the magnetic energy, should always be considered as a negative quantity, the electron behaves as if it only possesses a normal kinetic energy related to its intrinsic electric energy.

This conclusion will now be fully supported by analysing the inertial effects of an electron when it is accelerated.

## Accelerated Charge

The effect of accelerating a slow-moving charge $e$ will now be calculated. The electric field of a charge has the property of inertia and moves with the charge. The action of acceleration, however, means that the field motion is disturbed. The electric field is distorted. For example, if an electric charge is moving at uniform velocity and then undergoes acceleration to another uniform velocity during a short period of time $dt$ then at time $t$ later there will be a disturbance in the field region distant $ct$ from the charge. This assumes such low velocity that the charge is effectively still located at the centre of the radiated wave disturbance. Essentially, there is a regular radial electric field from the new position of the electric charge within the sphere of radius $ct$. This field is moving at the same velocity as the charge and it is therefore not distorted. Outside the radius $ct$ the field still centres on the position the charge would have had it not been accelerated. This field is still moving with the original charge velocity. The disturbance in the field is really wholly contained in a spherical shell of radius $ct$ and radial thickness $cdt$. It contains the lines of electric field flux which join the two regular field regions. The key question we face is whether the total electric field energy in this shell is different from the energy content if there were no disturbance. If the shell has extra energy, then this is energy carried off by radiation as the disturbance is propagated outwards at the propagation velocity $c$.

Referring now to Fig. 1.2, consider a charge $e$ to be moving in a straight line $BC$ at velocity $v$. At the point $C$ the charge is supposed to undergo sudden acceleration causing it now to move along $CD$ at velocity $v'$. $CD$ is inclined to $BC$. Both $v$ and $v'$ are taken to be very small compared with the propagation velocity $c$. At time $t$ after acceleration a field disturbance has moved to a distance $ct$ from $C$. The disturbance is contained within a radial distance $cdt$. Now consider a point $P$ in this disturbance region. To pass through $P$, a line of force will be inclined to the vector $v'-v$ at an angle $\theta$. This is

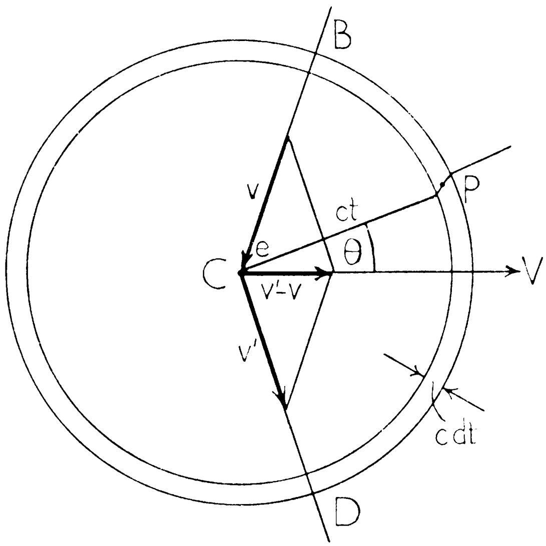


Fig. 1.2

the line of force emanating from the charge and traversing the wave region. In the region of $P$, however, the line of force has to undergo displacement. It is laterally displaced by the distance $(v'-v)t \sin \theta$ because, for example, if $v'$ and $v$ are unidirectional the field change across the wave region is an advance to a new velocity which causes a displacement in the direction of $v$ or $v'$ equal to the change in velocity times time. This displacement is $(v'-v)t$. At right angles to the line of motion of the charge we find the direction of this displacement to be perpendicular to the lines of force emanating from $C$ to the field region. Directly ahead of the charge in its line of motion we find that the displacement is along the lines of force emanating from $C$. The resulting lateral displacement of the field lines by $(v'-v)t \sin \theta$ requires an electric field component in the disturbance at right angles to the propagation direction and in or parallel with the plane containing $v'-v$. This field component will give rise to a separate electric field energy component. The transverse field is calculated quite easily, since its ratio to the main radial field $e/c^2t^2$ is the above lateral displacement divided by the radial disturbance distance $cdt$. By putting the acceleration $f$ as $(v'-v)t/dt$, this transverse electric field becomes $ef \sin \theta/c^3t$ Thus, the electric field energy per unit volume in the disturbance region is:

$$\frac{1}{8\pi}\left(\frac{ef \sin \theta}{c^3 t}\right)^2 \qquad (1.10)$$

The total electric field energy in the disturbance region, that is, the total energy carried by the disturbance, is found by integrating this expression over the volume of the shell. An elemental volume formed by an annulus through $P$ centred around the axis $v'-v$ is $2\pi(ct)^2 \sin\theta c dt d\theta$. Performing the integration between $\theta=0$ and $\theta=\pi$, gives:

$$e^2f^2dt/3c^3$$

Since $dt$ is the time during which the disturbance is formed and since this energy quantity is independent of the distance travelled by the disturbance, it is deduced that this energy is radiated by the charge when subjected to acceleration $f$ and during the time $dt$. Should the acceleration be sustained the rate of energy radiation in the electric field form becomes $e^2f^2/3c^3$.

This result is that classically obtained by applying Maxwell's equations to the problem of radiation by accelerated charge. It has to be doubled to follow the usual wave propagation theories, according to which electric and magnetic field energies are equal for wave propagation through a vacuum. Classically, magnetic field energy has to be added to the expression deduced in order to evaluate the total rate of energy radiation.

Now, this feature of energy radiation by accelerated charge, particularly electrons, is relied upon in many accepted physical theories. It has been accepted quite readily because energy transfer by electromagnetic wave propagation is fundamental. Yet, the energy quanta are supposed to come along as photons according to other physical theory and factual observation. There is nothing of a quantum nature about the derivation of the energy radiation presented above, or about the classical derivation using Maxwell's equations. Hence, there is a problem. It is part of an accepted mystery in physics. Acceptance emerges from the reconciliation by the physicist in believing that there can be two ways of looking at the same thing. The duality of wave and photon principles of energy transfer is no longer treated as an absurdity. It is an accepted and fascinating feature of Nature. Yet, if one dares to ask the question of how an electron can radiate energy and still stay an electron, or how the energy radiated is fed to the electron, one is asking too much from physical theory. We should look, instead, at the broader energy balance and make our analysis by reference to the field equations. How is it that the physicist has given in to this problem? Surely, we will never understand the real nature of the electron if we tolerate two conflicting explanations for the same phenomenon and stop asking the questions about the source of the electron's energy radiation.

One simple fact is evident. If electromagnetic wave propagation had not been discovered, energy radiation merely due to electron acceleration would be highly questionable. The physicist would retrace his theoretical steps, even revise his theory, before building his further theories on the notion that an electron can radiate energy. This should be even more a matter for concern in the light of the quantum features of energy transfer. Had the discovery of the photon preceded the theory of electromagnetic wave radiation, the conflict of the dual existence of wave and quantum theory could hardly have become a tolerable situation. At this stage, the author puts before the reader the clear proposition that *an accelerated charge does not radiate energy*. We will re-examine the above analysis to find out where it went wrong.

We do not have to look very far. It was postulated that the acceleration of the charge $e$ was $f$. From the time of Newton it has been known that acceleration cannot be assumed. It results from a force. To apply a force to an electric charge demands a field acting on the charge. No such field was incorporated in the analysis. Our object was to calculate energy and energy is a quadratic expression and cannot be calculated if fields present are ignored. Here, then, is the source of the error. Now, it seems absurd to suggest that such a mistake could have gone without notice for so many years. Perhaps this can be understood if we argue that the wave disturbance set up by accelerated charge must eventually pass well outside the region of any local accelerating field. Then the analysis must be valid. If energy is carried along by the disturbance it must come from somewhere. It comes from the direction of the accelerated charge. Presumably it comes out of the field at the source. It does not have to come from the electron itself. It is just that the acceleration of the electron is a necessary adjunct to whatever it is that causes energy to be radiated. This is an argument, but it does not eliminate the duality problem and it does involve an all-important assumption that energy is in fact carried by an electromagnetic wave. This is an assumption having no analogy in other physics. Waves on water involve local interchanges between kinetic and potential energies and no forward migration of water or energy at the wave velocity. It seems a better assumption to propose non-radiation of energy by the accelerated charge, non-transfer of energy by electromagnetic waves, and leave the physicist free to accept the quantum mechanism of energy transfer without ambiguity. At least, it is worth the effort of re-analysing the mechanism of wave propagation by an electron, allowing for the accelerating field. The method of analysis being used by reference to Fig. 1.2, incidentally, is a textbook method which is attributed to J. J. Thomson. It is only the following introduction of the accelerating field which is new.

An electric field $V$ is applied in the direction of acceleration of the charge depicted in Fig. 1.2. This field $V$ may be resolved at $P$ into two components, one radial from $C$ augmenting the regular field of $e$, and the other in opposition to the transverse field component from which the radiated energy is derived. Thus, expression (1.10) for the energy density in the disturbance region can be expressed as:

$$\frac{1}{8\pi}\left(\frac{ef\sin\theta}{c^3t} - V\sin\theta\right)^2 \tag{1.11}$$

Although it is tempting to choose $V$ so that this is zero for all $\theta$, we cannot do this because the square of the last term in the expression is an energy component belonging to the field $V$ and it cannot be assumed to move with the disturbance. The rest of the expression, including the interaction term found when the expression is expanded, does denote energy moving with the disturbance. The energy density which can move with the disturbance is different from that previously calculated by the reducing amount:

$$\frac{1}{8\pi}(2V\sin\theta ef\sin\theta/c^3t) \tag{1.12}$$

Upon integration, as before, this is $2Veftdt/3$. Thus, the total energy carried by the disturbance is:

$$e^2f^2dt/3c^3 - 2Veftdt/3 \tag{1.13}$$

Now, in considering the mass acted upon in charge acceleration, we must equate this mass to that of the electric field remaining to be accelerated. This is a function of $ct$. Expression (1.13) has to be zero on the basis of our assumption that the charge does not radiate energy. This means that:

$$Ve/f = e^2/2c^3t \tag{1.14}$$

This expresses the ratio of force $Ve$ to acceleration $f$, and is a measure of the effective mass of the electric field remaining to be accelerated. The energy of the electric field outside the disturbance region is $e^2/2ct$. Denoting this as $E$, we have from (1.14):

$$E = Mc^2 \tag{1.15}$$

where $M$ is the mass involved.

It follows that the assumption that an electric charge does not radiate energy leads to the conclusion that an electric field energy has mass according to the relation $E = Mc^2$. If this latter relationship is not valid, then there should be radiation of energy by accelerated charge and we are led back into the duality problem confronting physics. The duality problem is avoided if we accept that $E = Mc^2$ is a valid relation. Now, this latter expression is an accepted result in modern physics. It has been verified in its application to atomic reactions and electron-positron annihilation. Since it must be true, an accelerated charge cannot radiate energy. Therefore, if an electromagnetic wave carries energy with it, it must acquire this energy as it passes out of the field causing the charge acceleration. If it does this, we come back to the duality problem. Also, imagine two electric charges mutually attracted and accelerated towards one another. If both radiate energy generated somehow in their fields, they must lose some of their fields and so their charge. Note that they need not, theoretically, have much velocity but may have a high acceleration. In short, while it is not proved that there is no energy radiation from the field, it is certainly likely to present some peculiar problems to assume that the wave gets a supply of energy at some position remote from its source. If this assumption is avoided and we accept the validity of Maxwell's equations we are left with but one conclusion. The assumption made in applying the Poynting vector to deduce energy propagation by an electromagnetic wave is wrong. This assumption is that the energy of the wave is carried by the wave. In fact, the energy might come from a source in the medium through which the wave is propagated. It might come from the aether. Or it might not exist at all. If, in applying Maxwell's equations, we assume that because electric field and magnetic field are equal in a plane wave, we have an equal contribution of electric field energy and magnetic field energy *but only if both of these energy quantities are positive*. If magnetic energy is negative, the equality of field strengths predicted from Maxwell's theory corresponds to zero energy carriage by the waves and we have a wholly consistent approach to our understanding of the electron and its behaviour when accelerated.

A word should be said about the assumption in the above analysis that the electric charge had a velocity which was small compared with the velocity of light $c$. It is submitted that if we can prove that there is no radiation of energy from the accelerated charge at a low velocity we should not expect a different situation at higher velocity. Rigorous analysis to cater for high velocity charge motion is not necessarily worth while. The author has not attempted it, mainly because it is necessary to claim that the velocity of light is relative to something. If it is measured relative to an observer and the charge moves at high velocity relative to this observer and is accelerated, one will possibly get energy radiation. If it is measured relative to a different observer, one will get a different energy radiation. This seems ridiculous. If it is measured relative to the charge $e$, one can forget the idea of the electric charge moving at high velocity. It is effectively at rest in the frame of reference which matters. Put another way, an electric charge might know that it is accelerated but it has no way of knowing that it is moving at any particular velocity. Its energy radiation cannot, therefore, depend upon its velocity. Since it is zero at low velocity from the above analysis, it must be zero at any velocity.

The argument that it cannot tell whether it has uniform velocity follows from Newtonian principles. The talk about observers follows from Einstein's approach to Relativity. If anything, therefore, the non-radiation of energy by accelerated charge is an indication that some arguments available from Einstein's Theory of Relativity cannot be relied upon, although there is the inevitable result that zero-energy radiation for all velocities is consistent with the Principle of Relativity.

It is noted that the mutual requirement for $E=Mc^2$ and non-radiation of energy by accelerated charge was the subject of a contribution by the author to the discussion of a paper by P. Hammond, relating to the Poynting Vector (Aspden, 1958, a) see also Aspden (1966, a), where the author drew attention to this result in view of controversy about the proper formulation of electromagnetic radiation.

## Superconductivity

It has been concluded that an accelerated electron develops electromagnetic waves but need not radiate energy by these waves. This explains why electrons can move about in atoms without radiating energy and why electrons can travel through a superconductor without developing heat. We need not have recourse to arbitrary quantum assumptions to explain these basic facts of physical science. It is true that the motion of electrons through materials at normal temperatures results in heat generation. There are collisions between the electrons and the atoms. The electrons have kinetic energy and may transfer some of the atoms. Then, the atoms could be the source of the heat and not the electrons. Atoms do radiate energy in quanta. They are the source of photon radiation and, as we shall see later, an electron has a role to play anyway in the photon action. However, to emit photons one has to have enough energy to form a quantum. Thus, when an atom is part of a cold substance it has a small amount of kinetic energy. No doubt this energy varies about a mean value and as long as it is at least occasionally above the threshold needed to excite the photon emission there will be radiation. Meanwhile, the general interaction between the atoms and the exchange of kinetic energy will assure the manifestation of a temperature, even without such radiation. Electron flow merely adds to this kinetic energy exchange process and by its collisions will trigger off more photon emissions. If this electron flow and its collision action does not lift the energy level of the atom up to the threshold for radiation, assuming the material is at a really low temperature, no photons will be emitted. The collisions will occur without energy loss. Since they will be between electrons, either those carrying the current or those surrounding the atomic nucleus, they will be between particles of equal mass. Elastic collisions of this kind result in an exchange of velocities. Momentum is conserved. The result is that electrons can move without any apparent restraint through a loss free medium. The current will be sustained because the momentum is sustained by the electrons.

The above theory for superconductivity is merely suggested as the possible explanation. If it is valid, one would expect that if two superconductors composed of different isotopes of the same element are compared the heavier isotope will remain superconductive to a higher temperature than the other. The reason for this is that at the same temperature the heavier isotope has possibly a vibration condition of its atoms at a lower maximum velocity. Being heavier these atoms do not have to move so fast to keep the temperature balance with an interface at a reference temperature. It follows that their

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