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The Nature of Mass

The Einstein enthusiasts are very patronizing about the 'classical' electromagnetics and its ether, which they have abolished. But they will come back to it by and by. Though it leaves gravity out in the cold, as I remarked about 1901 (I think), gravity may be brought in by changes in the circuital laws, of practically no significance save in some very minute effects of doubtful interpretation (so far). But you must work fairly with the Ether, and Forces, and Momentum, etc. *They* are the realities, without Einstein's distorted nothingness.

Unpublished notes of Heaviside, March 1920*

The modern idea of the nature of mass dates back to 1904, when Mach put forward the principle now named after him. It is still only an idea. The nature of mass, like its great property gravitation, is still a mystery to the physicist, the philosopher and the mathematician.

Let us examine a few authorities on the subject. First, what is Mach's principle? Sir Edmund Whittaker explains it thus:†

According to Mach's principle as adopted by Einstein, the curvature of space is governed by physical phenomena, and we have to ask whether the metric of space–time may not be determined wholly by the masses and energy present in the universe, so that space–time cannot exist at all except in so far as it is due to the existence of matter.

Whittaker was writing in April 1953. Mass, space–time and energy stand or fall together as the basic elements of this fabric

* The author is indebted to H. J. Josephs for his kindness in providing the above quotation from Heaviside's unpublished work as kept in the archives of the library of the Institution of Electrical Engineers in London. Mr. Josephs wrote about Heaviside's manuscripts in 'Postscript to the work of Heaviside', at p. 511 of the December 1963 issue of the *Journal of the Institution of Electrical Engineers*.

† *History of the Theories of Aether and Electricity, 1900–1926*, E. Whittaker, Nelson, 1953, p. 168.

which is us and our environment. The inertia of mass is due to the interaction of mass with all other mass in the universe. At about this time Sciama was writing his Ph.D. thesis at Cambridge 'On the Origin of Inertia':*

Einstein's work . . . shows that inertia is connected with gravitation. However, as Einstein himself was the first to point out, general relativity does not fully account for inertia. Thus a new theory of gravitation is needed.

Ten years later, in 1963, we find Bondi writing:†

What is gravity? . . . We are more familiar with its effects than with perhaps the effects of any other force. Nevertheless, science finds it rather difficult to digest gravity, and our best modern theory of gravitation, Einstein's theory, is a very complete and beautiful theory that yet does not quite fit in with the rest of physics . . . we do hope to gain much more insight once this great difficulty, this gap between the theory of gravitation and the rest of physics, has been closed.

This was followed in 1964 by Hoyle:‡

Einstein's mathematics has always been a complete unit in itself. It has remained an isolated corner of physics which nobody has succeeded in relating in a really fruitful way to the rest of physics.

Is this progress? Surely we should heed Heaviside. We must come back to the aether, to classical ideas, to the circuital laws of electromagnetism. We must cast Einstein's 'distorted nothingness' aside, and our prejudice as well, and think again. We must heed Dirac's conclusions in 1938 that the boundaries of the electron extend to infinity and that space–time fails in the 'interior' of the electron. We must think again about the nature of this electron, and stop talking about signals travelling faster than light and particles being accelerated without accompanying force.

At the Kelvin lecture of the Institution of Electrical Engineers delivered by Hoyle in 1970 he spoke of signals from the future. In a report published by the Institution we read:§

* *Abstracts of Dissertations, 1953–1954*, Cambridge University Press, 1956, p. 276.

† See footnote reference on page 6.

‡ See footnote reference on page 6.

§ *IEE News*, p. 16, May 11, 1970.

Such signals would affect the form of the laws of physics, whereas signals from the past merely give information. The basis of such speculation is an analogy with the familiar 'action and reaction' concept in classical mechanics. To be able to 'signal' to a distant object, something must be propagating from the object to the signaller—a signal from the future. The backwards propagation has never been observed because it is impossible to 'waggle' a charge in isolation; the rest of the universe is always present. In 1945 Wheeler and Feynman calculated that the effects of all 'backwards' signals from all the particles in the universe cancel exactly. Conversely the future completely absorbs electromagnetic radiation.

I cannot understand all this. I know that we still read about the difficulties of explaining how an electron sustains the energy it is supposed to radiate when accelerated. I suppose the distant universe has to feed in, by some kind of signalling system, the energy needed by the electron to sustain radiation. But is this not just another way of saying that the electron interacts with the aether so as not to radiate its energy? Why go about in such a roundabout fashion to say this simple thing?

We should not explain gravitation without first finding the explanation for mass itself. We should not try to explain mass in terms of interaction with other mass, because that is to probe gravitation before we understand mass. We should, instead, explain mass in terms of electric charge, discarding Mach's principle for a new one, the principle we see in such clear evidence, the principle that an electric charge will move to preserve itself. It will react to electric disturbances in just such a way as to conserve its charge and its intrinsic energy. That is the principle revealed to us by Nature herself. All we have to do is to show that it accounts for the properties of inertia. It is easy to prove by mathematics* but, in view of the strong criticism levied against the mathematical approach in the previous chapters, we will proceed using pure physics.

Surrounding an electric charge there is supposed to be what we call an electric field. Electric energy of the charge is determined by multiplying the strength of this field by itself at every point and summing the resulting quantity over all surrounding

* *Physics without Einstein*, H. Aspden, Sabberton Publications, Southampton, 1969, pp. 11–13.

space. Energy and charge are the fundamental quantities, not field, but it does appear that the energy associated with electric charge has a spatial distribution which fits the above concept when taken with a vector field radiating uniformly from the charge. Also, the field apparently moves as an integral system with the charge when the latter is not accelerating. The system is depicted in Fig. 3. The field idea is useful when the interaction between two charges separated by a fixed distance is analysed. Then, by combining the field components of both charges before squaring and summing, the change of energy with separation distance can be calculated. Coulomb's law can be derived in this way.

When the charge in Fig. 3 is accelerated a disturbance in the field is propagated outwards. We assume that the propagation is at the fixed speed of light. This is logical because we have specified charge and energy and need a third dimensional constant involving time. All physics can be linked by the use of three dimensional quantities. Mass, length and time are the familiar dimensions used, but, fundamentally, we can take electric charge, energy and a velocity parameter, if we prefer. The algebra of physics will take us from one system to the other, but given energy, the universal character of the velocity of light and the fundamental role of electric charge, it seems best not to stay with mass, length and time in an endeavour to explain the nature of mass.

Fig. 4 shows how the field of the charge in Fig. 3 is distorted by an infinitesimal pulse of acceleration in the direction V. The field depicted shows the position of the radiated field disturbance as it speeds outwards to its infinite destiny. When an electric charge is accelerated it emits field disturbances which set up waves in space. There are two imaginary spheres bounding the disturbance zone. The outer one is centred on a position the charge had immediately before receiving the acceleration pulse. The inner one is centred on a new related position to which the charge had moved at the incremental velocity during the period taken for the disturbance to spread to the zone under study. The radial distance between the two imaginary spheres is equal to the distance travelled at the propagation speed in the small

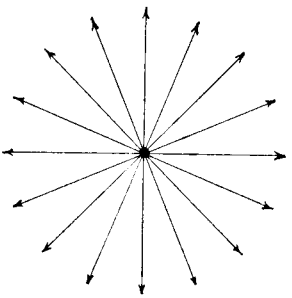

Fig. 3

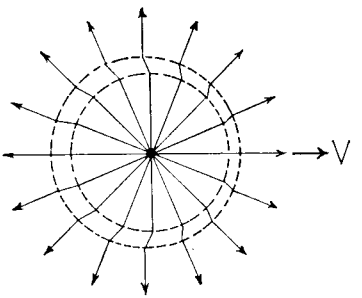

Fig. 4

interval during which the acceleration occurs. We can ignore the non-concentricity of the spheres because the acceleration pulse would have to increase the velocity of the charge by an amount equal to the propagation velocity itself to make the eccentricity distance equal to the radial separation of the spheres. We are dealing with the effect of a small acceleration pulse, productive of small changes in velocity as we experience in Newtonian mechanics.

The field lines in Fig. 4 radiate from the centres of the two spheres and are accordingly distorted, as shown, in the disturbance zone. Now, in effect we can separate the field into two systems, one of the form of Fig. 5 and another of the form shown in Fig. 6. The field directions of these two systems are orthogonal at all points. Thus, considering energy, we can square and add components separately using Pythagoras' Theorem. We then see how the disturbance has its own added energy in a wave zone. The total field energy of Fig. 5 must be the same as that of the non-accelerated charge, by comparison with Fig. 3. We have the added field components of Fig. 6 to consider, and these must, it would seem, add energy which is radiated outwards as the zone goes off to infinity.

Since we are portraying the process of energy radiation, we can easily see that deceleration will still send energy outwards. The radiation process is irreversible. Using mathematics this model can also yield the accepted formula for energy radiation. The method presented here has been attributed to J. J. Thom-

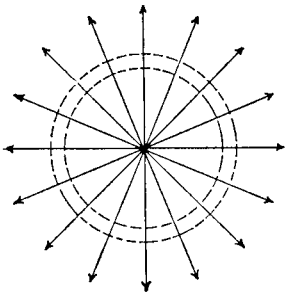

Fig. 5

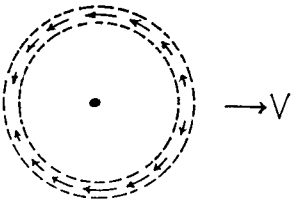

Fig. 6

son. Hence, the reader may ask how we can retain the assertion that the electric charge does not radiate energy. Well, the answer is so obvious once you see it. The business of squaring and adding only works to give energy correctly if there are no other electric fields present. We really can never say that our charge exists in complete isolation in a universe devoid of other electric field-producing charge, particularly if we wish to give it a little pulse of acceleration.

Let us assume that our charge has decided to move in the direction of the ambient electric field, seeking to conserve itself and being unwilling to radiate its energy as we have described. There is then an electric field in the direction V. This field is in the direction V because like charges repel and there is repulsion of the charge in the V direction. This ambient field itself does not move with the field disturbance radiating from the accelerated charge. Now, as is known, where we have two field components which act in opposition and which are not orthogonal but are directly opposed, we obtain three energy density components when we square the result. We have two quantities found by squaring each component independently and we have a negative energy density component due to the interaction of the components. The self combination of the components of the ambient field adds nothing to our energy radiation problem because the field itself is not moving. The energy radiation terms deduced from Fig. 6 do remain as positive radiation. However, the interaction with the field in Fig. 6 will introduce negative energy radiation as well. Now, the overall field energy at any

point can never be negative. A component can be negative if we have another component which is adequately positive. The negative energy component under review will appear in the wave zone as the disturbance travels outwards to infinity. This negative quantity can cancel the zone energy exactly. This is seen if we resolve the ambient field at each point in the zone into a component in line with the disturbance field components of Fig. 6 and other components in orthogonal directions. The component in opposition with the disturbance field component increases from zero to a maximum around the wave zone exactly as does the disturbance component. Now, if two terms separated by a minus sign are squared and added so that the interaction component cancels the square of one of the terms alone, this term is exactly double the other term. It follows, therefore, that for zero energy in the disturbance zone due to the acceleration pulse the ambient field must be exactly half of the maximum field component shown in the disturbance zone in Fig. 6.

Hence, if we have an electric charge in an electric field and it reacts to avoid energy radiation it will move so that it produces a distorted field satisfying this criterion. The field which produces the acceleration actually prevents energy radiation. An accelerated charge does not radiate its energy and thereby it derives its property of inertia.

Why has this been missed by the great thinkers of the classical period in physics? Probably because they were convinced that light conveyed its energy by waves in the aether. The discovery of the photon and the quantum features of energy transfer had not daunted their belief in wave theory and the clear mathematics of energy radiation by accelerated charge. They could take the disturbance zone of Fig. 6 out beyond the range of the local field producing the acceleration. Radio waves travel far from the electric circuits producing the electron oscillations in the transmitter. However, this is assuming that the energy ever gets away from the electron in the first place.* If there is an aether a wave might come along and merely ripple the energy already present in the aether itself. Field energy cannot be con-

* See later discussion in Chapter 12.

veyed by waves, as is so clearly evident from quantum behaviour in energy transfer. It is also evident from our illustrated analysis, because as the disturbance field components are propagated away from the charge they become weaker. The related components of the ambient electric field do not weaken in this way. Therefore, the passage of the wave causes a ripple of negative energy in the field-permeated surrounding space. This only means that the local energy is deployed into other forms, but it tells us something very important about the electric charge emitting the disturbance. The zero net energy condition has to apply at the surface of this charge.

If the charge is contained, say, in a hollow spherical shell containing a void and surrounded by the aether medium, there is nothing inside it to store any energy. It, the charge, is a mere spherical shell. It moves so as not to radiate any energy or even deploy any of its energy at the location of its charge. Hence, the condition for the half field response applies exactly at its outer surface. This means that given a unit strength ambient field acting on a unit strength charge, the charge will accelerate to develop a double unit field at its surface at positions lateral to the acceleration direction. The field which is developed here is found as the radial field of the charge as distorted by a deflection equivalent to multiplying it by the ratio of the eccentricity distance of the spheres already mentioned to the radial distance between the spheres. This ratio works out to be the acceleration times the time it takes for the disturbance to develop at the surface divided by the propagation velocity of the disturbance. This is simply the acceleration times the radius of the charge divided by the square of the propagation velocity. The radial electric field is simply the unit strength charge divided by the square of the radius, using the simple inverse square law of field. Thus, the disturbance field developed is the acceleration divided by the charge radius and by the square of the propagation velocity. For unit spherical charge, the charge radius is one half of the reciprocal of the energy stored by the charge. The disturbance field then becomes double the acceleration times the energy divided by the square of the propagation velocity, and we know that the acceleration is such that this field is two

units in strength. It follows that unit force developed by unit ambient field on unit charge will produce an acceleration inversely proportional to the energy divided by the propagation velocity squared. In other words, the electric charge, in responding so as not to radiate its energy, will display the property we term mass. Its mass will be equal to its energy divided by the square of the velocity of propagation of the aether medium. Thus, its energy will equal its mass multiplied by the square of the velocity of light.

We have now accomplished our task. Mass is explained as the property of an electric charge in contriving to avoid energy exchanges at its surface. It emits waves when it is accelerated by an electric field. It causes oscillations in the aether when it is oscillated itself. The energy in the aether is disturbed, but at the very boundary surface of the electric charge there is no disturbance. The charge has found a way of moving which brings a calm unruffled field condition to its surface form. Meanwhile the accelerating electric field puts some of its energy into another form in recognition of the acceleration imparted to the charge. This is the kinetic energy of the charge. It is stored in the field without disturbing the field remote from the surface of the charge and this can only be true if in fact the charge sphere shrinks a little to create more space for field energy. Kinetic energy is stored by the charge reducing its radius.

In explaining the nature of mass we have come to the well-known relationship between energy and mass, on which much of Einstein's recognition is founded. We do not see inertia as a property dependent upon gravitation. Mass is a mere property of electricity. Inertia is synonymous with mass. One implies the other.

It is to be noted that the above argument has been applied to a spherical shell of charge. It applies equally to a solid sphere of charge. The latter is merely an aggregation of spherical charge shells. There is no energy transfer at the surface of each shell due to acceleration of its own charge. Further, if we consider interaction field effects between any two such shells, since there is no interaction energy within the outermost shell, we can have no energy transfer in this regard at the surface of the outermost

shell. It works out that the mass property is linked to energy by the same relationship.

It remains to ask what happens if the electric charge moves at a very high speed approaching the speed of light itself. Increase in mass with speed has been observed. The answer is given already. The charge does not change but in shrinking to store the kinetic energy the electric field energy has increased. Thus, since mass is proportional to this energy for a constant speed of light, mass increases. As speed increases with increasing mass the effect is compounded and, mathematically, it may be shown that the speed of light is limiting. Mass would be infinite at this speed.