2

Gravitation and Magnetism

Retardation

The Coulomb interaction is fundamental in physics. In terms of electric field theory the energy density throughout space surrounding two interacting electric charges at rest can readily be calculated. When summed throughout space the resulting energy is found to depend upon the separation of the two charges and its dependence upon this spacing allows us to verify the Coulomb law of force.

The distribution of this energy becomes very important when we investigate the effects of charge motion upon energy deployment and the resulting interaction force.

Given two charges e and e' at a separation distance r, the charges now being in electrostatic units, we find that there is a Coulomb interaction energy ee'/r stored in the surrounding space, together with the energy of self-interaction of each charge, the latter being related to e^2 and $(e')^2$, respectively. The self-energy is that representing the mass of each charge. We expect then that as the two charges separate, assuming that they have like polarity, the interaction energy diminishes and is shared by the two charges in augmenting their self-energies. In other words they gain kinetic energy which augments their mass energy.

The question of interest is the mechanism of energy transfer from the surrounding space to the close proximity of either charge. This question led the author to ask about the spatial distribution of the interaction energy as viewed from either charge. Hence the interest in the previous chapter in working out the energy content of successive concentric shells centred on each charge and plotting this as a function of distance from the charge.

It is fascinating to find that the interaction energy, as seen from the perspective of either charge, is seated beyond the charge separation distance r. This was evident from Fig. 13, but we will now verify this using conventional field theory. Note first, however, that energy has to traverse the distance separating the charges in order to converge on the close locality of a receiving charge to augment its kinetic energy, particularly if one charge is relatively slow moving owing to its greater mass. The latter condition is one in which most of the interaction energy released is fed to speed up the lighter charge.

There is a quite simple graphical way of deriving the energy distribution shown in Fig. 13.* Consider a charge e in Fig. 14 developing a radial electric field V at radius x. Imagine then a charge e' distant r from e and developing an electric field V', at the radius x.

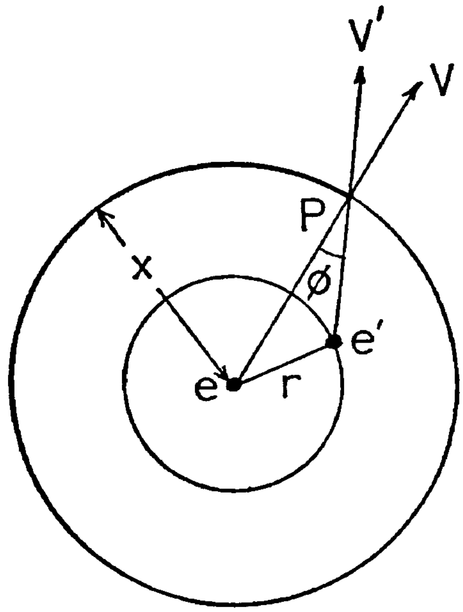

Fig. 14

Let y denote the distance between e' and a point P under consideration at radius x from e. Then, with φ as the angle between V and V', we know that the interaction energy density component at P is:

$$\frac{VV'\cos\varphi}{4\pi} \tag{28}$$

Also, V is e/x^2 and V' is e'/y^2. Now consider the volume of an elemental shell of the sphere of radius x and thickness dx, as subtended at P by a small solid angle from e'. The elemental volume is $y^2/\cos\varphi$ times this angle per unit thickness of the shell. Thus the

* H. Aspden, *Lett. Nuovo Cimento*, **25**, 456 (1979).

energy attributable to (28) in a shell of thickness dx is $ee'dx/4\pi x^2$ times the solid angle mentioned. Since this does not depend upon y, we can evaluate the total energy component dE for the full solid angle of 4π to obtain:

$$dE = ee'dx/x^2 \tag{29}$$

Now, provided x is greater than r, the fields V and V' are in the same direction. With x less than r the two regions of the spherical shell intercepted by the same solid angle have opposite and cancelling interaction energies owing to the change in direction of V relative to V'. Thus within the radius r the interaction field energy is zero.

This fully confirms the result inferred by a general interpretation of the inverse-square law of force, leading to the spatial energy distribution shown in Fig. 13.

If e and e' are in motion at the same velocity and carry their intrinsic electric fields bodily with them there will be no energy transfer and no retardation affecting the Coulomb force. Thus retardation of the electric action is not an answer to the electrodynamic interaction. The law of electrodynamics presented in Chapter 1 is attributable to magnetic effects, which, as we shall presently see, arise from the reaction of the space medium. However, if e and e' have velocities which differ, then there will be retardation associated with the electric interaction. Since electric fields propagate at the speed c, where c is the familiar parameter used in the mass-energy relationship $E = Mc^2$, we know, from Fig. 13, that it takes a time r/c for an acceleration pulse at e to communicate its effect to the interaction energy in the field. It takes exactly the same time r/c for e' to communicate with the interaction energy in the field. Accordingly, the total retardation time is $2r/c$ for the Coulomb interaction. Energy takes this time to transfer via the field from e to e' and energy in transit may not assert its action as part of the interaction energy accounting for the Coulomb force.

If the action of one electric charge on another is propagated a distance r in time $2r/c$ then the speed of propagation of disturbances in a sea of electric charge is $\frac{1}{2}c$. This is not to be confused with the propagation of electromagnetic waves or electric field disturbance. It is the displacement speed of charge in the propagation direction. This result will be applied later in this chapter.

Let us now consider the alternative spatial energy distribution presented in Fig. 12. This is presented again in Fig. 15, which includes an additional cross-shaded triangle to indicate the change resulting if r is reduced slightly. If r is reduced the interaction energy changes by the amount corresponding to the area of this triangle. Energy does not have to travel the full distance r, on average, to reach the interaction field. When there is a change in the spacing r between the

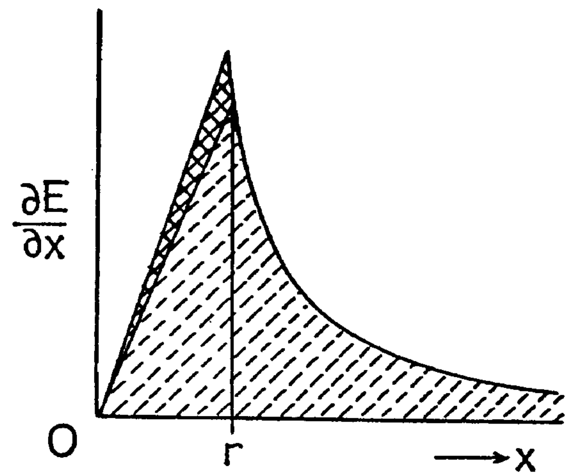

Fig. 15

interacting bodies the energy has to travel a distance $\frac{2}{3}r$ on average. This is because an energy element proportional to x travels a distance x and we need to evaluate the integral of the product of the two over the range O to r and find the average distance by dividing by the integral of the energy element factor x over the same range.

However, when considering the effects as a retardation we find that a retardation effect on energy has a perturbing action on force in proportion to the retardation squared. Therefore, in working out a mean retardation time for the above action, we must evaluate a root mean square of the elemental components of this time. So we need to know the root mean square of the distance travelled by the energy. This is the square root of the integral of x^3dx divided by the square root of the integral of xdx over the range O to r. The effective distance is $r/\sqrt{2}$.

The retardation time T is then the time taken to travel this distance to the field at the speed c and the time to make a similar return journey between the field and the other body. We may write:

$$T^2 = 2(r/c)^2 \qquad (30)$$

This retardation effect is one half that applicable for the spatial energy distribution corresponding to the Coulomb Law.

The Law of Gravitation

The most direct way in which to assess the effects of such a retardation for the interaction between sun and planet is to calculate the associated gravitational energy deficit, that is the amount in transit and so ineffective in asserting force on the planet.

The centrifugal acceleration f of the planet is v^2/r, where v is the orbital velocity in a circular orbit of radius r. This acceleration acting for the retardation period T gives a measure of the displacement under the central gravitational force corresponding to the deficit energy quantity:

$$\left(\frac{GMm}{r^2}\right)(\tfrac{1}{2}fT^2) \tag{31}$$

Here G is the constant of gravitation, M is the mass of the sun and m is the mass of the planet. M has been taken to be so much greater than m that the separation distance r is effectively the same as the radius of the planetary orbit. Newton's Law of Gravitation has been used in obtaining this result. Now put f as v^2/r and substitute T from (30). The energy deficit given by (31) becomes:

$$\left(\frac{GMm}{r}\right)(v/c)^2 \tag{32}$$

The quantity $-GMm/r$ is the gravitational potential energy of the system. Therefore, the effect of retardation, if we assume that gravitation involves a law of force conforming with the case (a) situation leading to the spatial energy distribution in Fig. 12, is to increase G as it applies in Newton's Law of Gravitation, effectively by the factor:

$$1+(v/c)^2 \tag{33}$$

In terms of force, note that conservation of angular momentum renders v inversely proportional to r, making the v-dependent *energy* term inversely proportional to r^3. This means that, upon differentiation with respect to r to obtain a force expression, the factor (33) converts to:

$$1+3(v/c)^2 \tag{34}$$

Thus, in a force equation, the value of G needs to be increased by this factor in order to account for retardation effects. This modifies Newton's Law of Gravitation:

$$\frac{d^2u}{d\varphi} + u = GM/h^2 \quad (35)$$

to:

$$\frac{d^2u}{d\varphi} + u = GM/h^2 + 3GM(u^2/c^2) \quad (36)$$

These are laws of motion based on the force relationship and expressed in polar coordinates u, φ. u is $1/r$ and $h = vr$.

Equation (36) is the law of gravitation which emerges from Einstein's General Theory of Relativity.

Had we used the spatial distribution of Fig. 13, as applies to Coulomb's Law, we would have obtained double the last term in (36). Hence, we can take this derivation based on the Fig. 12 distribution as correctly applicable to the problem of gravitation.

We are now a step further along in our quest to unify the electrodynamic and the gravitational force relationships. We have bridged the link between the basic inverse-square law and the law obtained from General Relativity.

It is of interest to pause here to discuss some aspects of this law of gravitation. Newton's Law is often said to be incorrect, when in fact it is a valid law for action at a distance. If gravitation is propagated at a finite speed then retardation has to be considered. This was well appreciated in the nineteenth century. Planets describe elliptical orbits. They continuously exchange kinetic energy with the gravitational potential of the sun-and-planet interaction. If the energy has to travel across distances of the order of the orbital radius of a planet then retardation effects can become important. The radial perturbation is subject to retardation which causes the natural frequency of oscillation radially to be less than the orbital frequency. As a result, the major axis of the elliptical orbit will advance progressively, producing an anomalous motion of perihelion.

The advance of Mercury's perihelion was, therefore, attributed to retardation. Gerber (1898)* presented an analysis and formulated the relationship between Mercury's perihelion motion and the speed of propagation of gravitation. His paper was entitled: 'The Space and Time Propagation of Gravitation'. His formula was exactly that later

* P. Gerber, *Zeitschrift f. Math. u. Phys.*, **43**, 93 (1898).

presented by Einstein, in applying his General Theory of Relativity to the same problem. The object of the paper was to show that gravitation is propagated at exactly the speed of light. It was following the publication on Einstein's Theory in 1916 that a paper (Gerber, 1917) repeating and expanding Gerber's analysis was submitted to *Annalen der Physik*, the journal publishing Einstein's paper. It issued in January, 1917. Seelinger immediately drew attention to a mathematical flaw in the Gerber analysis. Oppenheim responded, stressing that the issue of finite speed was still open, but Seelinger reasserted his position to ensure that his arguments were not eroded by Oppenheim's views.*

Such was the climate, but it was difficult to imagine that energy transferred between sun and planet at other than the speed of light and, when applied to transit along the path between sun and planet, it gives the wrong answer.

As recently as 1970, Brillouin† has reminded us that the question of the finite speed of gravitation is still open. Brillouin also refers to and endorses Heaviside's 1893 advice to study the spatial distribution of the interaction energy. The author has followed this advice and found that Einstein's equation for gravitation does result, simply because the energy travels from sun to planet via an indirect route. It goes into the field regions of surrounding space on its way. The energy travels at the speed of light along this route but it takes a little longer to reach the planet than do the direct rays from the sun.

The question now remains as to how gravitation can be correlated with electromagnetism. We need to establish that the electrodynamic interaction discussed in Chapter 1 has a spatial energy distribution conforming with Fig. 12. This will complete the unification as to form, because the direct inverse-square of attraction law has been found to be a specific case of the general law of electrodynamics of equation (14) and we have just seen how to develop a law of motion according to Einstein's General Theory, given one of the Newton form.

It is not possible to work out the magnetic field energy density in the space surrounding two interacting charges and, by integration, derive formulae for the spatial energy distribution. The reason is that the usual magnetic field formula is a derivation from the Lorentz Law

* See *Ann. d. Phys.*, **52**, 415 (1917), **53**, 31 and 163 (1917), **54**, 38 (1917).
† L. Brillouin, *Relativity Reexamined*, Academic Press, New York, 1970.

of Force (20). It is only valid for applications involving closed circuital currents. Hence the results of integrating magnetic field energy based on this formula are unreliable. The calculations have, however, been made and the spatial energy distributions plotted (Eagles and Aspden, 1980),* but, as Moon and Spencer (1954)† have argued, the Lorentz law as applied to isolated charges:

> is untenable and the whole process of defining a magnetic field from this equation is unsound.

The magnetic field concept seems only to have meaning in its present formulation if applied strictly to the closed circuit interaction. Therefore, we have a problem of knowing how to proceed to discover the electrodynamic spatial energy distribution.

Electromagnetism

The nature of the magnetic field is one of the most perplexing problems in physics. Magnetic energy appears for some purposes to have a negative potential, as evidenced by the mutual attraction of two parallel conductors carrying currents in the same direction. This is analogous in some respects with the action of gravitation, also a phenomenon represented by a negative potential. Yet, in other respects, as in the case of the magnetic energy stored in an induction coil, there is every sign that the energy seeks to transform into another energy form as if it has potential energy which tends to reduce. To understand this phenomenon it does not suffice to rely on empirical formulation. Some deeper insight into the energy transfer processes seems essential.

We will approach the problem from first principles and regard the existence of charge and electric field energy as basic. The motion of such charge through the space medium gives rise to magnetic effects. Our only scope, then, for probing this medium is to be guided by the fact that it can sustain Maxwell's displacement currents and assert that this space medium itself contains electric charge in an overall neutral state. To proceed in the most plausible way we will use the hypothesis that space is permeated by a uniform electric continuum of charge density σ and that within this continuum there are numerous identical charges q of opposite polarity. Here q is an electrostatic

* D. M. Eagles and H. Aspden, *Acta Physica Polonica*, **A57** (1980).

† P. Moon and D. E. Spencer, *Journal of the Franklin Institute*, **257**, 305 (1954).

charge. This is a working hypothesis not invented to explain the propagation of light, as was the classical aether, but rather to provide us with a starting point and a reference frame for motion, as well as a system whose energy characteristics can be formulated.

Initially we will consider the electrostatics of such a system. The charges q will be termed 'lattice particles' because they will form themselves into some kind of lattice arrangement. Indeed, they will define a structure in the space medium. Imagine that the effects of a disturbing charge e, not itself part of the space medium, cause the lattice particles to be displaced to new positions of equilibrium. Thus at a given region of the medium all the lattice particles will be displaced a distance D in company with one another. Whatever the direction of this displacement each particle will move from O on one side of a planar slice of the continuum to P on the other side of this planar slice. OP is the distance D. This is depicted in Fig. 16.

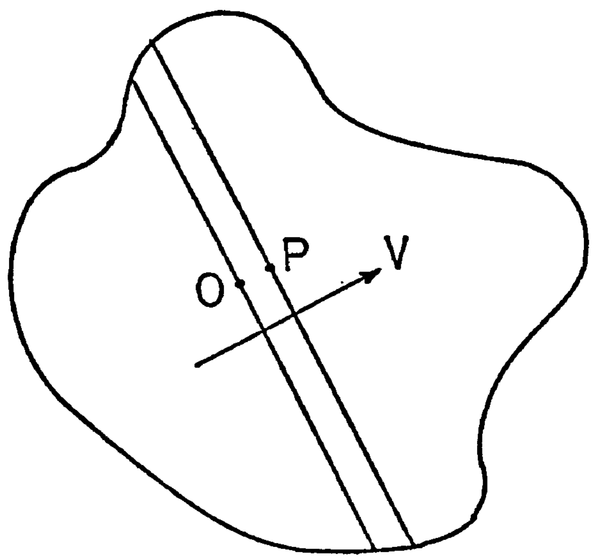

Fig. 16

The particle displacement will be a collective displacement corresponding to the presence of an electric field of intensity V, taken to be uniform over the section of the space medium depicted in Fig. 16. Thus there will be no change in the Coulomb force on any particle due to the action of its neighbours. They move in register with one another locally and remote actions balance anyway owing to the large scale distortions of the lattice structure governed by the charge e and boundary conditions. Any restoring force on the lattice particles will be that due to the planar slice of continuum of thickness D.

By Gauss' Theorem a planar slice of charge density σ and thickness D has a total normal electric field intensity of $4\pi\sigma D$ of which half is directed one way and the other half the opposite way. Hence $4\pi\sigma D$ is the change in field intensity experienced by a lattice particle in going from O to P owing to the action of the field V. The restoring force on q is therefore:

$$4\pi\sigma q D \tag{37}$$

This is equal to Vq. The energy stored by this displacement per charge q is:

$$\tfrac{1}{2}(4\pi\sigma q)D^2 \tag{38}$$

because the restoring force rate is linear with displacement. The energy density represented by (38) is found by multiplying by σ/q since the space medium is electrically neutral and there are just as many particles of charge q in unit volume as are needed to balance σ. Thus the energy density is given by:

$$\tfrac{1}{2}(4\pi\sigma^2)D^2 \tag{39}$$

But since Vq equals (37) we know that D is $V/4\pi\sigma$. Putting this in (39) gives the energy density:

$$V^2/8\pi \tag{40}$$

This is the formula for energy stored by the electric field of intensity V. Its derivation in this way means that the hypothetical system proposed has the property of being able to deploy energy from the field of the charge e and transfer this into electric field energy associated more directly with the space medium. Put another way, the electric field of the charge e has, at least in the main body of the space medium where there are charges q, been cancelled by displacement of this electrical medium. Here then is the basis for the displacement currents we associate with Maxwell's theory.

Examine now the disturbance caused by a charge e moving along a line CB at velocity v, as shown in Fig. 17. We study the effect upon a charge q displaced from its neutral position at A when e is at B. BA is a separation vector r making an angle θ with v. The position of q will change according to the velocity v. q is at A_1 for $v=0$, but moves to A_2 when e has a finite velocity. Note that A_1 and A_2 are in the very near vicinity of A and are effectively at A for the purpose of evaluating the electric field acting directly from e at B. For e at rest at B, A_1 is on the extension of BA. For e in motion, the effect of e is seen at A to emanate from a previous position of e, the position C. Thus A_2 lies on CA extended. A_1A_2 is drawn normal to CA because it represents an electric field vector not compensated by displacement. Energy

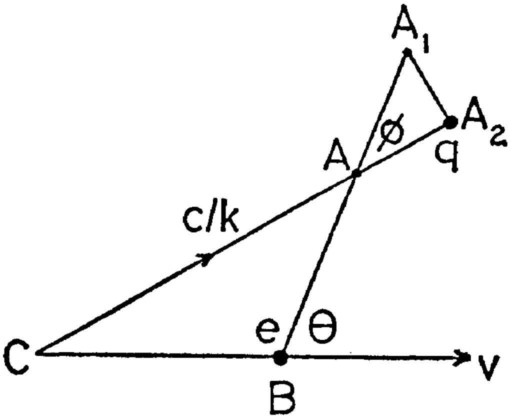

Fig. 17

minimization requires a minimization of this vector, making the angle between AA_2 and A_1A_2 a right angle.

The position of C can be determined, provided we know the speed at which the disturbance of the q charges propagates. Earlier in this chapter, just before we introduced Fig. 15, it was shown that this speed is $\frac{1}{2}c$. Readers may, however, not feel too comfortable about accepting this, because the concept of a natural propagation in the vacuum medium at half the speed of light is unfamiliar. Therefore, we will proceed using a general propagation speed c/k, where k is a constant believed by the author to be 2, on the basis of earlier analysis in this work.

The position of C is then seen to be given by the relationship:

$$CB/CA = kv/c \tag{41}$$

Let φ denote the angle between BA and CA. Since displacement is linearly proportional to electric field intensity we can then see that, if A_1A_2 represents a field of strength V, V becomes $\sin\varphi$ times the field intensity of e at A. Thus:

$$V = (e/r^2)\sin\varphi \tag{42}$$

By the sine formula:

$$CB\sin\theta = CA\sin\varphi \tag{43}$$

From (41) this is:

$$\sin\varphi = (kv/c)\sin\theta \tag{44}$$

Therefore, from (42) and (44):

$$V = (kev/r^2c)\sin\theta \tag{45}$$

which is Ampère's formula if k is unity and V is considered as the magnetic field strength.

Let us tentatively put k as unity and explore the field represented by V with electromagnetism in mind. How is the electric field energy deployed in Fig. 17? The electric field energy normally associated with the vector AA_1 has been apportioned to sustain the vectors AA_2 and A_2A_1. These vectors represent field intensities. They are squared to give energy densities and, by Pythagoras' Theorem, we see that the electric field energy at A attributable to the charge motion v is zero. All that has happened is that electric energy stored by displacement of the q charge has been transformed into non-displacement energy in measure determined by the electric field given by (45).

Accordingly, even if we speak of V as a magnetic field, we cannot, without further justification, state that there is a magnetic field energy added by motion of e at velocity v.

To resolve this problem let us simply be mindful of the fact that our experience of magnetic fields comes from collective motion of charge and not isolated charge in motion. It is likely to be the combined effect of numerous charges in motion that really cause the displacements of the q charges and the overall action may be quite complex. Indeed, the effect at A in Fig. 17 may well be moderated by inducing a reaction in the motion of other charge. A primary electric field disturbance at A, caused by the motion of charge e, represents a non-equilibrium state and is conducive to actions which tend to restore equilibrium. Therefore we can contemplate the electric displacement as a catalyst by which optimum reaction conditions prevail in the dynamic state. This is the process of induction, involving the transfer of energy from the primary charge to a reacting charge. This so-called magnetic energy is shared by reacting charge distributed throughout the space surrounding the charge e and takes the form of kinetic energy of the other charges in reacting motion.

The field parameter given by (45) is a measure of the field disturbance associated with this inductive process, but it does not tell us how much energy is transferred to the reacting system. To discover this, we argue that the electromagnetic disturbance is, in field terms, proportional to ev. In energy terms, the electromagnetic disturbance will be proportional to the sum of the cross products of the ev parameters for all the interacting primary charges. This follows from dimensional considerations, but formulation is no easy task because it depends upon the spacing and directions of the several interacting primary charges. Note also that we are not just concerned with the total magnetic field energy involved in the electrodynamic interaction. This could be deduced from the force relationships examined in Chapter 1. Our object is to determine the spatial energy distribution of this energy so that we can examine the retardation issue.

The optimum reaction conditions will undoubtedly require a maximization of the energy drawn from the electrodynamic retardation of two primary interacting charges in motion. Only the settled equilibrium state will be in evidence in our physical observations. Thus, when two primary charges of like polarity move in parallel at a controlled and set speed, their concerted action to maximize the reaction energy will urge them together, giving rise to the electrodynamic interaction force. More generally, we know from the analysis in Chapter 1 leading to equations (9) and (10) that the electrodynamic interaction between charges, however directed, incorporates, as its controlling component, a direct inverse-square law of force, which we can now attribute to the magnetic energy stored in the reacting system.

This permits us to regard the magnetic energy as distributed spatially according either to case (a) or case (b), as discussed at the end of Chapter 1. We spoke there of the distinction between these cases, regarding case (a), the Fig. 12 distribution, as that for which the interaction energy tended to be as close to the interacting bodies as possible, with case (b), the Fig. 13 distribution, being that for which the interaction energy tended to be as remote as possible from either body. However, Nature may not so distinguish in establishing the dual existence of such energy distributions. It could well be that there are constraints provided by a true electric field action and the case (b) distribution for the Coulomb energy may arise from field behaviour, as analysed early in this chapter. Then, so far as case (a) is concerned, this distribution may rather be the only natural distribution governed by the self-distribution of energy. We know that thermal energy does not seek to escape from its source. Rather, it seeks to distribute itself in a uniform manner, filling the space available with thermal energy at a uniform temperature. Then, so far as case (a) energy distribution is concerned, we can imagine that this is a condition of maximum energy dispersal within the constraints applied. The constraint is that $n = -2$ when x is greater than r, as we saw from equation (27). Maximum dispersal means minimum ordinate for the energy term $\partial E/\partial x$ at r. Thus as much energy as possible must lie between O and r. Yet n has to be a positive integer over this range. Accordingly, it must be unity, giving the case (a) situation already discussed.

Dispersal of energy is a characteristic of the thermal or dynamic state and it is natural to associate this with magnetic energy. However, whereas thermal energy in the experience we have from dissociation processes tends to fill the space available in a uniform way linked to the uniformity of the substance present, magnetic energy is constrained by the presence of the primary charge influence upon electric displacement in the vacuum medium. The magnetic reaction energy is dispersed in a manner which assures that the overall reaction is in balance with the primary action.

The Gyromagnetic Reaction

From the above argument, we see that the analysis leading to equation (45) tells us very little about magnetic action. It suggests that the electrodynamic disturbance could be larger by the factor k, double that expected classically, if the analysis is to be given credence, but we have had to infer, rather than deduce by formulation, the spatial energy distribution which is to be associated with the magnetic reaction.

Be this as it may, the task ahead is one of verification. If the argument is correct, the magnetic field energy is really stored as the kinetic energy of reacting charge and we can, presumably, consider as reacting the electrons in matter or the q charges in the vacuum, inasmuch as both can have motion components superimposed upon other ordered motion. However, the reaction must itself be somehow ordered from the magnetic viewpoint if it is to moderate the effects of primary charge in causing the displacement portrayed in Fig. 17.

The reaction develops reaction currents, which can become primary and transfer their energies back to the source circuits, in a circuit configuration.

The need to recognize this reaction phenomenon may have eluded physicists because there is no apparent evidence of free electron diamagnetism when magnetic fields are applied to electrical conductors. If there are free electrons moving around in conductors, as we believe, how is it that in a steady magnetic field they do not develop a reacting helical motion and substantially cancel the field? This is a classical problem. There was no evidence of substantial diamagnetism, and so statistical arguments were applied and, unfortunately, these are based on some rather arbitrary assumptions. The subject is well summarized in a book by Van Vleck (1932).* Statistics were applied in a way which tends to conflict with the accepted laws of magnetic induction. Reactions which require angular momentum of electrons to be unidirectional were avoided by asserting that angular momentum is shared equally between opposite directions. Alternatively, it is argued that there are collisions between electrons and the notional boundaries of a conductor and these collisions supposedly introduce a reverse component of angular momentum. Another argument is that the Lorentz force on a reacting charge is at right angles to the charge motion. Hence the magnetic field to which the charge is reacting cannot transfer energy to the reacting charge, which in turn means that there is no diamagnetism. All these arguments are unconvincing. They require arbitrary and questionable assumptions, especially the latter, which seems to deny Faraday's discovery of induction. It is better to accept that diamagnetism exists and investigate why its effects are hidden.†

First, note that if there is no externally applied magnetic field the random motion of free charge in a conductor will not become a concerted motion producing fields of its own accord. Each charge in motion is potentially both a primary field producer and potentially a reacting charge developing a field in opposition. There are statistical exchanges of role which assure that there is no overall polarization of the magnetic action. However, if we apply a magnetic

* J. H. Van Vleck, *The Theory of Electric and Magnetic Susceptibilities*, Oxford University Press, 1932.

† This problem was the starting point of the whole research recorded in this book, which began in 1955 shortly after the author completed his Ph.D. research at Trinity College, Cambridge, on more orthodox aspects of magnetic reaction effects.

field, then there must be some reaction producing diamagnetism. But not all the charges in motion in the conductor participate at the same time. They will, as before, tend to oppose the field actions of one another, but will, in some optimum way, react to the applied field to a limited extent.

Thus, we take the true applied field to be H_o and suppose this to be offset by a diamagnetic reaction field H_r to produce an effective field H. Thus:

$$H_o - H_r = H \tag{46}$$

By Lorentz's law the force Hev/c acts on a charge e of mass m moving at speed v perpendicular to the magnetic field of strength H. Then the charge is deflected into a circular orbit with this force in balance with centrifugal action:

$$Hev/c = mv^2/x \tag{47}$$

x is the radius of the orbit. Regardless of the direction of motion or the polarity of the charge, the deflection is always in the sense that results in a reaction field. This is found from the reaction current moment $evx/2c$, that is the area πx^2 times the current $ev/2\pi xc$.

Thus the total reaction current moment per unit volume of the field is given by:

$$\sum(evx/2c) = \sum(\tfrac{1}{2}mv^2)/H \tag{48}$$

from (47). The summations apply to unit volume. The value of H_r is, conventionally, 4π times this quantity, but we will now introduce the factor k of (45), because the theory developed tells us that k should not be ignored. Thus:

$$H_r = 4\pi kE/H \tag{49}$$

where E now replaces the kinetic energy density of the reaction.

Combining (46) and (49) we obtain:

$$H_oH - 4\pi kE = H^2 \tag{50}$$

k is constant and, as we have seen, the magnetic interaction requires energy to be fed to the kinetic energy of the reacting system to the maximum extent possible. Hence there will be diamagnetism set by the condition that E is a maximum in (50). H will vary as a result to assure that:

$$H_o = 2H \tag{51}$$

It follows that the field is invariably halved by diamagnetism of free charge. For this to pass undetected in our research the magnetic field theory must account for a doubling of the magnetic effects of charge in motion. Thus the factor k in (45) must be 2, and it is interesting to find that we had already anticipated this from the analysis of retardation in Coulomb interaction. It is thus explained why this diamagnetic aspect of all magnetic field reactions had eluded detection.

The value of the kinetic energy density E can also be determined from (50) and (51). With $k=2$, E is found to be $H^2/8\pi$. This is the magnetic field energy density formula. It confirms that the reaction component of kinetic energy density can be identified as magnetic field energy, as already suggested.

We are led to the result that the establishment of a magnetic field, whether in materials or the vacuum, leads to the injection of kinetic energy of amount we associate with magnetic field energy. This energy will merge with the thermal energy but at least this amount of kinetic energy must always be present to sustain the reaction. Even the vacuum cannot 'cool' below the temperature needed to sustain this magnetic field. We will come back to this in Chapter 9 when it will be shown how this accounts for the cosmic background radiation temperature in the vicinity of the Earth.

Next, before returning to the problem of unifying electrodynamic and gravitational force, we will digress just a little to observe that the factor $k=2$ is very much in evidence in an experiment dating from 1923.

Richardson (1908) suggested that when the magnetism in a pivotally mounted ferromagnetic rod is reversed, the rod should experience a counter-balancing change of angular momentum.* It was expected that the gyromagnetic ratio, the ratio of the change of angular momentum to the change of magnetic moment, should be $2mc/e$. This was the quantity applicable to the electron in free orbital motion, where e is the electron charge, m its mass and c the speed of light in vacuo. Einstein and Haas (1915)† first observed the effect. Suckmith and Bates (1923) then found that the effect was only one half of that predicted.‡

This halving effect is, of course, in full accord with the magnetic moment being double that expected on conventional theory. The

* O. W. Richardson, *Physical Review*, **26**, 248 (1908).
† A. Einstein and W. J. Haas, *Verh. d. Deutsch. Phys. Ges.*, **17**, 152 (1915).
‡ W. Sucksmith and L. F. Bates, *Proc. Roy. Soc. London*, **104A**, 499 (1923).

reacting conduction electrons halve the magnetic moment, but they also halve the angular momentum of the overall electron contribution. Therefore, the experiment gives a true measure of the gyromagnetic ratio and confirms that $k=2$.

The gyromagnetic ratio has been related to the half-spin quantum of electrons and caused physicists to regard the ferromagnetic state as due to electron spin, rather than orbital motion. Theoretically, the factor of 2 features in the quantum-based relativistic treatment of Dirac, but this is a little abstract in character and so can be questioned, especially in the light of the alternative account in this work. A slight departure from the factor of 2 is observed in measurements of the spin magnetic moment of the electron. Indeed, the anomalous g-factor, as this is called, is regarded as one of the theoretical triumphs of quantum electrodynamics. We will come back to this in Chapter 5. Meanwhile, we revert to the problem of gravitation.

The Graviton

We set out to discover the spatial energy distribution associated with the electrodynamic interaction. Magnetic field theory was avoided because in its conventional form it applies only to closed circuit interactions. By inference from the fact that magnetic field energy is a kinetic energy of environmental charge in a reacting mode, we have found that the spatial energy distribution is of the form needed to establish the link with gravitation.

Hence we can, with confidence, embark upon the task of determining how the Neumann Potential given by equation (8) can become a gravitational potential.

The answer lies in the recognition that there exist in the continuum of the vacuum medium what will be termed 'gravitons'. These are very small in physical size and they adjust in size to store energy and so complement and balance the mass-energy of matter present. This adjustment affects their electrodynamic action, bearing in mind that they displace the charge in the continuum. Then, their concerted mutually-parallel motion relative to the electrodynamic reference frame set by the q charge system induces a small electrodynamic effect, which causes an inverse-square force of mutual attraction, an electrodynamic action, which we will identify as the gravitational interaction. The Constant of Gravitation G will be deduced in terms of the mass-energy of the graviton and the latter will be verified both by theoretical enquiry and experimental evidence linked to elementary particle physics.

It is in this way that we will establish the connection between the gravitational and electromagnetic action, the study of the spatial energy distribution associated with these phenomena having shown us that Einstein's formula for gravitation does have common ground with electrodynamics. However, we have to pursue this enquiry against the background of success of Einstein's General Theory of Relativity and it is appropriate to comment briefly on the broader gravitational questions posed by this theory.

There are essentially three tests of Einstein's General Theory of Relativity. These are the planetary perihelion advance, the effects of gravitation upon light speed and deflection and, finally, the gravitational red shift. The first two of these tests relate to the equation of motion associated with Einstein's law of gravitation. These, therefore, support, with equal effect, the retardation thesis on which the same law has been derived in this work. The third test, the red shift, has never been regarded as a particularly strong test of general relativity. The red shift is hardly more than Nature's recognition that the emission of spectral lines by atoms depends upon energy states which, in turn, depend upon gravitational action. Dicke (1964) in his book *The Theoretical Significance of Experimental Relativity* dismisses the red shift with the words:

> The red shift can be obtained from the null result of the Eotvos experiment, mass-energy equivalence, and the conservation of energy in a static gravitational field and static co-ordinate system. For this reason the gravitational red shift is not a very strong test of general relativity.

In Dicke's book just mentioned he also writes:

> To me the geometry of a physical space is primarily a subjective concept. What is objective is the material content of space, the photons, electrons, pions, neutrinos, protons etc., and *gravitons.* I give emphasis to the idea, not yet substantiated by observations, that in the same sense that electromagnetic forces are induced by interactions with photons, gravitational forces are due to collisions with gravitons. I here use the word 'graviton' in a generic sense to mean any type of particle responsible for the effect of gravitation.

The idea that gravitational effects are due to collisions with gravitons presents great difficulties, if one relies too heavily on the analogy with photons. The author prefers to retain the electrodynamic interaction concept as the basis for explaining gravitation and look to the mediating action of the graviton in the process. Already, the electrodynamic approach has shown how we can develop a link with the form of the Einstein law of gravitation. The General Theory of Relativity is no obstacle either to this approach. To progress towards a successful theory of gravitation we need to derive the Constant of Gravitation G in terms of other fundamental quantities, as, for example, the graviton energy quantum, and then demonstrate that this energy quantum exists in Nature. We, therefore, are set on a course which causes us to challenge some of the fundamentals of Einstein's theories, as we enquire into the elementary particle world revealed by the inherent properties of the vacuum medium.

At the beginning of this chapter we examined the nature of the space medium permeating the vacuum. It is electrically neutral but is full of charges q set in a sea of opposite charge of uniform charge density σ. We have found that the correct law of electrodynamics applicable to action between discrete electric charges gives a direct inverse-square attraction force provided the charges are like charges moving mutually parallel. The mutual gravitational force between two electrons is 10^{-39} times that of their Coulomb repulsion. The mutual electrodynamic attraction between two electrons, according to the law derived, is $(v/c)^2$ times their Coulomb repulsion, where v is their common velocity and c is the speed of light. Thus, the electrons would have to move extremely slowly to experience an electrodynamic interaction matching their gravitational interaction. Accordingly, we should not look to the charge possessed by matter when seeking to understand gravitation, especially as gravitation is a property of matter which is electrically neutral overall.

We are left, therefore, to examine the effect of the charge continuum σ. Imagine that matter and the structured lattice formed by the q charges define our local electromagnetic frame of reference and regard σ as having a universal flow (which could be oscillatory). Consider what happens as this uniformly-dense continuum of charge is deflected past an electron. This is pictured in Fig. 18. The electron is depicted as a sphere obstructing the flow. The uniformly-dense character of the continuum charge makes this situation analogous to that of the flow of an incompressible fluid through a pipe in which there is an obstruction partially impeding the flow. The amount of fluid flowing through the pipe is unaffected. It is just that the fluid speeds up in passing the obstruction. Thus, the electrodynamic effect of the flow of continuum charge is unaffected by the presence of the electron. The continuum has merely gone a little faster in being

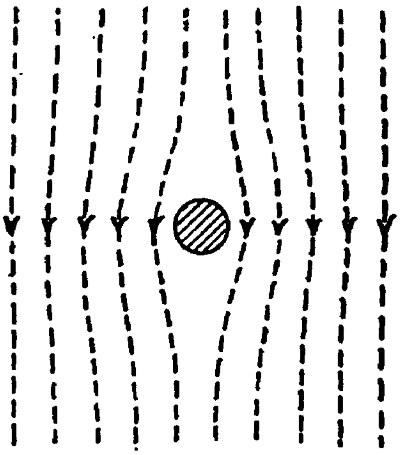

Fig. 18

diverted around the electron. This, therefore, gives us no scope for developing a small electrodyamic effect associated with the existence of the electron.

But remember that we need to relate the effect with mass and that 'gravitons' have been mentioned. Assume that gravitons are standard-sized spheres possessing the same charge *e* as normal elementary particles, but differing in the one respect that they move with the continuum. It may then appear that this is of no help either in attacking our problem of relating electrodynamic action with the mass of matter, because the mass of the electron in Fig. 18 plays no role and the electrodynamic effects are in no way connected with the electron.

There is, however, one fundamental difference between the effect of the electron and that of the graviton. The electron can vary in physical size without affecting the electrodynamic action. The graviton cannot. If the volume of the graviton contracts very slightly, then the continuum can fill the space vacated, stay uniform, and allow the electron or other charges in the electromagneitc reference frame to expand slightly. The electrodynamic effects of the continuum are not affected by the change in physical size of the particles in the matter frame, as we have shown by reference to Fig. 18. The electrodynamic effects are augmented by any change in size of the graviton, because there is no compensating continuum flow past the graviton. It follows that if the graviton is squeezed into a smaller volume it will generate an electrodynamic effect in the continuum. The graviton, having a charge e, will add energy if this charge is squeezed into less space. Hence, energy added to the graviton system can lead to a related electrodynamic effect. The mutually-parallel nature of the electrodynamic action for two such events implies, by our law of electrodynamics, a mutual attraction between the two energy disturbances. Thus, if we can match the mass-energy of the electron or other matter present in the electromagnetic reference frame with that stored on the graviton system, we can argue that there will be mutual attraction between matter proportional to the product of the masses interacting. This can all be formulated.

To relate the size and energy of the graviton we will use the classical formula:

$$E = 2e^2/3x \tag{52}$$

This has been suggested by J. J. Thomson and will be discussed later in this work, but it can be justified independently of J. J. Thomson's argument as being the self-energy E of the electric field of a charge e confined within a sphere of radius x, when the charge distribution assures a uniform field energy density or pressure within the sphere.

If E increases by dE, x is reduced and there will be a graviton volume contraction $4\pi x^2 dx$. The value of dE/dx is $-2e^2/3x^2$ so the volume contraction can be estimated in terms of dE. The effect is to modify the electrodynamic current element by $\sigma u/c$ times this volume contraction or:

$$(6\pi x^4 \sigma/e^2)(u/c)dE \tag{53}$$

where u is the velocity of the continuum relative to the electromagnetic or matter frame.

Two such current elements at unit distance are mutually attracted by a direct action along the line joining them and in direct proportion to the product of two quantities such as (53). Therefore, identifying this force as gravitation and using the formula $E = Mc^2$ to relate energy and mass, we can write:

$$G = (6\pi x^4 \sigma uc/e^2)^2 \tag{54}$$

Given the mass of the graviton we would know x. This leaves for evaluation the velocity u and the charge density σ. Also we have to explain why dE has any relation to the mass of an element of interacting matter, because we have added as much energy to the graviton as we have mass-energy in the matter frame. The interesting point, however, is that we have a formula for G which offers scope for understanding the very weak nature of the gravitational force. G is proportional to x^8 and x is a very small distance.

The challenge confronting us is to determine these parameters in (54). It is a task which involves the full analysis of the lattice structure of the space medium, and therefore one which requires acceptance of a kind of aether. This causes us to pause to discuss Einstein's Special Theory of Relativity, because some regard this as refuting the aether concept. However, it is a profitable line of enquiry, as we shall see, and we do find an answer to the mass-energy connection between matter and gravitons.

Before concluding this chapter, we will interject a comment about the parameter u. The approach we took in coming to our electrodynamic formulations suggests that the speed of interacting charge should be low in relation to c. This restriction does not apply to the very small charge disturbances in the continuum. The reason is that the undisturbed continuum has a completely balanced interaction with other charge in the space medium. Electrodynamic forces due to the continuum charge arise when the continuum is disturbed by deflection past elements of matter or by secondary effects which matter has upon gravitons. Therefore, the relevant velocity is not that of the undisturbed speed of the continuum. It is the incremental velocity of the continuum deflected by the presence of matter. Bearing in mind that a vastly greater volume of continuum is disturbed than the small volume displacement at the graviton, we must expect this incremental velocity to be effectively quite small. On the other hand the current quantity involved is correctly specified by u in formula (54). Therefore, provided we are considering electrodynamic effects remote from the source and provided these arise from motion confined within a limited region, such as an oscillation, u can be as great as we please and could equal c without affecting the applicability of the result.

On a similar point note that one cannot expect electrodynamic effects to govern the self-actions of electric charge, whether gravitons or electrons, because such effects are only asserted over ranges set by the scale of the q charge structure. This we have to determine in order to evaluate σ. It will be shown that the spacing between the q charges is large enough not to affect the self-action of a charge by electrodynamic interaction.