are two experiments which seem at first sight to contradict Fizeau's experiment. First, the fact that a rotating disc of matter has no effect on a magnetic needle placed at its centre. Second, the fact that light suffers no retardation or acceleration when passed along the lines of force between two plates at different potentials, and placed in an electrolytic bath.

The first is readily explained when we consider that when the disc is rotating it is carrying with it ether as a whole, *i. e.*, equal quantities of positive and negative electricities, or is equivalent to two currents of equal strength flowing in opposite directions, and consequently can produce no effect outside of the body. Or, to use Prof. J. J. Thomson's symbolism, the ends of the Faraday lines are both within the body, and do not pass outside, whereas in Professor Rowland's experiment the Faraday lines have one terminal on the disc, and the other outside. The two cases are not similar.

The second case, that of the electrolytic bath. In this the ether does not move as a whole, there is merely a shearing of plus and minus electricities past each other, and the algebraic sum of the velocities of the components of the ether is therefore zero. Or, the ether does not move, so far as any possible effect on light is concerned.

THE "GLACIAL PERIOD" PROVED AS A NECESSARY CONSEQUENCE OF THE EARTH'S MOVEMENTS.

BY MAJOR GENERAL J. C. COWELL, WINDSOR CASTLE, ENGLAND.

FROM the increasing interest that is manifested in all that relates to the glacial period, and the discovery, by General Drayson, of the Second Rotation of the Earth, it will be of value to those who are studying the geological evidences of the ice ages, to devote some time to the ascertained facts proving the Second Rotation as compared with the accepted theories, since these appear to supply all the conditions necessary for the explanation of the glacial phenomena, at regular intervals; and it is with the object of rendering the subject clear to them that the following remarks are offered to the readers of *Science*.

It has hitherto been stated by Herschel and other writers of his day, that the movement of the Earth, which caused the precession of the equinoxes and solstices, and the changes in Polar distance, and Right Ascension of the Stars, is "a conical movement of the Earth's axis round the pole of the Pole of the Ecliptic as a centre."

Drayson claims that this definition is vague, if not misleading, even as regards that part which speaks of a conical movement of the axis. He claims that it is the two half axes that trace cones, the apex of these cones being at the centre of gravity of the Earth.

He also claims that this conical movement of the two half axes is the mere mechanical result of a Second Rotation of the Earth, just as the conical motion every twenty-four hours, of all lines from the Earth's centre to points at the Earth's surface, is the result of the daily rotation of the Earth.

An examination of the annual changes in Right Ascension of every Star in the Heavens (see pages 163 to 219 in "Untrodden Ground in Astronomy and Geology") proves that a second rotation is the *only* movement which will explain the recorded changes in the Right Ascension of Stars. Hence, instead of some vague and undefined movement of the Earth occurring whilst the axis has what has been called "a conical motion," the detail movements of each point on the Earth's surface are accurately defined by the second rotation. Secondly, the Earth's axis traces *a circle* round the Pole of the Ecliptic *as a centre*, keeping constantly at the same distance of 23° 28′ from it, wrote Herschel and others.

In the face of the fact that the obliquity (*i. e.*, the angular distance between these poles) decreases about 47″ per century, the above statement is obviously erroneous.

As an escape from this error it has been asserted by some that the Pole of the Heavens moves about 20″ annually at right angles to the arc joining the Pole of the Heavens with the Pole of the Ecliptic, but as the latter