ites, slates and granites from the Amotape mountains, and those derived from the underlying Tertiary.

The intense block faulting of the Tertiary preceded the Tablazo period, but there has been subsequent differential warping since the surface of the oldest or Mancora tablazo declines from an elevation of eleven hundred feet at Mancora to two hundred feet at Payta. The younger tablazos are progressively less extensive and less elevated, and the latest or Salina plain has been brought above sea level by a recent uplift of from ten to fifteen feet. The contemporaneous breccia fans bordering the mountains, and river terrace and other deposits are also dealt with. The author is impressed with the vast time involved in the oscillations and consequent events of Quaternary time in this region, amounting, if one may take his remarks on page 259 literally, to some five million years.

Part 4 is devoted to desert conditions and processes and is a most valuable description and discussion of land forms and processes under conditions which are little known to the average geologist. Part 5 is a not altogether satisfying account of the petroleum industry in the region. The chapter on the occurrence of oil in fault blocks, often of small size, is as interesting as it is unusual.

In conclusion the work is a most commendable one and indispensable to any one interested in or contemplating working in the region. As an example of book making there are some features that might have been better done. The five parts into which it is somewhat artificially divided are not coordinated and there is considerable repetition. One questions the wisdom of splitting it up into 76 chapters, some of which are only a paragraph in length, and in a book with one hundred and fifty figures besides many plates the readers might dispense with several views of the author at the plane table, which is a well-known instrument even in Peru. With all due appreciation of this as the first comprehensive work on the region it would seem that previous workers have been given but slight consideration, and in particular the main stratigraphic units do not differ greatly from those of the Cuerpo de Ingenieros de Minas of Peru, which is not mentioned.

The author's insistence on a range of pre-Tertiary desert mountains, which he states were higher in earlier times than they are at present, may well be questioned. Obviously the Andean region underwent changes of level both by uplift and erosion throughout its history and some of its rocks were folded in very ancient times, but I am not prepared to accept the author's conclusions, based on the absence of Eocene deposits elsewhere on the west coast of South America to the southward of this region, the enormous estimated thicknesses of the Eocene, and the presence of Andean pebbles, as proof of a high range, particularly as the fossil plants found in the Zorritos formation[2] show no evidence of desert conditions or of high mountains across the path of the easterly humid trade winds, and the topographic form of the mountains themselves precludes such a conclusion, as does also the paleobotanical evidence of Pleistocene elevation derived mostly from Bolivian localities, but recently discovered as near the region treated by Bosworth as Cajamarca in northern Peru.

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SPECIAL ARTICLES

THE LOCATION OF ENERGY

A CALCULATION of the mass of an electron, based upon the modification of electromagnetic theory proposed in a recent paper,[1] has led to the surprising result that the mass inside an electron in uniform motion, when calculated from the momentum, is equal but opposite in sign to the mass outside.

Before the calculation was carried to eight decimal places the sum of the two masses appeared to be a small positive multiple k of e/ac^2, where e is the charge of the electron, a its radius and c the velocity of light. The boundary of the electron is supposed to be a sphere of radius a when the electron is stationary.

It was thought at first that this calculation indicated that a must be much smaller than is generally supposed, of the order 10^{-17} cm., for

[2] Berry, E. W.: *U. S. Natl. Mus. Proc.*, Vol. 55, pp. 279-294, 1919.

[1] *Physical Review*, September, 1922.

instance, but further consideration has led the writer to the view that the equality of the two masses is exact and that it may be advantageous to regard the mass of the electron as being situated inside the electron rather than outside.

A few remarks will now be made to make this point of view seem reasonable. It is supposed in the new theory that an electric charge produces both a vector field (the electromagnetic field) and a scalar field which may be specified by means of retarded potentials and which exists both inside and outside the electric charges. The scalar field is derived from a single potential Ψ which reduces to the ordinary electrostatic potential when all the electric charges are stationary but differs from it in general when charges are in motion.

Associated with the two fields there is a tensor T whose components give the densities of energy and momentum and also the fluxes of these quantities. Two tensors T_1 and T_2 were mentioned (in the paper) which would give no radiation of energy and momentum to infinity on the whole when an electron describes a periodic orbit under the influence of an electrostatic field of infinite mass. By slightly modifying the second tensor it is possible to retain the property just mentioned and arrive at the same expression for the body force per unit volume as was obtained from the first tensor, except that there is a difference in sign. This modified form of the second tensor will be called T_2. In addition to these a third type of tensor must be considered.

A state of the ether will be regarded as *chaotic* when there is no flow of energy, no density of momentum and a density of energy which is constant and the same for different standard observers that are moving uniformly relative to one another in various directions. The flow of momentum across a surface is then always normal to the surface and on the whole there is no flow of momentum into or out of a closed surface which is fixed relative to a standard set of axes. The ether thus not only exerts no body force on the ether within the surface, but the surface forces depending on the flow of momentum form a system in equilibrium. The tensor T_0 corresponding to a chaotic state of the ether will be called a *chaotic tensor,* the stress-system represents a constant positive or negative pressure which is equal in magnitude to the density of energy. It is found that the best results are obtained by assuming that the tensor T associated with a system of electric charges is of type $T = T_0 + \frac{3}{8}T_1 - \frac{5}{8}T_2$, where T_0 is a chaotic tensor whose magnitude inside an electron is different from its magnitude outside, the difference being sufficient to make the stress across each surface element of the electron continuous.

In order to retain the Newtonian law of motion in the form, rate of change of the momentum in any region equals the impressed force, it seems advisable to depart from the usual convention of electromagnetic theory and change the signs of the densities of energy and momentum and that of the flow of energy. It may be mentioned that the usual convention was adopted in order to force the energy and mass of an electron to be outside the electron, the result being that the rate of change of the electromagnetic energy inside the electron is represented as being equal to minus the resultant of the body and surface forces. With the assumption, however, that there is no momentum inside, the body force is shown to be equivalent to a surface force which is in accordance with the idea of Maxwell and others that all actions in the ether are really contact or surface actions.

This principle is also adopted in the new theory, but the body force is supposed to vanish in virtue of a set of equations which are assumed to be equivalent to the equations of motion. The new theory must be regarded simply as an experiment, its adoption or rejection must depend entirely upon whether the equations of motion do or do not give results that correspond with the facts.

So far the results seem rather promising. A mathematical reason is found why an electron, which has returned to rest after any type of motion, may have the same size and mass as before. If, moreover, we adopt as a criterion for the possibility of a given steady state of motion the requirement that there should be no radiation of energy to infinity we can say that

an electron may apparently describe a circular orbit round a positive nucleus of infinite mass, but two electrons at opposite ends of a diameter could not describe such an orbit because there would be a continual radiation of energy to infinity.

The chief disadvantage of the new theory is that it makes the electromagnetic energy negative and requires that negative electromagnetic energy should be radiated, when an electron is accelerated, to compensate for the positive energy, depending on the scalar potential Ψ, which is radiated in various directions.

The existence of negative energy in the ether may be avoided by adding a chaotic tensor of suitable magnitude, whichever type of energy we regard as positive; the magnitude of this tensor outside the electron is, however, greater when electromagnetic energy is regarded as negative than when it is regarded as positive. This may be regarded as a disadvantage of the convention adopted here, consequently it seems advisable to leave the question of sign open and to assume temporarily that T_0 is zero outside the electrons and positive nuclei. Then, when the question of sign has been decided, a positive chaotic tensor may be added, if necessary, to make the density of energy everywhere positive. When we speak of negative energy we mean simply that its sign is different from that of the energy inside an electron and that it represents a deviation from the chaotic state in which there is a uniform distribution of energy. If we suppose that the present ordered state of the ether has been derived from a chaotic state, then the idea that a surplus of energy in one place is balanced by a deficiency in another seems reasonable. With this supposition, too, the total momentum must be zero, a condition which is satisfied in the case of a single electron if, as we found by calculation, the momentum inside is equal but opposite in sign to the momentum outside. This means that the mass of the electron can be calculated from conditions inside just as well as from conditions outside.

When an electron is moving along a straight line with uniform velocity v the contribution of the chaotic tensor T_0 to its internal energy is proportional to $\sqrt{1 - \frac{v^2}{c^2}}$ since the volume is diminished in the ratio $\sqrt{1 - \frac{v^2}{c^2}} : 1$ on account of the Lorentz-Fitzgerald contraction. The chaotic energy inside the electron, which is greater or less than the normal amount, according to the convention as to sign, may thus be regarded as proportional to $m_0 \sqrt{1 - \frac{v^2}{c^2}}$ where m_0 is the stationary mass. Now this is just the type of expression that occurs in the form of Hamilton's principle that has become so important in the modern theory of relativity, consequently the assumption of a chaotic tensor may be necessary for a physical interpretation of the Principal of Least Action.

The idea that the electromagnetic energy in a wave of light is negative may seem strange and contrary to the fact that light exerts a pressure, but it should be remarked that in our opinion the energy in a wave of light is really positive and depends for its positive quality on the disturbance specified by the retarded potential Ψ. So long as there is positive energy on the whole and a flow of positive energy in the direction of the waves there will be a pressure proportional to the density of energy.

In conclusion it may be remarked that the tensor, T, for an electron has been chosen so that in the state of uniform motion the mass, m, and total internal energy, E, are connected by Einstein's relation, $E = mc^2$.

The constant k in the expression for the mass appears to be $1/16\pi$ but it is not certain that this is the value which is actually measured, for, judging from a rough calculation, the total force exerted on an electron by the scalar and vector fields is, in a simple case at least, three times the ordinary electromagnetic force, the force exerted by the scalar field being twice as big as that exerted by the electromagnetic field. It should be remarked that both the total energy and the electromagnetic energy can be regarded as positive if an additional tensor is introduced for the interior of an electron and the usual convention of signs adopted. The value of k is then $\frac{1}{2\pi}$.

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