LETTERS TO THE EDITOR.

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The Structure of the Ether.

THE recent interesting communication of Sir Oliver Lodge to NATURE (March 28) and the *Philosophical Magazine* on the density of the ether recalls an objection to theories of the ether which identify magnetic intensity with resultant ethereal velocity that does not seem to have received the attention it deserves. The objection arises when the distribution of momentum in the system is taken into consideration.

It will be remembered that Sir Oliver Lodge commences by pointing out that the volume occupied by the electrons which constitute a mass of platinum is small compared with the volume of the platinum itself, whence it follows, if the mass of the electrons is that of the ether they carry with them, that the density of the ether must be enormous compared with that of platinum. This conclusion appears to be inevitable if we are to have a hydrodynamical theory of the ether. I do not wish to contest the contention that the density of the ether is enormous.

The second method used by Lodge to evaluate the density of the ether assumes that the magnetic intensity at any point is always proportional to the speed of the ethereal flow. By equating the mechanical and magnetic expressions for the energy of the field, and assuming that the ethereal circulation at the equator of an electron is equal to the velocity of its forward motion, Lodge arrives at the relation

$$e=4\pi a^2\sqrt{\frac{\rho}{4\pi\mu}},$$

where e is the charge and a the radius of an electron, and ρ is the density and μ the magnetic permeability of the ether. This may be combined with the known values $e^2\mu=10^{-40}$ gm. cms. and $a=1{\cdot}2\times10^{-13}$ cms. to give $\rho=3{\cdot}83\times10^{10}$ gms. per c.c. This gives for the velocity of ether drift in a magnetic field of intensity equal to 1 electromagnetic unit the value $w=1{\cdot}44\times10^{-6}$ cms. per sec. These figures enable us to calculate the momentum due to any given magnetic distribution.

A moment's consideration of the simplest possible case, that of a moving charged sphere or an electron, will serve to show that this distribution of ethereal velocity leads to impossible results. We have seen that $\rho=e^2\mu/4\pi a^4$, and by making use of the expression for the magnetic field due to a moving charged sphere of radius a we find that the velocity of ethereal flow w, at a point the coordinates of which are r, θ with respect to the electron and its line of motion, is given by

$$\tfrac{1}{2}\rho w^2=\frac{\mu e^2u^2\sin^2\theta}{8\pi r^4}$$

or

$$w=\frac{a^2}{r^2}u\sin\theta.$$

Hence the momentum per unit volume at a point r, θ from the centre of a sphere of radius a and charge e moving with velocity u is given by

$$\rho w=\frac{e^2\mu u}{4\pi a^2}\,\frac{\sin\theta}{r^2}.$$

Since the momentum is distributed in circles round the line of motion there is no resultant momentum, but if the above expression be integrated it will be seen that there is an infinite quantity of momentum in the field for any finite value of u, and, moreover, there is an infinite moment of momentum about the line of motion. The existence of this momentum would make it impossible to set a charged sphere in motion; the same result would be arrived at by any theory which makes the velocity of the ether proportional to the magnetic force.

Electrodynamic theory has led to an expression for the momentum per unit volume of the ether by ways which are less speculative. This expression is $1/4\pi$ times the product of the electric and magnetic displacements, and it has the merit of making the momentum in the ether equal to the product of the (electric) mass and velocity of the moving charge. If we are to have a hydrodynamical theory of the ether it seems reasonable to make this agree with the fluid momentum. We thus get for the case of the charged sphere

$$\rho w=\frac{\mu e^2u\sin\theta}{4\pi r^4},$$

and from the energy expressions

$$\rho w^2=\frac{\mu e^2u^2\sin^2\theta}{4\pi r^4},$$

whence $w=u\sin\theta$ and $\rho=\mu e^2/4\pi r^4$. This result makes the velocity of flow of the ether independent of the radial distance from the electron, but the amount moved varies inversely as the fourth power of the distance. It has been pointed out by J. J. Thomson that this result can be interpreted hydrodynamically by supposing that the ether is carried along by the tubes of electric force, and that the extent to which the ether is "gripped" by the tubes of force is proportional to the square of their concentration. If we suppose the whole of the ether to be carried along at the equator of the electron, this method would give the same estimate for the density of the ether as that found by Lodge. If only part of the ether were carried along by the tubes of force even at the equator of an electron, the density of the ether would have to be correspondingly increased, so that this method can be regarded as giving the value $\rho=\mu e^2/4\pi a^4=3{\cdot}85\times10^{10}$ gms. per c.c. as an inferior limit to the density of the ether. The actual value may be much greater than this.

The hypothesis of no ether slip at the equator of the electron leads to what seems to be a difficulty, at present at least. From what has been said it will be seen that it definitely establishes the relation $e=4\pi a^2\sqrt{\rho/4\pi\mu}$, so that the charge on an electron is equal to its superficial area multiplied by a quantity which depends only on the properties of the ether. Thus the size and mass of any electron are determined as soon as its charge is known, and any one of these quantities is determined by any non-identical combination of the others. The experiments of Bragg on the stopping power of different substances for α rays lend support to the suggestion, first put forward by H. A. Wilson, that these are positive electrons. Now the experiments of Rutherford have shown that the value of e/m for the α rays emitted by a large number of radio-active elements is very nearly 5×10^3 e.m.u. per gm. This value of e/m leads, on the hypothesis of no equatorial slip, to the value $e_2=10^{-13}$ e.m.u., or 10^7 times the charge on the negative electron. It would be difficult to make an electron with a charge of this magnitude the foundation of atomic structure. This difficulty occurs with at least equal force on the assumption of magnetic ether flow.

The argument of the last paragraph, so far as it is deserving of weight, tends to show that the ethereal density is greater than the limiting value. The considerations brought forward earlier would appear to show that the ethereal flow, if it exists, is at right angles to, and not along, the lines of magnetic force, and that the effect sought for experimentally by Sir Oliver Lodge is not to be expected.

O. W. RICHARDSON.

Princeton, N.J., May 12.

Radium and Geology.

WITH apologies to Prof. Joly (p. 55), I think my estimate of a gradient of 1° F. for 98 feet in the Simplon Tunnel will bear examination. From a contemporary notice in the *Daily Mail* of October 3, 1904, it is clear that the heat in the tunnel was endurable until the hot spring was tapped. The water is stated to have been at 131° F., which agrees *exactly* with 55° C., "the highest temperature" of Prof. Joly. Surely, then, this was the temperature of the spring, and not of the rocks.

I would also remark that Mr. Strutt considered that the amount of radium in the igneous rocks examined by him would, on his theory, account for a gradient as high as 1° in 42·2 feet, a very different thing from the 1° in 70 mentioned by Mr. Fox.

O. FISHER.

Graveley, Huntingdon, May 17.