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The Role of Energy

Relativistic Mass Increase

In the first two chapters of this work we have seen how electrodynamics can be linked to gravitation and have derived Einstein's formula for gravitation without recourse to his General Theory of Relativity. It has been shown that, given this new approach to Einstein's law of gravitation, there is little of consequence in his General Theory. Then, in our third chapter, we have addressed the issues of the Michelson–Morley experiment and found that there is scope for reviving the aether concept and so questioning much of Einstein's Special Theory of Relativity, particularly the concept of time dilation. In doing this there has been reliance upon two of Einstein's famous laws, the energy-mass relation and the relativistic formula for increase of mass with speed. However, these were said to have justification in classical electromagnetic theory quite independently of Einstein's theory. Our task is now to enlarge on this theme and show that $E=Mc^2$ has its origins in a very important energy conservation property.

At the outset it is stressed that experimental verification of $E=Mc^2$ is not proof of the Theory of Relativity. Einstein's theory dates from 1905. Einstein was not the first to theorize about the transmutability of energy and mass.

It was textbook knowledge in 1904 that electrons and positrons might mutually annihilate one another and create energy. In an article in *Nature* by Jeans* (1904) this mutual annihilation was proposed and argued to be a 'rearrangement of the adjacent aether structure'. Quoting from Jeans' paper:

> There would, therefore, be conservation of neither mass nor material energy; the process of radioactivity would consist in an

* J. H. Jeans, *Nature*, 70, 101, June 2, 1904.

> increase of the material energy at the expense of the destruction of a certain amount of matter.

Jeans' ideas were mentioned in the 1904 book by Whetham*;

> A more fundamental suggestion has been made by J. H. Jeans, who imagines that radio-activity may result from the coalescence of positive and negative electrons. On this idea, the energy of radio-active atoms is supplied by the actual destruction of matter.

This was before Einstein wrote on the $E = Mc^2$ subject and, of course, very much before Dirac theorized about the existence of the positron and the mutual annihilation of electrons and positrons. Simple dimensional analysis tells us that if energy and mass are interchangeable they must be related by a speed dimension squared. The early twentieth century physicists were seeking to understand how the Sun could pour out its energy for so many years and yet not appear to cool down. Here was their answer, but the speed parameter had to be very high. The connection was the speed of light c.

Quoting again from Whetham's 1904 textbook (p. 283):

> Theory shows that, for a slowly moving corpuscle, the electric inertia outside a small sphere of radius a, surrounding the electrified particle, does not depend on the velocity, and is measured by $2e^2/3a$ where e is the electric charge of the particle. But when the velocity of light is approached, this electric mass grows rapidly; and, on the assumption that the whole of the mass is electrical, Thomson has calculated the ratio of the mass of a corpuscle moving with different speeds to the mass of a slowly moving corpuscle, and compared these values with the results of Kaufmann's experiments. In this remarkable manner has it been possible to obtain experimental confirmation of the theory that mass is an electrical or aethereal phenomenon.

Here we refer to physics as it was before Einstein presented his theory. Yet we speak today of relativistic mass increase of the electron as if we owe its justification exclusively to the principles first enunciated by Einstein.

* W. C. D. Whetham, *The Recent Development of Physical Science*, John Murray, London, p. 290, 1904.

It is of interest that Jeans,* writing in 1929, disclaimed the priority of his idea about mass-energy transmutability:

> More than twenty years ago I directed attention to the enormous store of energy made available by the annihilation of matter, by positively and negatively charged protons and electrons falling into and annihilating one another, thus setting free the whole of their intrinsic radiation. On this scheme neither energy nor matter had any permanent existence, but only a sort of sum of the two; each was, theoretically at least, convertible into the other.
>
> When I put forward this hypothesis, I thought I was advocating something entirely revolutionary and unheard-of, but I have since found that Newton had anticipated something very similar exactly two centuries earlier. In his *Opticks* (1704) we find:
>
> 'Query 30. Are not gross bodies and light convertible into one another; and may not bodies receive much of their activity from the particles of light which enter into their composition? The changing of bodies into light, and light into bodies, is very conformable to the course of Nature, which seems delighted with transmutations.'

In classical electromagnetic theory the electromagnetic momentum of a field is equal to the flow of energy through unit area in unit time divided by c^2. c is the speed of an electromagnetic wave in a vacuum. In attributing this knowledge to Sir J. J. Thomson, Wilson† goes on to show that, since energy can be converted from one kind to another while momentum is conserved, there must be general validity for:

$$E = Mc^2 \tag{64}$$

Here E is the total energy associated with a mass M. Then from this Wilson deduces the dependence of mass upon velocity v, obtaining the usual (so-called relativistic) formula:

$$M = M_0(1 - v^2/c^2)^{-\frac{1}{2}} \tag{65}$$

His analysis relied upon there being *no loss of energy by radiation.* Let a force F act on a particle of momentum Mv. Then:

$$Fdt = d(Mv) \tag{66}$$

* J. H. Jeans, *EOS or the Wider Aspects of Cosmogony*, Kegan Paul, Trench, Trubner, London, p. 36, 1929.

† H. A. Wilson, *Modern Physics*, 2nd ed., Blackie, London, p. 8, 1946.

where dt is a short interval of time. Write the amount of energy transferred in this short interval of time as dE, which from (64) is c^2dM. This is put equal to the work done by the force F to give:

$$Fvdt = c^2dM \tag{67}$$

From (66) and (67):

$$v\,d(Mv) = c^2dM \tag{68}$$

Multiply this by M:

$$(Mv)d(Mv) = c^2MdM \tag{69}$$

Integrate (69):

$$(Mv)^2 = c^2M^2 + K \tag{70}$$

where K is a constant.

Now write M as M_0 when v is 0:

$$M^2v^2 = c^2(M^2 - M_0^2) \tag{71}$$

Rearranged this gives the formula (65). In fact, we have deduced the 'relativistic' mass formula from $E = Mc^2$ using simple Newtonian principles.

This rigorous mathematical treatment proves that the Einstein mass-energy formula and the relativistic mass formula are only compatible if there is no loss of energy by radiation due to acceleration. This is seemingly in direct contradiction to Wilson's derivation of $E = Mc^2$ in terms of energy transfer by electromagnetic radiation.

In this connection reference is made to a commentary by Krause* who discusses the thought experiment proposed in 1904 by Hasenohrl. This concerns the behaviour of electromagnetic radiation trapped by internal reflection within a lossless cavity. It is a method of explaining $E = Mc^2$ discussed by Lenard† and it has reappeared in the literature recently in a new form in the work of Jennison and Drinkwater.‡ The point made by Krause is that, if $E = Mc^2$ is explained by associating mass properties with radiation, then there is incompatibility with the assumption that E is conserved and that energy is not dispersed by radiation. However, as Krause notes, if E is conserved as trapped radiation how can we be justified in using the formula $dE = c^2dM$, as we do in equation (67) above? If E is the total trapped energy in the wave system and it is constant, then we cannot suppose it to change. It becomes, therefore, difficult to

* *American Journal of Physics*, **43**, 459 (1975).

† P. Lenard, *Physik*, vol. 4, Lehmann's Verlag, Munich, p. 157 (1936).

‡ *Journal of Physics*, **A, 10**, 167 (1977).

deduce the relativistic mass increase from Hasenohrl's thought experiment in such circumstances.

What is really needed is an explanation of $E=Mc^2$ which overcomes these difficulties and is itself based upon the assumption that there is no loss of energy by radiation. Einstein's method of deriving the formulae for the relativistic mass increase and the mass-energy relation also do not escape criticism on this issue of energy radiation. Relativity gives no comprehensive account of the radiation processes. Indeed, the numerous papers on the subject fail to provide a coherent treatment of the problem, as we shall see in the next section.

The author believes that the true interpretation for this paradox is that Nature assures an effective 'no radiation' condition for electric charges undergoing acceleration. Space is seething with energy in an equilibrium state. If there is radiation disturbing this equilibrium then energy must be fed back to radiating matter to restore the balance. Quantum electrodynamics may play a role in this. However, Einstein's theory provides inadequate physics, even with regard to its basic formulae (64) and (65) above.

Energy Radiation

The scientific literature abounds with confusion on this question of energy radiation by accelerated charge. One view is that of Stabler* who has suggested that an accelerated charge does not radiate energy but that, collectively with other charge, it may somehow participate in an energy radiation from the mutual field system. Aharoni† in a detailed text on Relativity has written at length on the subject of energy radiation by the accelerated electron, but has made it appear quite mysterious:

> The radiation, whether into the source or away from it, introduces an asymmetry in time, or a time arrow, and this cannot be explained in electromagnetic terms.

He then refers to the theories of Wheeler and Feynman (1945) and follows that by the treatments of Dirac (1938) and Rohrlich (1960), arriving at a point where he writes:

* R. C. Stabler, *Physics Letters*, **8**, 185 (1964).

† J. Aharoni, *The Special Theory of Relativity*, 2nd ed., Oxford University Press, pp. 186 and 198, 1965.

> It is typical of the new situation that the law of causality in its strict classical form does not hold. Already a short time before a force is applied the electron begins accelerating and the acceleration begins to diminish a short time before the applied force is stopped (assuming that such a step force can be produced). The time in question . . . is the time it would take an electromagnetic wave to cross an electron. It is possible to interpret this result by saying that the electron has finite size and that at the instant the fringe of the electron experiences a force, it is transmitted with infinite velocity through the electron (breakdown of ordinary space-time laws inside the electron).

Some argue that the Theory of Relativity is inconsistent with the radiation of energy by accelerated charge. For example, Weber* talks of the equivalence principle and annulling of gravitational fields by appropriate acceleration. In free fall within an elevator he says:

> A body would move within it as though no gravitational field were present, and no observations made on the body could enable a distinction to be drawn between an inertial frame and the space inside the elevator. . . . It is not clear that this will still be true if the body within the elevator is electrically charged.

Weber then refers to several papers discussing radiation by a point charge electron. The authors are Bondi and Gold (1955), DeWitt and Brehme (1960), Drukey (1949) and Fulton and Rohrlich (1960). After talking of the complication arising from the infinite self-energy of a point electron, Weber concludes:

> It may be that when the internal structure of elementary particles is properly taken into account, a charged particle will be found to radiate and have a non-vanishing radiation reaction when falling in a uniform gravitational field. It would follow that by observing a charged and uncharged body falling freely we can distinguish by local measurements whether we are in an inertial frame or falling freely in a gravitational field. The equivalence principle then becomes merely a guide for the formulation of the equations of the gravitational field alone, and not a general law of nature.

* J. Weber, *General Relativity and Gravitational Waves*, Interscience Publishers, New York, 1961, p. 146.

It is evident from this that the radiation of energy by the accelerated electron is an enigma confronting Relativity. DeWitt and Brehme* in the abstract of their paper write:

> The particle tries its best to satisfy the equivalence principle in spite of its charge.

But, surely, it might be more a question of the particle, not being a point charge with infinite mass, trying its best to conserve its charge in spite of its finite mass. The principle of equivalence, meaning the role which the inertial mass plays in being also the gravitating mass, seems rather too fundamental to be questioned due to energy radiation problems, particularly in view of the total lack of experimental evidence that a discrete accelerating electric charge radiates any energy continuously.

Far from being resolved with the progress of time, the problem gains momentum. Bonnor† drew attention to the implications of charge radiation in company with energy radiation. Wilkins‡ (1975) has discussed the paradox raised by Weber and, in accord with other writers, concluded that there can even be energy radiation by charges which are not moving. Meanwhile, the classical radiation problem has been addressed by Geodecke§ (1975), Moniz and Sharp** (1974) and Cohn†† (1975), the latter's work being challenged by Kapusta‡‡ (1976).

Reacting to Weber's comments, is it not better to accept the principle of equivalence and declare that an accelerated electron does *not* radiate energy? It is the simple answer and it is not a new idea. Referring to Pauli's contention that there is no energy radiation, Fulton and Rohrlich§§ wrote:

> Is Pauli's proof in error? If it is correct and if therefore uniformly accelerated charges do not radiate energy, where does the proof of the well-known radiation formula, found in the standard textbooks, break down?

* B. DeWitt and R. W. Brehme, *Annals of Physics*, **9**, 220 (1960).
† W. B. Bonnor, *Nature*, **225**, 932 (1970).
‡ D. C. Wilkins, *Physical Review*, **D12**, 2984 (1975).
§ G. H. Geodecke, *Nuovo Cimento*, **30B**, 108 (1975).
** E. J. Moniz and D. H. Sharp, *Physical Review*, **D10**, 1133 (1974).
†† J. Cohn, *Nuovo Cimento*, **26B**, 47 (1975).
‡‡ J. Kapusta, *Nuovo Cimento*, **31B**, 225 (1976).
§§ T. Fulton and F. Rohrlich, *Annals of Physics*, **9**, 499 (1960).

We will examine this question in the next section. It will be shown that close to the accelerated charge there is an action which suggests that any radiation of energy is not sourced in charge itself. One could argue that the well-known formula breaks down because it depends upon the *assumption* that energy is radiated rather than being locally exchanged with the space medium. Long ago, Livens* (1926) has shown how Poynting's theory can be modified, without departing from formulae consistent with observation, to become a theory which:

> does not associate energy at all with the radiation, so that no question of its transference arises.

When Dirac† (1938) adapted the classical theory of energy radiation by accelerated charge to accommodate relativistic principles, he concluded:

> It would appear that we have a contradiction with the elementary ideas of causality.

It is appropriate, however, to note that Dirac relied to some extent upon the earlier ideas of Schott‡ (1915) who had shown that the work done by the accelerating field:

> is converted into kinetic energy as if there had been no radiation at all.

The price paid in linking radiation with this balance of energy between the interacting field system and the kinetic states was the introduction of a separate energy called 'acceleration energy'. In Schott's work this was based upon the action of a *mechanical aether*.

Grandy§ was another voice on the subject:

> There is no paradox in the Lorentz–Dirac theory of the classical electron. Nevertheless, the physical picture provided by the theory is somewhat unsatisfactory, because one does not completely understand the physical origin of the Schott energy. . . . Plainly, the problem is that a clear insight into the Schott energy is outside the scope of classical electrodynamics. No relief is to be found in

* G. H. Livens, *Theory of Electricity*, Cambridge University Press, 2nd ed., 1926.

† P. A. M. Dirac, *Proc. Roy. Soc.*, **A167**, 148 (1938).

‡ G. A. Schott, *Phil. Mag.*, **29**, 49 (1915).

§ W. T. Grandy, *Nuovo Cimento*, **65A**, 738 (1970).

quantum electrodynamics, either, which is totally unable to account for the structure of the electron. We must, therefore, wait for a satisfactory theory of fundamental particles, if one should ever emerge, in order to gain a more satisfying physical picture.

The problem of electromagnetic energy transfer by the radiation process is not satisfactorily answered in modern works of reference. How can energy be radiated continuously by acceleration and yet satisfy our belief that energy is transferred in quanta? The problem could involve the mere assumption implicit in the use of the Poynting vector, namely that energy is radiated. The supposition that a wave does carry energy at the speed of light is itself suspect. We associate particles with transfer of energy and particles never quite reach the speed of light. Photons are imagined to travel at the speed of light but deemed to transfer energy in quanta. The waves on the sea do not convey water along at the speed of the wave. The water present locally is disturbed to form the wave motion as the disturbance is communicated from adjacent water. Can it be that space is permeated by energy in a form which can be disturbed to give the appearance of something progressing through it at the speed of light? These are speculations which are unlikely to clarify the situation, but they need to be kept in mind.

The other argument is that energy is released in quanta but does not travel in quanta. The photon may be an event in which energy is released and disseminated throughout space by a dispersal unrelated to the wave radiation, but the reverse photon event by which energy is extracted from the space medium may be statistical in character. The energy might appear to travel at the speed of light but, in reality, it is added to the sea of energy in space and spreads gradually until equilibrium asserts balance. This equilibrium process coupled with the action of the spreading wave can seemingly induce a resonance in the space medium and transfer an energy quantum from the sea of energy present to the matter associated with the resonance condition.

Whatever conclusions are drawn on the question of energy radiation, it remains logical to regard the accelerated charge as a conservative element, preserving its energy on a shared basis with other interacting charge. If there is energy radiation in the field then it could be that the field medium itself is a whole seething sea of electric charges of the two polarities, all busy exchanging energy with matter. This must then be a two-way process, assuring that charge does not have any net radiation loss of energy when accelerated. It will be shown that, apart from the non-radiation condition reconciling the Einstein mass-energy formula and the relativistic mass formula, it can be the basis of explaining the nature of inertia and the actual derivation of $E = Mc^2$. This will be the subject of the next section.

First, however, it is appropriate to mention that in high energy collisions between electrons it has been verified experimentally that momentum is shared in accordance with dynamics based upon the relativistic mass formula, but only provided there is no loss of energy by radiation in the collison. This was firmly shown by Champion.*

Also, we should refer to Einstein's own argument. In his basic paper† 'On the Electrodynamics of Moving Bodies' there is the derivation of the relativistic energy equation:

$$E = Mc^2[(1 - v^2/c^2)^{-\frac{1}{2}} - 1] \tag{72}$$

He argues:

> As the electron is to be slowly accelerated, and consequently may not give off any energy in the form of radiation, the energy withdrawn from the electrostatic field must be put down as equal to the energy of motion of the electron.

This must raise questions about the relevance of the Larmor radiation formula.

Later in the same year Einstein‡ presented a second paper entitled 'Does the Inertia of a Body Depend upon its Energy Content?' His method of calculation relied upon three elements:

(1) the Maxwell–Hertz Equations for empty space,
(2) the Maxwellian expression for the electromagnetic energy of space, and
(3) the Principle of Relativity.

In a footnote it is observed that the principle of the constancy of the velocity of light is contained in Maxwell's equations. The energy content of an electromagnetic wave is introduced and Einstein arrives at the conclusion that the emission of energy E by radiation diminishes the mass of a body by E/c^2. He writes:

* F. C. Champion, *Proc. Roy. Soc.*, **A136**, 630 (1932).
† *Annalen der Physik*, **17**, 891 (1905). ‡ Ibid., **18**, 639 (1905).

The fact that the energy withdrawn from the body becomes energy of radiation evidently makes no difference, so we are led to the more general conclusion that the mass of a body is a measure of its energy content.

The perplexing question we are left with is why energy radiation is needed to explain $E=Mc^2$ but energy radiation is expressly forbidden if we are to correlate $E=Mc^2$ with the formula for relativistic mass increase. Let us resolve this problem by showing how we can deduce $E=Mc^2$ from the very opposite viewpoint, the fact that there is no radiation of energy by accelerated charge.

The Energy-Mass Formula

Consider the problematic Larmor formula:

$$\frac{dE}{dt}=\frac{2e^2f^2}{3c^3} \tag{73}$$

and examine its derivation. It expresses the rate at which energy is radiated from an electric charge e when accelerated at the rate f.

The formula was founded upon the assumption that waves are developed by an accelerated charge and spread remote from the charge into empty space. Then, by the additional assumption that energy is carried by these waves, an energy radiation as given by the Larmor formula is obtained. The effects of the accelerating field are irrelevant at large distances and do not affect the waves. Accordingly, the accelerating field need not be considered in the classical derivation of the formula. It is this latter comment that attracts our attention in this critical examination.

Let us first summarize how the Larmor formula is derived using a textbook method attributed to J. J. Thomson. Refer to Fig. 21. At a point P in the wave zone distant ct from a charge e centred at O the electric field disturbance which gives the energy radiation is of the form:

$$\frac{ef\sin\theta}{c^3t} \tag{74}$$

Here θ is the angle between OP and the direction of an accelerating electric field V or acceleration f. The field given by (74) is at right angles to the electric field of e acting along OP.

The Larmor formula is deduced by integrating the energy density attributable to this field term (74) for an elemental volume $2\pi(ct)^2 \sin\theta\ cdt\ d\theta$ between the limits $\theta=0$ and $\theta=\pi$, and then doubling the result to allow for the equal contribution of magnetic field energy

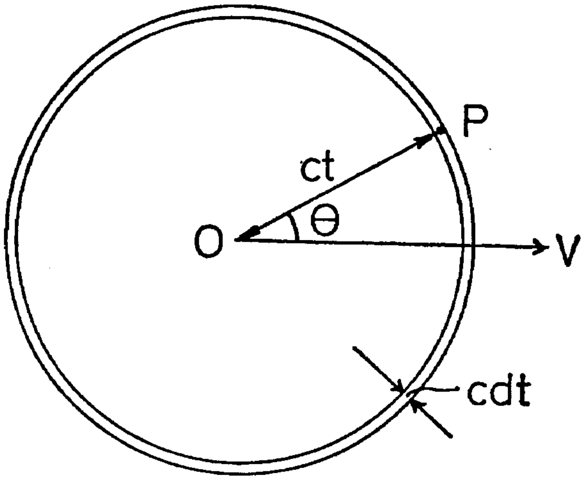

Fig. 21

and electric field energy characteristic of Maxwell's equations. This will give the energy radiated in the time interval dt. The result is:

$$2\int_0^\pi \left[\frac{1}{8\pi}(ef\sin\theta/c^3t)^2 2\pi(ct)^2\sin\theta\ cdt\right]d\theta = 2e^2f^2dt/3c^3 \qquad (75)$$

At this stage we are not interested in what happens remote from the charge. We question the assumption that energy is radiated at all and concentrate attention on the source of the alleged radiation. This is where the accelerating field V does its work and interacts with the field set up by e itself. The field energy density must then include the interaction with V omitted from the derivation of the Larmor formula. The field given by (74) is then:

$$\frac{ef\sin\theta}{c^3t} - V\sin\theta \qquad (76)$$

Squaring this and restricting attention to the time-dependent components, we obtain:

$$(ef\sin\theta/c^3t)^2(1 - 2c^3tV/ef) \qquad (77)$$

It is then immediately evident that there is no energy radiation if the latter part of this expression is zero, that is, if:

$$Ve/f = e^2/2c^2(ct) \tag{78}$$

Since it is the basic hypothesis of this attempt to deduce $E = Mc^2$ that there is no radiation of energy, we must admit (78). To proceed, let us distinguish between an electric charge confined by a boundary of radius a and the empty space surrounding this charge boundary. Regard the field of the charge in this surrounding space as an integral system. On this basis we may expect the Coulomb self-energy of the electric charge in the field surrounding the charge to exhibit a single-valued mass property related to the energy:

$$E = e^2/2a \tag{79}$$

E is now energy associated with the charge e but located outside radius a. This is the energy corresponding with the expression Ve/f in (78) when ct is equal to a. Therefore:

$$Ve/f = E/c^2 \tag{80}$$

becomes the condition for no energy radiation across the radius bounding the charge. Ve/f then becomes the mass property associated with the Coulomb energy E. We have arrived at the anticipated result that $E = Mc^2$.

We must now consider the case in which the charge e is so distributed within the sphere of radius a that there is additional Coulomb energy within this sphere. We will adhere to the assumption that the self-energy of any charge exhibits a single-valued effect outside the spherical boundary confining that charge. In line with this the mutual interaction Coulomb energy of two spherical shell elements of the same body of charge will be deemed single-valued outside the outermost shell. It is, of course, zero within this shell.

In the case to be considered we regard the whole body of charge in uniform acceleration f. Thus a whole succession of shells of charge de_x of thickness dx at radius x undergo acceleration at the rate f simultaneously. It may then be shown, by tracing through the above analysis and developing a formula such as (75) based upon (76) rather than (74), that the energy radiated in time dt is given by:

$$(4f^2/3c^2)[\textstyle\sum de_x(\sum de_x/2c^2 - Vct/f)] \qquad (81$$

where the value of ct is equal to the higher x value for any cross-product component term involving $de_x de_x$. The reason for this is evident if we write the two terms as de_x and de_y, where y is greater than x. For $(de_x)^2$ there is no radiation from the radius $ct=x$, the actual radius of the charge de_x. Similarly for $(de_y)^2$ there is no radiation of energy from the radius $ct=y$. For $(de_x)(de_y)$ there is no energy within the radius y and we can only look for radiation from the radius y, but as we say there is none then the condition that (81) is zero is that the value of $ct=y$ applies to cross-product terms at the higher charge radius.

For each such component interaction it is then evident that the identity:

$$\frac{(de_y)\sum(de_x)}{2c^2}=\frac{(de_y)Vy}{f} \tag{82}$$

with y greater than x applies and may be written in the form:

$$\frac{(de_y)\sum(de_x)}{2y}=\frac{V(de_y)c^2}{f} \tag{83}$$

Bearing in mind that all charge interactions are counted twice in a summation, the left-hand side of the above expression is the Coulomb interaction energy component dE. Summing this for the total charge e gives:

$$E=(Ve/f)c^2 \tag{84}$$

This is the same as (80) but it now applies generally to any spherically-symmetrical charge distribution confined within a bounding sphere. It tells us that such a body of charge will, when subject to the field of other charge, be bound to move with an acceleration f if it is to avoid dispersing its energy by radiation. Thus we have deduced the property of inertia. By denoting Ve/f as the mass M we obtain:

$$E=Mc^2 \tag{85}$$

By the above analysis it is seen that there is a very good case for developing the $E=Mc^2$ formula based on the assumption that energy is not radiated. The flaw in the Larmor formulation has been discovered. It did not take account of the effects in the near vicinity of the charge due to the interaction of the applied accelerating field. However, all we have shown is that no energy emerges from a discrete charge when accelerated. This does not mean that the collective actions of many charges and the propagation of electromagnetic waves by accelerated charges play no role in energy transfer. Nevertheless one does need to be cautious about the assumptions in conventional field theory that energy is radiated, bearing in mind the scope for energy fluctuations within the sea of energy which appears to pervade space.

The essential point made in the above analysis is that the mass property is related exclusively to the intrinsic Coulomb energy of the discrete charge. This raises the question of how this energy is augmented when the charge is accelerated to increase the mass. Is the charge compacted into a smaller volume? Alternatively, are we to expect perhaps the creation of charge pairs in some quantum statistical manner? At least from the analysis in Chapter 2 we know that we need not look also for separate explanation of magnetic energy. This is a reacting kinetic energy and so must be a Coulomb energy associated with reacting charge.

Charge Equivalence

It is important to note that the derivation of the $E=Mc^2$ formula developed above involves a parameter c which is not the assumed electromagnetic propagation speed, but rather the speed at which an electric field disturbance propagates from an electric charge. This distinction commands attention because the parameter c for electric disturbance could well be more fundamental than that for electromagnetic disturbance. This leads us to consider the problem of charge equivalence, that is the identity of electric charge and that in evidence in electromagnetic actions.

First we consider the Principle of Equivalence given such great attention in Einstein's theory. This is the identity of inertial and gravitational mass. This is one of the earliest known facts of experimental physics. Galileo's legendary experiment at the leaning tower of Pisa and the later experiment in 1891 by Eotvos confirmed this equivalence. Further experiments by Dicke* have checked the accuracy of this equivalence to less than one part in 10^{10}.

Einstein's theory elaborates on the theme of equivalence of inertial and gravitational acceleration but it takes us no nearer to an understanding of the physical basis of the constant of gravitation G. Nor is there anything particularly surprising about the discovery that the mass which we know from inertia happens to be the mass developing

* R. H. Dicke, *Scientific American*, **205**, 84 (1961).

the gravitational effect. It obviously suggests that some inertial effect associated with a mass element produces the local distortion of the field medium, which in turn results in the gravitational attraction.

The equivalence of electric and magnetic charge is taken for granted in Einstein's physics. It is not wrapped up in a mystical 'principle'. Yet it is equally significant. An inertial mass M has a gravitational property we may express as $G^{\frac{1}{2}}M$. An electric charge e has a magnetic property we may express as e/c. There is the basic experiment by Rowland (1875) by which the magnetic action of moving electric charge could be related to current. Rowland's experiment was just as important as that of Galileo or Eotvos. Miller* in an article entitled 'Rowland's Physics' has discussed the importance of the experiment in confirming Maxwell's use of c in his theory, which was, of course, based upon the principle of charge equivalence.

The curious feature of this comparison is that c is basic to relativity, but the principles embodied in relativity are silent on the subject of charge equivalence. The development of magnetic theory has been less silent on the correlation of G with electric charge. It is interesting to trace the history of the Schuster–Wilson hypothesis,† according to which mass does exhibit a magnetic field as if it has an electric charge $G^{\frac{1}{2}}M$.

The derivation of $E=Mc^2$ by Einstein stems, as we have seen, from the use of c by Maxwell in his electromagnetic theory. Why electric charge and its magnetic equivalent are related by c is not explained.

In the new derivation of $E=Mc^2$ presented above, c was introduced as the speed at which electric field disturbances propagate from the charge exhibiting mass. This is the only speed that we can look to to account for the propagation of the Coulomb interaction between two charges via their field systems. It was in this way that the parameter c used in Fig. 17 was introduced to give an indirect connection with electromagnetic effects. Thus c becomes also the ratio of electrostatic charge and electromagnetic charge, that is the parameter used in Maxwell's Equations.

In concluding this chapter, it is noted that the J. J. Thomson formula for the electric inertia of the electron, $2e^2/3a$, as mentioned earlier in a 1904 quotation, is confirmed as a true mass formula, but for other reasons. The charge here is in electromagnetic units.

* J. D. Miller, *Physics Today*, **29**, 39 (1976).

† See H. Aspden, *Modern Aether Science*, Sabberton, pp. 28 *et seq.*, 1972.

Were e stated in electrostatic units then this formula would give Mc^2 as it applies to the electron. Thomson's derivation was based upon the integration of magnetic field energy throughout the space surrounding the charge sphere of radius a. This seems inappropriate, bearing in mind that we regard in this work the magnetic reaction as attributable to other discrete charge and the magnetic field concept is unlikely to have meaning over the microscopic range so close to the charge e. On the Coulomb energy explanation, note that the field energy outside radius a is $\frac{1}{2}e^2/a$ and, for uniform field intensity within the sphere, the field energy within the radius a is the volume $4\pi a^3/3$ times $(e/a^2)^2/8\pi$, or $e^2/6a$. The total Coulomb energy is $2e^2/3a$, which we equate to Mc^2 to find the same mass as J. J. Thomson. This formula will be used extensively in the further analysis in this work.