## Retardation in the Coulomb Potential

## Harold Aspden

#### Abstract

The spatial disposition of field energy owing to mutual interaction of two particles is not usually considered in retardation force interaction theories. Stimulated by a comment from Allen [Phys. Essays 6, 614 (1993)], the author briefly summarizes his own prior published analysis of the electrostatic, electromagnetic, and gravitational field energy distributions and their bearing on action-at-a-distance and retardation theories.

Key words: gravitation, electrodynamics, Coulomb force, action-at-a-distance, retardation potential

### 1. INTRODUCTION

In a recent issue of *Physics Essays* Allen<sup>(1)</sup> challenges a proposition concerning retardation in the Coulomb interaction offered by the present author in an earlier paper.<sup>(2)</sup> The proposition is that there has to be retardation as energy adjusts to change in the Coulomb interaction. This proposition is based on the fact that, as viewed from either charge, the spatial deployment of electrostatic field energy set up between two electric charges and attributable to the interaction shows no net energy within a sphere with any radius up to the charge separation distance.

This suggested that when the two charges are in motion and their spacing changes, meaning that the electrostatic energy has to change, then, if any of that energy transits through the seat of either charge, whether as action or reaction, none of that energy change can become part of the electrostatic potential until a time lapse at least equal to the charge separation distance divided by the speed of propagation.

By this research the author was following a theme that sought to establish whether electrodynamic retardation effects are compounded by an action-reaction sequence requiring an energy transit time of double that just suggested, because energy fed in through the seat of one charge has to reach a remote field zone before it can begin the equidistant journey between that zone and the other charge. There has to be retardation in this process.

The logic of this does, of course, depend on one's perception of the speed at which energy can travel and whether that speed is finite or infinite, corresponding to retarded or instantaneous action.

Allen argues, to the contrary, that there is no delay in energy travel and hence no retardation. His view is based on the fact that a spherical shell centered exactly between the instantaneous position of two charges and having a radius equal to half their separation marks the separation between positive and negative interaction energy density. So equal and opposite energy increments can be drawn by each charge in instantaneous synchrony.

Note that the argument relies on the assumption that the electrostatic field set up by a charge has no dependence on time, being an action that is instantaneous. The question warranting debate, as seen by this author, concerns the prospect that an energy form that is not part of the electrostatic potential can travel through that field and, after the transit time, convert into electrostatic energy. In the reverse mode, electrostatic energy shed by the remote field zone assumes a different form before making the passage through the electrostatic field to reach the actual seat of charge.

Seen in retrospect and in the light of this author's onward research of later record, this conflict between two quite opposed physical interpretations of the same mathematical analysis can be resolved, but, as will be shown, some important fundamental questions are involved.

We will first consider the spatial deployment of field energy in a general way before examining the analysis which applies to the point made by Allen. Later, having regard to the fact that a retardation effect is involved in the calculation of energy radiation by accelerated charge by reference to the progressive deployment of electric field energy, it will be shown how the conventional treatment of the subject warrants some reinterpretation.

### 2. PRELIMINARY DISCUSSION

Consider, as shown in Fig. 1, two electric charges denoted by their location at P and Q and focus attention on the element of field energy set up in a volume sector as shown at point X. Note that we are only taking account of conditions for which P and Q are deemed to be at rest inasmuch as our concern is action in what we can term the "Coulomb gauge." Our intention in this regard is to begin from such a starting point and then consider how change of position affects the redeployment of field energy, thereby involving us in retardation questions and leading into the electrodynamic field situation.

The element of field energy at X is denoted  $\delta E$  and we can write

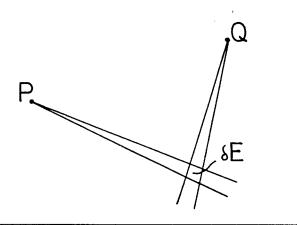


Figure 1. Field energy attributable to charges P and Q.

$$\delta E = f_{s}(F_{p}) + f_{m}(F_{p}, F_{0}) + f_{s}(F_{0}), \tag{1}$$

where F denotes field strength, and the suffix labels P, Q, s, and m refer to the two charges and self-action (s) or mutual-action (m) of those charges. Thus  $f_s$  would be a function in which the field F is squared to represent an energy term.

Now, given this two-charge system, we can never, in a real physical scenario, assume that it exists in isolation from other charges. There will be numerous other charges always present, and all these have interplay that can affect the way the charges respond to the above-formulated interaction, but it seems in order to assume that the  $f_{\bullet}$  terms are characteristic of the individual source charges P and Q and, as energy components, are independent of any influence asserted by interaction with other charge.

It is this author's belief that  $\int f_i(F_p)\delta V$  over the whole volume of space represents the  $E=Mc^2$  energy-mass property of P and further that  $\Sigma f_m(F_p,F_Q)$  summed over all charge interactions as mutual energy in a region of space at a particular locality is collectively at "rest" and so represents, by its deployment in space, the inertial reference frame operative at that locality. Otherwise, one needs to bring into later discussion the question of the mass-energy property attributable to the motion of mutual energy components, and in physics we have not hitherto had to worry about "mutual kinetic energy" as it applies to separate bodies in independent motion. Nature may have a way of sparing us that complication by the simple expedient of assuring that the quantity is always zero, at least in a macroscopic sense, which it can do by local determination of the inertial frame of reference as a function of that mutual energy situation.

In any event, the self-energy terms are deemed to be those that govern the mass property and so the inertia of each individual charge in any system and where the author refers below to the "intrinsic" energy of a charge is a reference to its self-interaction electric field energy. The latter is always finite because we are not envisaging point charges, but rather charge confined to a finite volume of space.

The question now confronted is how energy at X in Fig. 1 can affect forces on P owing to Q. Experience of physical situations

suggests some kind of retarded action, but whether it is by intuition or logic depends upon one's viewpoint. One can best answer this by regarding such retarded action as a "knock-on" effect or buffer action of the environmental "ether" charge that pervades all space and so is intermediate P, Q, and X.

Something determines the finite speed at which waves propagate through "empty" space, and it is only logical to see that something as seated in the vacuum charge which is displaced in the sense of Maxwell's theoretical formulations.

So, if charge other than P and Q is the retarding influence for actions as between P and Q, we then have to decide whether, so far as  $f_m(F_P, F_Q)$  is concerned, this is subject to its own retardation properties or if it "sees" P and Q as an action-at-a-distance.

In a later section we will address the retardation question as it arises in the self-field intrinsic to a discrete charge when accelerated, but here our attention is centered solely on that mutual energy problem.

It is this author's submission that if we adopt the hypothesis that intervening vacuum charge accounts for the speed-of-light retardation effects in the field between two charges P and Q, we could take the middle ground between that proposition and orthodox retardation theory and explore the interaction of P and Q on the assumption that the instantaneous action-at-a-distance theme applies to the determination of  $\delta E$  in Eq. (1). In other words, we could assume that if P moves closer to Q, there is an instantaneous setting up of a condition throughout space by which  $\delta E$  has a new value given by Eq. (1) and, as in any physical system subject to energy conservation as a quasi-equilibrium develops, so this means that energy is exchanged locally with what must be a background sea of zero-point energy permeating all space.

That hidden world can be in turmoil as energy is then redeployed in what is an ocean of activity, but, owing to that instantaneous interaction between charges P and Q, the forces exerted on them are of a definite nature and are immune from that turmoil. This is important in that, otherwise, we could not assure that the interaction forces were compliant with our finding that charge interactions can be superimposed without interfering with the principles governing their component actions.

For example, suppose at point A we have two charges +e and -e and at B we have two such charges. Suppose the charges at A move at the same speed in opposite directions, as do those at B. In terms of electrostatic field action there is negligible mutual electric field energy in the remote field zones that are intermediate A and B, but in terms of electromagnetic field energy there is a finite and significant mutual field energy in those zones.

If one sees electrodynamic action as a retarded effect generated by retarded adjustment of the mutual electric field energy, then one faces formidable questions. However, if the mutual electric field action is an instantaneous action-at-a-distance, so the calculation of electrodynamic response can proceed referenced directly on the individual source charges rather than indirectly on the retardation treatment of the mutual electric field action.

It was this that caused the author, in following a lead suggested by Brillouin, (3) to examine the spatial deployment of field

energy in relation to distance from the source charge.

## 3. BRILLOUIN AND THE SPATIAL DEPLOYMENT OF FIELD ENERGY

In his 1970 book entitled *Relativity Reexamined*, Brillouin discussed the seat of energy or mass in the interaction field between two particles. His analysis concerned the Coulomb interaction between two charges, and his treatment was quite cursory and an approximation. His conclusion:

The present discussion proves that mass renormalization is not only needed in quantum theories, but that it must already be introduced in classical relativity, where it was completely overlooked by the founders of relativity. Sommerfeld and Dirac were not aware of the difficulty, and their formulas must be very carefully revised.

In a sense this reference to "mass renormalization" is what this author has assumed with regard to the zero inertia of the mutual interaction energy of two bodies by asserting that they share a collective action with all free charge locally and so determine the locally applicable inertial reference frame. Brillouin says that "mass renormalization" must already exist in classical relativity, and so this proposition concerning the seat of energy in a collective interaction field is implicit in that assertion.

The idea of "renormalization" is that if analysis in our physics leads us astray and confronts us with a difficult or seemingly impossible conclusion, such as bringing in infinities where we know that actions are finite, then we contrive to look at the problem knowing that nature brings the act together in a meaningful way. If the mass problem associated with a concerted motion of a mutual interaction energy field is too formidable to address, then the answer might well lie in saying that nature makes the answer zero, as by ensuring that the local inertial reference frame is determined to assure that conclusion.

The Mach principle takes us to the other extreme by saying that the mass of a body depends upon its collective interaction with all other matter in the universe without explaining how the energy adjustments could occur over such vast distances. This author says that the mass of a body is determined in the self-energy field of that body as it contrives to conserve that energy and that the "mass renormalization" of interaction with other bodies is not because the reacting universe gives mass to that body, but because instead it deliberately ensures that no further mass is added by virtue of interaction with those other bodies.

Now, bearing in mind that mutual energy as between two charges P and Q has a way of transferring from the field in intervening space to become seated in the kinetic energy of the self-actions of each interacting particle, one has no choice but to question how the mutual interaction energy on average is deployed in terms of distance from either charge. Note that the energy term  $f_i$  in Eq. (1) does not include kinetic energy. Our working assumption concerning the form taken by kinetic energy is that this energy develops a statistical presence of an electron-positron population in the field in the vicinity of the nucle-

ating charge and so each of these quantum electrodynamic charges has its own transient presence of energy expressed by a term such as  $f_{i}$ . This does not affect our analysis of the direct Coulomb action as between P and Q.

Note next that at any point X, the field energy density of the P, Q system has to be *positive*, but this does not mean that  $f_m(F_P, F_Q)$  is everywhere positive. On the contrary,  $\delta E$  can be positive, while the  $f_n$  terms are both positive and the  $f_m$  terms can be negative or positive depending upon the position of X and the polarities of the two charges P and Q.

The physical question then is whether at a given point X we can expect the  $f_*$  energy terms to "lend" energy to allow the  $f_m$  term to become negative, or whether the so-called "zero-point" background field energy of the ether acts as the banker keeping the mutual energy balance.

Now, when the author wrote the paper<sup>(2)</sup> criticized by Allen,<sup>(1)</sup> it was there suggested that the evident energy void applicable to  $f_{\rm m}$  up to the range set by the separation distance between P and Q meant that any energy transfer in the Coulomb field had to traverse that separation distance to transfer to or from kinetic energy. Hence there was reason to think in terms of retardation by a time lag d/c, where d is that separation distance and c is the speed of energy transfer.

# 4. ANALYSIS OF THE SPATIAL DISTRIBUTION OF FIELD INTERACTION ENERGY

The paper in dispute<sup>(2)</sup> was published in 1979, and it offers a very simple solution to the problem of determining the Coulomb interaction energy spatial distribution by geometrical analysis.

Whereas we know that the self-field energy density sourced in a charge sphere has a distribution as shown in Fig. 2, with no energy inside the sphere and the energy gradient reducing as the inverse square of distance x from the charge center, it may seem surprising that a similar curve applies to the electric field interaction energy. Given two charges P and Q of like polarity, the sum of the interaction energy within a radius R equal to the charge separation distance is zero.

This led the author in that 1979 paper<sup>(2)</sup> to ask how such energy might deploy in exchanges with kinetic energy or magnetic energy when the two charges move apart, and although it was inferred that the Coulomb interaction might suffer retardation, that question led to interesting comparisons with the energy distributions that one can compute for the Lorentz electrodynamic force interaction. This analysis was very complex, even though the findings were easy to portray and included a linear energy distribution replacing the zero net energy zone of Fig. 2. Such analysis, published in 1980, was mainly the work of coauthor Eagles.<sup>(4)</sup> This distribution is shown in Fig. 3.

Note that there is a very perplexing situation here, because the Lorentz force law requires the force between two moving charges P and Q to vary according to the orientations of their different directions of motion relative to each other and also relative to their separation vector PQ. Curiously, regardless of these directional criteria, the quite rigorous analysis leads to a linear form of energy distribution ranging up to the separation

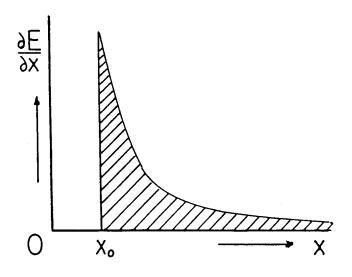


Figure 2. Coulomb field energy distribution set up by hollow sphere of charge of radius  $x_0$  or that of the mutual interaction of two like polarity charges separated by the distance  $x_0$ .

distance and then a discontinuity in the general case as the distribution between (a) and (b) adjusts to a common inverse form at increasing distance. This, in this author's opinion, reveals a weakness inherent in the Lorentz interpretation because it seems a quite extraordinary physical circumstance if one is to accept that there could be anything other than a continuous transition in the energy distribution field at that range PQ from either charge.

A continuous transition in the field energy distribution may well apply if the conventional analysis based on the Lorentz formula when applied to a system in which at least one of the charges is part of a continuous closed circuital current. The empirical basis of the law involved such circuit continuity and that is no assurance that the field implications involved extend to the actions between two discrete electrical charges in general motion.

This is a very fundamental question, because, in taking physics forward by relying on the empirical findings confined to actions involving a closed circuit current (this including a magnetic field source), physicists have abandoned the one link that can provide a bridge across the gap between conventional electromagnetism and the underlying quantum world. The latter involves a field populated by particles asserting dynamic action from discrete charge centers rather than collective action as mere followers in a continuous current circuit.

Following the exploration of the electromagnetic field energy distribution set up between two charges in motion, this author focused attention on the gravitational interaction. The latter should, if we apply standard gravitational field theory, have a field energy distribution exactly similar to Fig. 1, although it must be noted that the gravitational interaction energy between two masses is negative, just as would apply if the Coulomb interaction was between charges of opposite polarity.

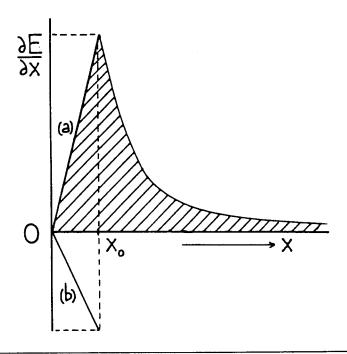


Figure 3. Magnetic field energy distribution set up by the mutual interaction of two charges in motion at a separation distance  $x_0$ : (a) with mutually parallel charge motion along the separation vector and (b) with mutually parallel motion perpendicular to the separation vector, (a) also applying to gravitational field energy distribution.

This author dealt with the gravitational action in another 1980 paper<sup>(5)</sup> and argued the very fundamental principle that, if the interaction energy tended to be as remote as possible from each reference body, then the case shown in Fig. 2 would apply, but if the energy sought the closest proximity with each reference body, then the only distribution that would be consistent with an inverse square law of force would be one with a linear distribution over the distance separating the two bodies, one of the cases shown in Fig. 3. Indeed, the case (a) that corresponds to there being no sudden step discontinuity of energy density in the distribution profile is the one that suits the gravitational situation.

There is, however, a clear physical difference between the action of the Coulomb force and the electromagnetic interaction force and, urged by an interest in solving the field unification problem, the key question arising is whether the gravitational field is seated in an electrodynamic action or is something standing alone as akin to the Coulomb interaction.

The physical difference, as we all know, is that field energy redeploys in a different sense for action between like bodies as asserted by Coulomb's law and by Newton's law of gravitation. The electric energy potential set up between two like charges is positive and seeks to reduce by shedding energy as the charges separate, whereas the gravitational energy potential is written as a negative quantity because energy is shed as two masses come closer together. This makes gravitation a property akin to that of an orderly dynamic state, as of a flywheel which sheds energy

as nonordered kinetic energy (heat) when braked to rest.

The underlying physics could well be that of a field in which energy seeks to redeploy in its spatial distribution, tending to be as remote as possible from the source charges in the Coulomb case and as near as possible to the source masses in the gravitational case. Electric field energy seated between the charges will then push them further apart, whereas gravitational field energy, as a positive quantity sitting between the masses, in being augmented by release of energy no doubt from an electric field source, will seek to build up between the masses in a way which brings them closer together.

It was evident from the spatial energy distributions presented that the best route to adopt in the further study was that which required the gravitational field action to be a special case of electrodynamic interaction.

The question then addressed in that second 1980 paper<sup>(5)</sup> was how a propagation delay would affect force interaction governed by the form of energy distribution.

Here the task was to seek explanation of the anomalous perihelion motion of the planet Mercury, since the advance of perihelion is simply a phenomenon by which the circular component of orbital motion observes a nonretarded action and so has an orbital time period that is determined by Newtonian law, but the radial perturbations involve energy redeployment owing to the changing spacing of the Sun and planet and so are retarded. This means that some energy is in transit and so is effective in regulating the gravitational action governing the perturbation. Since gravitational energy potential energy is negative in character, a deficit state to cater for energy in transit means a stronger negative gravitational action. In effect it is as if G, the constant of gravitation, is increased. Therefore, the radial perturbations, which, unlike the circular orbital component of motion, involves energy exchanges, occur as if G is larger and so have a faster rate of oscillation than the orbital period. The result is an advance of perihelion.

The author's paper, (5) which faced very demanding scrutiny by referees acting for the Institute of Physics in the United Kingdom, demonstrated how the field energy distribution that corresponded to a type of electrodynamic action was the form applicable to gravity by deriving the precise law of motion that explains the anomalous perihelion advance of the planet Mercury. It was identical to that emerging from Einstein's theory but had not involved use of the relativistic four-space doctrine.

In summary, therefore, this was really the purpose of the field energy distribution analysis in connection with all three force actions. The distance that energy had to deploy in readjusting to changes of relative position of the interacting bodies does have bearing upon the retardation of force action and certainly applies to electromagnetism and gravitation.

## 5. THE ALLEN CRITICISM

Allen<sup>(1)</sup> has drawn attention to the fact that, for that Coulomb interaction, one can further prove that the sphere having a diameter linking the two charges provides a surface boundary between positive and negative energy. This is shown in Fig. 4. Note that there are nine plus symbols which represent units of

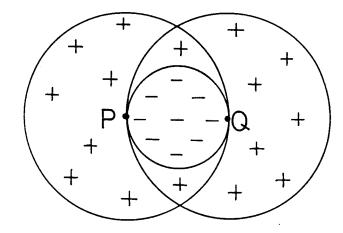


Figure 4. Coulomb field interaction energy as between two charges P and Q of like polarity, the plus and minus symbols indicating units of positive and negative energy.

that energy and that in each of the two larger spheres there are nine minus symbols. As already stated, as viewed from either charge, the net energy within a range equal to the charge separation distance is zero, but yet there are regions of positive energy and regions of negative energy in each sphere.

Allen argues that, because each charge is precisely positioned at a boundary surface on one side of which there is positive energy and on the other side of which there is negative energy, but at the boundary between which there is no energy, this causes the Coulomb interaction between charge to be unretarded.

However, one still has to explain how energy distributed in the Coulomb interaction field can travel to and from the source charges P and Q to keep a balance with their kinetic energies as they change relative position.

In short, assuming Allen's position holds up and that no net energy can traverse the boundary sphere, if that spherical boundary separating positive energy from negative energy density components does change in radius because the two charges move apart, somehow that balance of energy has to travel around the boundary sphere to reach a source charge. There is no escape from a retardation effect once we displace charge relative to other charge.

What is interesting in this debate is the clear finding emerging from what Allen says, that if the two charges were to move together to keep their relative positions constant, so the Coulomb spatial interaction energy distribution would not need to transfer energy to or from the individual charges. In this circumstance there could, arguably, be no observable retardation effect in the force action between the charges, but there is still something happening involving energy transfer in the field system.

The latter is particularly the case if the two charges were seen to be in balanced motion in circular orbit about a common center of mass, because here our proposition that the mutual interaction energy, when taken collectively with all other local interactions present, is at "rest" in the inertial reference frame and so cannot affect the validity of this argument, whatever the speed of the

two charges.

This has special relevance to the question of the nature of the ether, the subject of a *Physics Letters* paper by this author and Eagles, <sup>(6)</sup> because a two-charge ether system having the balanced dynamic property just described is there presented, and it is essential to that theory that there is no retardation in the charge interactions in the basic nondisturbed ether. This is notwithstanding its state of motion that accounts for the Heisenberg jitter, the so-called *Zitterbewegung* that underlies quantum theory.

That latter paper is based on the conviction that there is something about the universe and space that gives form and order to what would otherwise be chaos, a situation reflected in the basic physical constants. Something determines why the fine-structure constant is the same everywhere in the universe and one may take an example from the pure ordering of crystals. Would crystals really form if the physical properties of the molecules involved were not regulated to fit a uniform mold? Or, perhaps we can say that by forming a crystal a substance has been made to conform with the universal pattern.

Action-at-a-distance has meaning if something akin to a crystal determines the constancy of physical constants and the space medium is to avoid wobbling like a jelly or dissolving into a characterless fluid.

Indeed, it was a pursuit of many years by the author to pinpoint the basis of the Neumann potential which governs the electromagnetic force interaction, eventually solved by accepting that the Coulomb action is instantaneous and does involve balanced forces notwithstanding the distance separating the charges. The action occurs as if there is some fundamental energy conservation process in an underlying field medium that sustains the two balanced force reactions while serving as a source of a vacuum energy fluctuation that deals with the energy transactions we associate with the change of charge separation. This gives the underlying medium the task of sorting out the energy equilibrium by propagation effects confined to its own energy system. Such action in no way retards the Coulomb force interaction, but it is that free energy in transit in that hidden medium that is a measure of the energy we associate with electrodynamic force and gravitation and that does exhibit, via gravitation and electromagnetism, a retardation feature. The full analysis of this is presented elsewhere. (7)

Given a theoretical causal physical basis for the Neumann potential, one can derive the Lorentz force law and other possible laws of electrodynamics, the different forms of law depending upon which type of energy exchanges are to be deemed physically appropriate. For example, if one accepts that electrodynamic interactions between two charges in motion can develop a turning couple or an out-of-balance force exerted on other charge, or both or neither of these, all lead to different forms of law. Much has been written on this topic in recent years and is discussed elsewhere. (8,9)

## 6. DO PHOTONS REALLY CONVEY ENERGY AT THE SPEED OF LIGHT?

The author has avoided discussing the nature of the energy flow as the interaction field adjusts to change. Generally, it is supposed that photons travel around and carry energy, but the merit of what is suggested in this paper resides in the proposition that the energy transactions in the field are determined, in the Coulomb gauge, by action-at-a-distance effects which signal instantaneously the changes of state leading at each point in space to energy being borrowed or lent to the zero-point field background. There is retardation set up by the electromagnetic response that is signaled by waves which propagate at the speed of light, but even here one can imagine that the energy transactions occur also by exchange with that zero-point energy background.

We need not then know how that background sea of energy contrives to adjust, although this author suspects that there is a virtual muon field involved in this process.

This brings us to two debatable questions, one concerning the nature of the photon and one concerning the relevance of the Poynting vector and energy transport by waves.

They are linked by the wave-particle duality issue, and it seems absurd that physics should have two alternative ways of describing electromagnetic energy transfer. Only one can be right if energy is really transferred by either, but both phenomena can have valid meaning if *neither* transports energy in fact.

Concerning the photon, this is only known as an "event." No one has ever seen a photon in flight. All we know is that a package of energy released at one point A in space can reappear elsewhere as a package of energy at a point B. The communication signaled between A and B could be that of a wave and the energy involved could be that transferred by exchange with the zero-point field background.

This author is firmly of the opinion that the wave-particle duality has a real physical basis in that both the photon and the wave exist as real phenomena but neither transports energy. The wave signals frequency and direction and somehow the underlying zero-point fields system communicates momentum, the latter being the regulator that governs statistical effects and overall energy balance. This became a plausible viewpoint once it was established that particles have energy and mass which become virtually infinite as their speed approximates that of light.

Owing to the open question of how energy is actually transported in the electric field system of two interacting charges, there is purpose in considering the conventional theory of energy radiation from electric charge. We need therefore to discuss how the self-energy expressed by the  $f_{\bullet}$  components in Eq. (1) responds when an isolated charge is accelerated.

## 7. ENERGY DEPLOYMENT BY ACCELERATED CHARGE

Before the author had embarked on the study of energy deployment as between interacting charges, he had already investigated the classical basis on which the radiation of energy develops in the successive regions of the field surrounding a single electric charge when accelerated. (9.10) It was clear from the Larmor derivation of the formula for energy radiation that the question of what causes that acceleration had been overlooked. "Let there be acceleration" is the usual starting point and then, for each acceleration pulse, one needs to assume that

the electric field lines travel as if rigidly connected with the source charge, apart from experiencing a kink as the wave disturbance propagates at the speed of light through that field. The extra field energy in that "kink" was the supposed energy radiated.

This author recognized the need to have another charge interacting with that accelerated charge to give account for the acceleration. The question then arose: What really happens to that "kink" field component of the field energy in space as the wave disturbance passes through the field of the other charge? It is all too easy for us to make a mathematical approximation and say that once the wave carrying the radiated energy is initiated, it travels outward through space until eventually it is too far away from the source charge and its accelerating influence for the remote wave zone field calculation to be affected. We assume that once energy sets out on its journey in free space it keeps moving at the speed of light and is lost as "radiation."

Now, of course, when the interaction energy is studied close to the accelerated charge (taken as a point charge) and the wave disturbance ripple is examined through the interaction energy, as well as the self-energy, what we find is that there is an inversion radius at which no energy travels outwards or inwards from the charge.

The author saw this as very relevant, because the Poynting vector theory assumes energy is radiated by an accelerated electron and does not prove it. Should the reader be tempted to appeal to our experience of radio transmission, it is well to keep in mind that energy radiation by concerted acceleration of many billions of electrons is no proof that each individual electron is a self-radiator. The Larmor formula for energy radiation is proportional to the square of the total charge accelerated and  $(nq)^2$  is hardly to be distinguished from  $n(n-1)q^2$  when that assumed self-radiation energy  $n(q)^2$  of n electrons is removed. Radio transmitters involve billions of electrons oscillating together!

What is clear is the fact that there is no radiation, given that we know that single electrons moving in atoms with their "Pauli exclusion" passport do not radiate their energy. This is consistent with the quantum hypothesis, but historically, because we failed to study the seat of that Coulomb interaction energy and how energy might redeploy, we missed the vital fact that an electron will contrive to preserve itself by not radiating its intrinsic energy.

When the author determined the boundary radius of the inversion (zero energy transfer) condition, it was found that it depended upon a unique relationship between the assumed rate of acceleration f of the charge, the sum total E of the self-energy of its electric field, and the speed of propagation c of the wave disturbance developed. The zero energy radiation condition is nothing other than the raison d'être for the very existence of the inertial property. Mass M is the connection linking f, E, and c in the formulation of the no-energy transfer inversion condition<sup>(10)</sup> and, as one might expect, the self-conservation property of the electron is a causal foundation for  $E = Mc^2$ .

This author, therefore, did endorse Brillouin's opinions on the

need to reexamine relativity, and the study of the Coulomb interaction became a pathway for probing the gravitational and electromagnetic interactions by detailed study of how field energy is deployed in the space.

Concerning the analysis involved, it may suffice to consider the following very simple summary as provided elsewhere in much greater detail.<sup>(9)</sup>

One standard textbook derivation of the Larmor radiation formula first deduces the radially propagating electric field disturbance as a vector lateral to the radial electric field from electron charge e. At a point in the wave zone distant ct from e and subtending an angle  $\Theta$  with the direction of acceleration f, the disturbance field is

$$ef \sin \Theta/c^3 t$$
, (2)

where c is the speed at which the disturbance propagates. By integrating this in its energy form, that is, its squared formulation as energy density, over the full volume of a spherical shell of thickness  $c\delta t$ , one then deduces the usual Larmor formula for rate of energy radiation in time  $\delta t$  as

$$2e^2f^2\delta t/3c^3. (3)$$

Once one superimposes an electric field of intensity V directed in the acceleration direction, the field expression in (2) is offset by a component  $V \sin \Theta$ , and it follows that there is a condition for which no energy is radiated at all, which is when

$$ef/c^3t = 2V. (4)$$

Note that the 2 has appeared in this equation because the energy radiation cannot involve terms in  $V^2$ . Remember that Eq. (1) comprises three terms, and if the charge source of V is at rest, there can be no energy transport of its self-action component. Also, the formula (2) has excluded the radial electric field from the electron charge e by restricting attention to vector field transverse to the radial reference axis. So our derivation of Eq. (4) involves squaring the offset field combination and eliminating the  $V^2$  term, thereby introducing the factor 2.

Rearranged, (4) becomes

$$Ve/f = e^2/2c^2(ct), (5)$$

and this is an expression for force divided by acceleration, otherwise defined as a mass property M, whereas  $e^2/2(ct)$  is well known as being an expression for the Coulomb energy or self-energy of the electron field disposed beyond the radius of the propagating wave front. We may denote this E to derive the formula

$$E = Mc^2. (6)$$

What this really means is that any component of intrinsic or self-energy of the Coulomb charge e of an electron that is accelerated by waves propagating as kinks in its field system

must contribute an inertial property as a mass value defined by this Eq. (6). The most basic formula of energy physics,  $E = Mc^2$ , has therefore been derived by contending that Larmor's radiation formula does *not* apply to the individual discrete source charges in an accelerated charge system. This is the reason why electrons in a nonexcited atom can sustain enormous accelerations without shedding energy continuously.

The point of special interest is that underlying the derivation of the Larmor formula and leading to  $E = Mc^2$ , there is the requirement that the electric field of an electron moves with it as if rigid when there is no acceleration. This implies action-at-adistance in the Coulomb gauge, which is an accepted hypothesis anyway by many theoretical physicists. Then one faces the problem of knowing what field energy really is in true physical terms, as opposed to mathematical formulas. If the "mass" of an electron is seated in its entire rigid field composition, how is mass deployed? The author's argument about inertial and E = $Mc^2$  requires mass to be seated in centers of charge, and so one cannot really introduce other charges in the field to account for incremental inertial properties of that same mass at higher speeds. However, virtual lepton charged pairs can be deemed to populate a field in proportion to and field energy density added as kinetic energy.

It is also to be noted that if one were to regard the mass of an electron as a fixed quantity that accelerates as one rigid body, then the wave ripple that transfers changed motion to successive newly centered spherical field regions would not give that  $E = Mc^2$  relationship unless one accepts the consequent analysis findings that energy is propagated outwards from the electron center and inwards from the external field. This energy flow is presumably absorbed by the electron's inertial field because at a spherical boundary, a cutoff boundary, at which zero energy flow applies either way, one can there establish the connection between E and  $Mc^2$ . A short summary analysis of this is provided elsewhere by the author. (10)

### 8. CONCLUDING DISCUSSION

To complete this account, the derivation of the Neumann potential from the Coulomb action-at-a-distance hypothesis has been dealt with by the author under the title "Instantaneous Electrodynamic Potential with Retarded Energy Transfer," but see also a summary account in a 1989 *Physics Essays* paper on "The Theory of the Gravitation Constant."

One aspect of the author's theory that should be kept in mind is that nature somehow manages to run the universe in an orderly manner, at least where gravitational effects are involved. Judging by the extreme mathematical complications of theories based on retarded potentials, which seldom yield simple explanations, there is much to be said for a hypothesis that requires action-at-a-distance as the ruling action, with the chaotic unseen energy world of virtual leptons rippling with activity to keep the equilibrium. Such activity does not lend itself to exhaustive mathematical treatment of any consequence, except in the refinements of standard quantum electrodynamics as applied, for example, to anomalous magnetic moments of electrons.

Given that the form of the law of gravitation embracing the

planetary perihelion anomalies can be derived, as can the law of electrodynamics, without using retarded *potential* theories, and relying instead on action-at-a-distance, diminished or enhanced by the balance of energy in transit, there is much to be gained by seeking to avoid the complications of retarded potential theory.

This, at least, is the author's conclusion, but one needs to understand the logic of the author's endeavor, as summarized above, in order to appreciate the points made.

#### 9. OBSERVATIONS BY REFEREE

Referee: The case put above is that in deriving the Larmor formula for energy radiation the treatment is partial and the cause for charge acceleration is not included, but it is worth noting that the converse is also true: in writing the Lorentz force law to model the acceleration, we implicitly leave out the radiation. There is no radiation reaction in the Lorentz force law and that makes it partial too. There is no coherent overall treatment.

Author's response: This is a very valid observation which eludes mention by textbook authors.

Referee: The author recounts without comment that in a standard approach "one needs to assume that the electric field lines travel as if rigidly connected with the source charge..." This peculiar behavior is under discussion by Allen, Whitney, and possibly others in *Physics Essays*. It could at least be flagged as a subject worthy of scrutiny.

Author's response: The assumption is, of course, the *ab initio* standard textbook presumption that the Coulomb action of components of a discrete charge form acting back on itself is an instantaneous action even though it does extend throughout the field in surrounding space. The complementary point is that two charges are distinct as discrete separate entities when the energy attributable to their overlapping electric field lines is not part of what can be said to be a rigidly connected system. This leads into the referee's next remark.

Referee: The author states that the rigidity implies action-at-a-distance in the Coulomb gauge. I don't think Coulomb gauge is necessary here; rigidity alone is enough to do it. And it is certainly noteworthy that a putatively relativistic theory gives us such a prerelativistic behavior.

Author's response: I agree, but in writing the paper I was influenced by words I heard used by a famous proponent of quantum theory who I am sure would not speak in terms of a charge field having "rigidity" but who did, in his lecture, speak of "action-at-a-distance" in the "Coulomb gauge." Sometimes, as a matter of modern style in presenting physics, it is prudent to avoid being blunt in saying what is obvious and instead develop a debate in more acceptable terminology directed to the same conclusion.

Referee: The author correctly notes that we have no proof that an individual electron is a self-radiator. He cites single electrons moving in atoms as evidence that maybe they don't. Here he brings in the Pauli exclusion principle, which I think is irrelevant to the observation. More to the point, a single electron spins and that doesn't seem to cause radiation either.

Author's response: Since I imagine electron spin as something that involves an electron charge center being at rest in the electromagnetic reference frame, even though that frame has a jitter motion relative to the inertial frame, (6) I have not regarded this as generating radiation. My reference to the Pauli principle by which electron oscillation modes in an atom are mutually exclusive gives expression to my familiarity with the energy aspects of harmonic and nonharmonic interactions of field wave forms and their Fourier analysis. Given that a single electron moves to avoid radiation of energy, a plurality of electrons interacting have states of motion in which they may or may not cooperate to radiate energy. The multielectron atom can be excited from its ground state into a radiating state but in its ground state where it does not radiate, so one needs to understand why. One should not be satisfied by a "principle" as a sufficient explanation when the onward analysis that may develop from what is said in this paper could give causal reasoning explaining the physics underlying that "principle."

Referee: On the point of nonradiation of energy by electrons, the converse is also worthy of note. We can have a large number of electrons going around as a steady current in a macroscopic circuit. This situation certainly has acceleration, but it does not give radiation.

Author's response: This is a very valid point but given that the individual electrons do not radiate energy owing to their inertial mass being given by  $E=Mc^2$ , there is then need to understand why their collective mutual action as a steady circuit current does not radiate energy, inasmuch as there is no inertial mass directly linked with that mutual interaction and so no massrelated energy conserving reaction. Here it is really a question of whether the energy of that mutual interaction has to change at any point in the field. By asserting that the current flow is "steady," one is saying that the field at that point is not changing. That means that no energy needs to redeploy in the field and, without energy seeking to change position, there is then no basis for what we term "radiation."

Other points raised by the referee have been answered by amendment to the body of the paper, but the author faces challenge on the importance of ongoing research into retardation theory. The referee says: "We need to be sure we know where we are and how we go astray before we can be sure that a theory really can't be made to work. But that's just an opinion."

Author's response: Much depends here on the target objective

of what it is that the theory is to explain. So often we see retardation formulas presented as solutions to a given problem, but the problem I could never solve by retardation theory was that of deriving the Neumann potential, starting from two charges in motion and not begging the question by bringing in the Lorentz force law *ab initio*.

The Neumann potential can lead to the unifying link with gravitation, (11) and the author's paper (7) presents his action-at-a-distance derivation of the Neumann potential. These papers are incorporated as appendices in a 1994 update on inertia and gravitation, (12) which debates an inertial theory recently proposed by Haisch, Rueda, and Puthoff. (13)

A simple summary of the author's position is that the Lorentz force law can be derived as a special case (meaning that originating in a closed circuital action source) from a simple general law of electrodynamics (8) founded on that Neumann potential. The same generic electrodynamic law includes as a different special case (the one where the two like charges move in parallel directions) the inverse square of distance action directed in the line linking the charges that we associate with gravitation. Physics has gone adrift on the "chicken and egg" question trying unsuccessfully to get Lorentz (the chicken) to lay a variety of eggs (including gravitation) and not realizing the need for an alternative, the scenario where several chickens (Neumann potentials) cooperate to determine a general law of electrodynamics which lays eggs of different varieties in different circumstances (Lorentz force and gravitation). It has gone adrift further in not resolving the conflict between energy radiation and quantum processes by taking notice of the flaw in the Larmor theory.

### Acknowledgment

I am indebted to Dr. Panarella, the editor of *Physics Essays*, for giving me the opportunity to comment on the paper by Allen<sup>(1)</sup> and, indeed, to the latter for questioning my comments in my first paper on this theme.<sup>(2)</sup> Without this interest I would not have seen purpose in writing this account linking this aspect of my published work, but I now realize that unless the several papers are seen in context as part of a whole, their contribution is so easily missed. I wish also to thank a referee to whom the evaluation of this paper was assigned, because that referee has stressed a number of points that warranted mention.

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