3. Systems Violating the Second Law

Occasionally creationists make statements which allow room for exceptions to the second law, such as: "Now, if one examines closely all such systems to see what it is that enables them to supersede the Second Law locally and temporarily . . ."[5] But there is no evidence that even temporary or local violations of the law exist. A well-known physicist wrote, concerning exceptions to the second law: "In fact, no violation can be brought about in this case, nor with any of the ingenious and often subtle engines which have been devised with the object of circumventing the law. Moreover, the consequences of the law are so unfailingly verified by experiment that it has come to be regarded as among the most firmly established of all the laws of nature."[6]

In view of the strength of this statement (and many others like it), it would seem that the burden of proof for exceptions to the second law should lie heavily upon the evolutionist. In an excellent article,[7] Dr. Emmett L. Williams showed that though biological systems are so complex that they have not yet been rigorously analyzed, there is much evidence that the second law does apply to living organisms, and no evidence that it does not. "There is simply not enough scientific information available to substantiate the claim that living systems violate the second law of thermodynamics."[8]

Therefore, since there is such strong experimental evidence that the second law applies to all systems, open or closed, living or non-living, creationists do not need to grant to evolutionists the ground of possible exceptions to the second law of thermodynamics.

References

[1]Prigogine, I., G. Nicolis, and A. Babloyantz, 1972. Thermodynamics of evolution, part one, *Physics Today*, November, p. 24.

[2]Pippard, A. B. 1957. The elements of classical thermodynamics. Cambridge University Press, London, pp. 36, 37.

[3]Zemansky, M. W. 1957. Heat and thermodynamics. Fourth Edition. McGraw-Hill Book Co.. Inc., New York, pp. 176, 177.

[4]The energy flux from the sun is about 2 calories per minute per square centimeter (Handbook of Chemistry and Physics. 1970, 51st edition, Chemical Rubber Company, Inc., p. F-151, under "solar constant"), or about 0.033 cal/sec-cm^2. The area the earth presents to sunlight is about 1.27×10^{18} square centimeters, so the earth is receiving a total of about 4.2×10^{16} calories per second from the sun. Dividing this energy flow by the approximate average temperature of the earth's surface and atmosphere, 300 °K, gives us an entropy flow of $1\text{-}4 \times 10^{14}$ calories per °K per second.

[5]Morris, H. M., editor, 1974. Scientific creationism. Creation-Life Publishers, San Diego, p. 43.

[6]Pippard, A. B. *Op. cit.*, p. 30.

[7]Williams, E. L. 1971. Resistance of living organisms to the second law of thermodynamics, *Creation Research Society Quarterly*, 8 (2):117-128.

[8]*Ibid.*, p. 125.

A NEW THEORY OF THE ELECTRON

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In this article work begun in a previous one, Reference 20, is continued. Two matters especially are considered. One is the increase of mass of charged elementary particles moving at high speeds. Special relativity includes this increase, but offers no physical explanation; it is hard to see how arguments about observers can explain what happens when no observers are present. Here the increase of inertia is seen to be due to the magnetic field generated by the motion. The other matter is the stability of elementary particles such as electrons. These particles are basic to electrodynamics; but electrodynamics predicts that the particles would explode, unless there be additional forces to bind them together. Here such a binding force is investigated; and an incidental outcome of the investigation is the removal of a discrepant factor, such as 4/3, which has long plagued theories of the electron.

Outline

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I. Introduction

Since its beginning with Galileo toward the end of the sixteenth century, classical physics has enjoyed many great accomplishments. In 1630, Johannes Kepler provided a foundation for astrophysics when he was able to formulate his three laws of planetary motion utilizing the empirical data of Tycho Brahe. Fifty-seven years later, Isaac Newton published *Mathematical Principles of Natural Philosophy* in which he presented his Universal Law of Gravitation and Three Laws of Motion.

Two centuries later, using Michael Faraday's new field concepts, James Clerk Maxwell devised his *electromagnetic theory of light* in which three previously separated areas of physics were unified. On the basis of Maxwell's four field equations, physicists have been able to explain almost the entire scope of electricity and magnetism. With this brief history it is understandable why the situation appeared favorable for physics toward the end of the nineteenth century.

As time progressed, however, problems arose. Newton's laws of motion were known to be invariant between frames of reference moving with respect to one another with constant velocity (i.e. inertial frames of reference). This was not surprising; since Newton's laws have to do with acceleration. With Maxwell's equations, which involve velocities, however, mathematical invariance was not found to hold under the classical Galilean transformations.

The reason for this, it was generally believed, was that electromagnetic radiation moved with respect to the "luminiferous ether,"[1] an assumed substance filling space which served as the medium for the propagation of light and other electromagnetic effects.[2] The frame of reference with respect to which this substance was at rest was considered to be the absolute frame of reference.

Various experiments were performed, however, which cast considerable doubt upon the concept of a universal ether. The most notable of these was that performed by Michelson and Morley in 1887. As a result, physicists were faced with three possible alternatives: 1) Maxwell's equations were wrong (as Ritz believed), 2) the Galilean transformations were incorrect, or 3) a preferred frame of reference could still somehow be identified.

Albert Einstein, in 1905, proposed, in his *special relativity*, that the Lorentz transformations, (used earlier by Lorentz, and still earlier, for another purpose, by Voigt), which leave Maxwell's equations invariant, as desired, should replace the intuitive Galilean transformations also in mechanics, and generally. From this arose the variations of length and time with motion, and also the (now) well known relations:

$$E = mc^2 \tag{1}$$

the equivalence of mass and energy*, and

$$m = \gamma m_o \tag{2}$$

the increase of mass m with velocity where m_0 is the mass at rest and $\gamma = [1 - (v/c)^2]^{-1/2}$

The special theory of relativity has been considered to be one of the greatest achievements in science because of these results, especially (1).

While special relativity has indeed suggested many things in physics, if taken seriously it would greatly change one's conception of the real world. In a history text entitled *Civilization Past and Present* the authors acknowledge:

> "While Newton's mechanics still continue to be of satisfactory use in everyday science and engineering, Einstein's more advanced concepts have completely reoriented men's attitudes toward the structure and mechanics of the universe."[3]

The main reason for this altering of classical ideas would be Einstein's second postulate of the constancy of the speed of light as seen by all inertial frames of reference. This postulate leads to the notions of "length contraction" and "time dilation". These are negligible in normal activity, becoming significant only at speeds approaching that of light. According to this theory a rod four meters long, for example, will contract to a length of just two meters if traveling at 87% of the velocity of light. Length is not considered to be absolute, but diminishes with velocity. Time is also believed to be relative, i.e., physical processes slow down with motion.

Einstein suggested that these changes are real and gave an illustration which is known as the *twin paradox*. To illustrate that paradox consider twin brothers twenty years of age. Pretend that one of them enters a hypothetical rocket ship that will travel with 99% of the velocity of light. This twin leaves the earth with this very high speed and does not return until his stay-at-home brother is ninety years old. According to Einstein's equations the twin in the rocket is only thirty years old when he returns to earth. Such seeming fantasies are physical realities according to the special theory of relativity.

Before Einstein the universe as a whole was considered to possess three absolute entities: energy, space, and time. Even now energy is thought to be absolute in the sense that the total quantity is always conserved. Energy of course has various forms such as heat, light, and mass; but the total quantity is a constant. If the energy of a given particle increases with velocity it is only because the energy increase was supplied by the force accelerating it to that particular velocity, the total energy of the combined system remaining constant.

In special theory, as already noted, length and time are not absolute but change in magnitude with motion, i.e., the length of an object, and the rate of a physical process, are affected by motion. Whether the changes are real or apparent is disputed; but according to the special theory of relativity this is the way the real world changes with motion. There is one seemingly inconsistent quirk resulting from the first of Einstein's postulates, namely that one can not really tell whether or not a body is in motion. It is assumed that there is no absolute frame of reference from which to tell that there is any uniform motion. All in all it is indeed an abstraction of strange hypothesized conditions.

*The connection between energy and mass can also be derived from the pressure of radiation, roughly as follows, If a jet of fluid, of density ϱ, travelling at a speed v, strikes a surface and is absorbed, it is easy to see that the pressure exerted on the surface by the jet is of magnitude ϱv^2. Likewise light, falling on a surface, exerts a pressure equal in magnitude to the density u of energy in the light. Since the speed is c, it must be that $\varrho c^2 = u$. But u is the energy per unit volume, and ϱ the mass; hence energy = mass times c^2. See O'Rahilly, A., 1965. Electromagnetic theory. Dover (reprinted from 1938) pp. 304-323.

One may wish to oppose special relativity on the basis of its abstract and bizarre concepts, felling that such things just could not be true. If, however, special theory is in agreement with the experimental evidence, if it is self-consistent with no logical contradictions, and if there are no reasonable alternatives, then one has no scientific basis upon which to reject its validity. It is the purpose of this treatise, however, to show that there are problems with special theory and that there is an alternative.

This paper will begin by reviewing the present relativistic foundation for electrodynamics and modern physics in the light of its presumed experimental support and internal consistency. It will conclude with the presentation of a new approach which culminates in a new theory of the electron based upon classical concepts.

II. The Special Theory of Relativity

A. An Evaluation of the Experimental Evidence

One of the most important aspects of physical science is experimental investigation. A theory may stand or fall on the basis of a single experiment. Robert Millikan affirmed this in his nobel lecture, "Science walks forward on two feet, namely theory and experiment."[4] The first inquiry in evaluating a hypothesis is whether or not it is in agreement with the experimental evidence.

To begin with, it must be noted that there is no evidence to support the concept of length contraction. In a book on special relativity Albert Shadowitz states:

> "It is an amazing fact that there does not seem to exist any direct or simple experimental verification of the Lorent-Fitzgerald contraction . . . . This very fundamental conclusion of the theory awaits actual proof."[5]

With time dilation the situation is considered different. There are several experiments which are claimed to support time dilation. In one experiment several caesium beam atomic clocks were flown around the world and compared with other clocks of the same type which had been at rest on the earth.[6] A slight time difference was found which the experimenters attributed to the expected dilation of time.

However, Dr. L. Essen, a well known authority on atomic clocks, pointed out that only some of the data seemed to have been used in calculating the result. A recalculation, using all of the data, gave no evidence for the alleged dilation.[7]

This comment of Essen's was called to our attention by Dr. G. B. Brown, formerly of the University College of London.

The *muon time dilation experiment* is claimed to have established the alleged time dilation as an actual fact.[8] Mu-mesons (radioactive charged particles also called muons) from cosmic rays, coming down through the atmosphere at speeds close to that of light, are said to take longer to decay than mu-mesons at rest. This is put forth as direct evidence for time dilation.

An initial assumption is that if there were no time dilation a muon travelling at high speeds *should* decay at the same rate as if it were at rest. There is no real basis for that assumption. No one has yet discovered what causes radioactive decay. There may be another relationship between the process of decay and the motion of a radioactive particle. If properly interpreted, this experiment may give some insight into the causes of decay rather than providing any evidence for time dilation. Also, the motion of the mesons at high speeds in the Earth's magnetic field might have some effect.†

A muon travelling at 99% the speed of light possesses about seven times as much energy as at rest and thus might be said to be in an energetic "excited state." Would one expect such a muon to decay in the same amount of time as a less energetic one, one at rest? In a book entitled *Relativistic Kenimatics* H. Arzelies affirmed his belief in the dilation of time, but admitted:

> ". . . The results are scattered over a rather wide range of values, however, and it so happens that one is not very certain of the nature of the meson one is working with. The quantitative verification of the relativistic formula [$\delta t = \gamma \delta t_0$] is therefore not very exact, and fresh experiment is necessary."[9]

It must also be noted that an isolated neutron has a radioactive lifetime of about seventeen minutes while a neutron in a helium atom has what we might call an infinite lifetime.[10] This illustrates how the state of a particle can directly affect its decay rate.

The final consideration of the experimental evidence behind special relatively must concern the matter of Einstein's second postulate of the absolate speed of light in all inertial frames of reference. In a well known book entitled *Classical Electrodynamics* the author J. D. Jackson notes:

> "It seems clear that most of the early evidence for the second postulate is invalid because of the interaction of the radiation with the matter through which it passes before detection. The phenomenon is encapsuled mathematically in the *extinction theorem* of Ewald (1912) and Oseen (1915) . . . As discussed in detail by Fox (*op cit.*), essentially all of the older evidence and many recent experiments concerning the second postulate are vitiated by the consequences of the extinction theorem."[11]

The extinction theorem states that light possessing a possible relative speed $c + v$ will be absorbed and re-emitted (as it passes through a medium) with a new speed c characteristic of that medium. A relative speed, if it exists, will thus be cancelled out in this manner, for the medium, in effect, becomes the new source. Jackson then goes on to point out nevertheless,

> "There are, however, some recent experiments that do not suffer from the criticism of Fox. The most definitive is a beautiful experiment performed at CERN, Geneva, Switzerland in 1964."[12]

This CERN experiment, however, has also been criticized recently by Wallace Kantor in his book *Relativistic Propagation of Light*:

†Indeed, if it is true that the lifetimes of particles which decay in radioactivity increase when the particles are moving rapidly, that might fit in well with the theory developed here. Consider alpha decay. The alpha particle, and the other positive parts of the nucleus, can be considered to repel each other, and ultimately to break apart. Now, according to the discussion under "A resolution of the Force Meter Paradox" the force of repulsion would be less if the particle concerned should be moving rapidly. So it would be quite reasonable that it should take longer for the particle to come apart. (Editor)

"On the basis of an experimentally unsupported and theoretically inapplicable extinction length formula, computations were obtained for an extinction length for the possible relative speed of the γ rays. It was thus *only an assertion* that the modification of the possible relative speed of the γ rays in the various traversed media was negligible. Based on this experimentally unsubstantiated *hypothetical* assertion, it was concluded that the hypothesis of the absolute speed of light was proved from the measured speed of the γ rays, found to be c . . . It is empirical ignorance of the actual attenuation effect that renders the CERN experiment and other experiments on the speed of γ rays from high speed particles ambiguous and inconclusive. The substitution of one hypothesis (extinction) to establish another (absolutivity) is *not* conductive to productive results."[13]

Kantor later goes on to point out experimental evidence supporting the relative speed of light:

"The interferometer Kantor experiment, the falling photon experiments, and the rotating disk experiments all provide *direct* kinematic evidence that the speed of light emitted by a moving source *does* depend on the motion of the source."[14]

In the light of this discussion, it must be pointed out that the experimental verification of the special theory of relativity is not as strong as one might think. At any rate, it must at least be acknowledged that the empirical issue is open to question!

B. Logical Fallacies in the Present Approach

The British scientist Herbert Dingle is probably one of the greatest authorities in the world on the special theory of relativity. He has studied the theory for over fifty years of his life in addition to having written two books on the subject. He personally discussed the theory with men such as Einstein, Eddington, Tolman. Schrodinger, Born, and others (some of whom he knew very well), and was even asked by *Encyclopedia Brittannica* to write the article on relativity for one of their editions. After coming across what he believed to be a fallacy in the theory he cast it aside as being untenable and wrote a book concerning the matter entitled *Science at the Crossroads.*[15] Dingle's argument is simple and has never been satisfactorily answered. Consider two frames of reference A and B moving with respect to one another with constant velocity v and suppose that each frame possesses a clock. Since, according to the first postulate, there is no preferred frame, A may be said to be at rest, B moving with respect to it, and thus B's clock running more slowly than A's. Or vice versa, since neither frame is preferred. As Dingle, (considering, in his argument, a particular relative velocity) pointed out: "The same theory thus requires each clock to work twice as fast as the other, which is contradictory. The necessary conclusion is that that theory must be wrong."[16]

Another fundamental fallacy in special relativity may be seem by considering a hypotheticl experiment. Let there be two equal charges q, say positive for definiteness, connected by a rigid rod, of length l, as shown in Figure 1. Between them, say at the center of the rod, is a force meter, to measure the force between the charges. In principle, the force meter might be something like a spring balance.

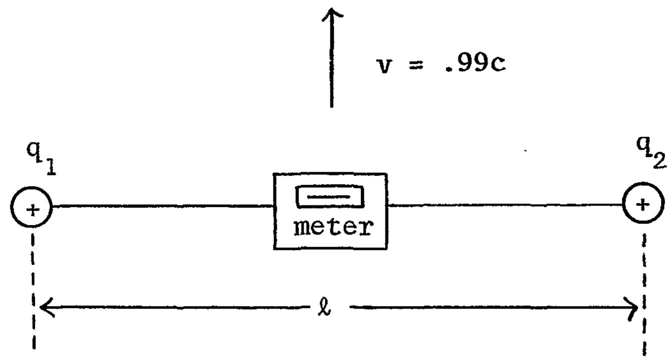

Figure 1: Force meter measures the coulomb repulsion between the charges.

Some caution is necessary here. It might be argued that the calibration of the meter would change with motion, e.g. because of the supposed relativistic contractions of the parts. But it would always be possible to arrange matters so that those effects of the motion, if they exist at all, would compensate one another in the different parts. This would be something like the idea in a chronometer, in which thermal effects in different parts compensate one another. It will be taken, then, that the force meter is not affected by the motion.

One could think of frames of reference, in the relativistic tradition. In regard to the frame S, the charges would be moving at a velocity $v = 0.99c$. Physically, in principle S could be associated with a vehicle, carrying the desired instruments, moving through the laboratory.

Both frames, of course, could be populated by observers in the relativistic tradition.

With regard to the frame S', the force F' of repulsion between the two charges is given by

$$F' = qE' = \frac{q^2}{4\pi\epsilon l^2} \tag{3}$$

since in that frame the charges are at rest, so there is just the Coulomb repulsion.

With regard to the frame S the charges are moving. So there is a magnetic effect, and the total force if Fm given by

$$\mathbf{F} = q[\mathbf{E} + (\mathbf{v} \times \mathbf{B})] \tag{4}$$

Since $\mathbf{v} \times \mathbf{B} = -\beta^2 \mathbf{E}$, and $\mathbf{E} = \gamma \mathrm{E}'$, the force F reduces to

$$F = \frac{qE'}{\gamma} = \frac{F'}{\gamma} \tag{5}$$

so that F is less than F' by the factor $1/\gamma$. Since $v = .99c$, by the definition given earlier $\gamma = 7$, so that F in this case is one-seventh of F'. The obvious contradiction is that it is physically impossible for two observers to see a different reading on the *same* force meter. The absurdity would be especially blatant if the force meter were just a link whose breaking strength would be say $3F$.

III. A Classical Foundation for Electrodynamics

Having considered the problems in the experimental basis and logical consistency of the present approach, one may return a moment to the beginning of the twentieth century. It has already been said that the three alternative facing physicists were: 1) Maxwell's equations were incorrect, 2) the Galilean transformations were wrong, or 3) a preferred frame of reference somehow existed. Einstein of course chose alternative number two and later stated:

> "In classical physics it was always assumed that clocks in motion and at rest have the same rhythm, that rods in motion and at rest have the same length. If the velocity of light is the same in all coordinate systems, if the relativity theory is valid, then we must sacrifice this assumption. It is difficult to get rid of deep-rooted prejudices, but there is no other way."[17]

One might wish to say that special relativity solved the ether paradox by sacrificing the classical conceptions of space and time. The term "classical" will be defined as being that portion of physics to which Galilean or "common sense" principles apply.[18] At any rate, is there "no other way"? Suppose for an instant that one could choose alternative number three, save the Galilean transformations as well as Maxwell's equations, and restore unto physics the classical concepts of space and time! This paper attempts to realize that objective, that is, to present a classical foundation for electrodynamics.

A. The Michelson-Morley Experiment

One might think of light as being an electromagnetic wave whose medium of propagation is the field of the charge which was it source. Thus an accelerated charge sets up a "light wave" in its own electric field which propagates with respect to that charge at the speed of light c. In the Michelson-Morley experiment, the light waves moving across the two arms of the Michelson interferometer are both traveling with respect to the same light source and thus with respect to the same medium of propagation. With this interpretation of light, one would not expect any difference in time for the two light beams and the Michelson-Morley experiment should come out precisely as it did. Likewise Trouton and Noble's experiment, etc.

B. The Electromagnetic Field Transformation Equations

The electric field of a stationary charge may be expressed as

$$\mathbf{E} = \left[\frac{q}{4\pi\epsilon r^2}\right] \mathbf{u}_r \qquad (6)$$

whereas the electric field of a moving charge is altered according to the relation

$$\mathbf{E} = \frac{q}{4\pi\epsilon r^2}\left[\frac{1-\beta^2}{(1-\beta^2\sin^2\theta)^{3/2}}\right]\mathbf{u}_r \qquad (7)$$

The magnetic induction due to a moving charge is thus

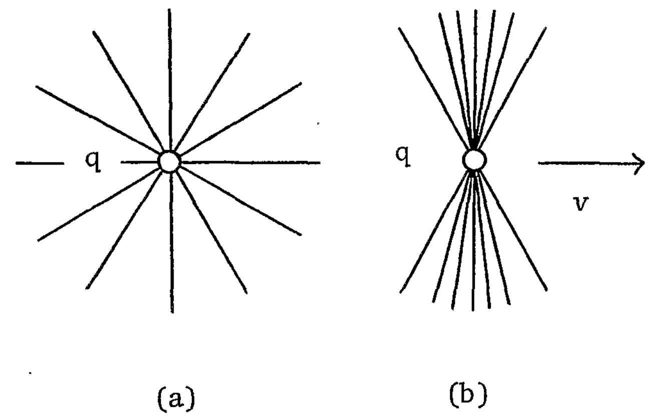

Figure 2. This diagram shows the effect of motion on electric field lines. Part (a) shows the electric field of an elementary charge q at rest while part (b) illustrates the electric field of the same charge *q* in uniform motion with *v* = .94*c*.

$$\mathbf{B} = \frac{qv\sin\theta}{4\pi\epsilon c^2 r^2}\left[\frac{1-\beta^2}{(1-\beta^2\sin^2)^{3/2}}\right]\mathbf{u}_\phi \qquad (8)$$

Equation (7) is perhaps the most important transformation in electrodynamics. As is illustrated in Figure 2, the electric field lines of a moving charge are shifted toward the direction transverse to the velocity.

In special relativity equation (7) is derived from the Lorentz transformations and is interpreted as a length contraction effect.[19] It has been shown in a previous paper, however, that this equation could also be derived assuming a feedback field mechanism.[20] In this approach the "ambient field" through which the charge is moving produces the mechanism which "feeds back" the induced electric field into the moving frame of reference of the charge. The resultant electric field of the charge is thus a superposition of its original electric field plus the induced electric field which is fed back onto it. Equation (7) was derived in this manner.

The ambient field which produces the feedback mechanism is considered to be the preferred frame of reference. This field is not a mental construct but is a physical entity associated with the matter at rest with respect to the moving charge, and therefore one is not allowed to choose just any frame of reference as being preferred over another—the preferred frame must be the one which contains the ambient field. This entire concept is in need of further investigation, but the remarkable thing about this postulate is that it resolves the force meter paradox of special relativity—a paradox which makes the relativistic approach untenable. Something more will be said about this point later.

C. A Resolution of the Force Meter Paradox

In this new, classical approach to electrodynamics the relativistic modifications of the ideas of space and time may be eliminated. In addition, as will now be demonstrated, the previously mentioned paradox of the force meter having two different readings at the same time can be resolved.

Equations (3) and (5) give the readings of the force meter in Figure 1 as seen by the S' and S frames of reference. In this new approach, equations (7) and (8) of the electric and magnetic fields as observed in the fixed frame of reference will hold exactly the same as in special relativity. The resultant force F of the S frame will therefore be exactly the same as in equation (5).

The fundamental difference between the two theories can be observed by viewing the results as seen in the S' moving frame. In special relativity there is no state of absolute motion and one may always consider his own frame of reference to be at rest. The resultant force between the charges in the S' frame is therefore given by equation (3). In this new approach, however, no length contraction has been assumed and therefore equation (7) holds in the S' frame as well as in the S frame.

Since both charges are moving relative to the preferred (ambient field) frame of reference, each is traveling in the magnetic field laid down by the other and thus experiences a magnetic effect, so that the net force is decreased in magnitude by the factor $1/\gamma$.

This is because the magnetic field of a moving charge does not itself move with the charge but is continually being induced in the fixed frame of reference. Each charge therefore travels at a velocity v with respect to the magnetic field continually being generated by the other. Equation (4) thus applies in the same manner to both frames of reference, and so the two observers will end up seeing the same reading on the force meter. This "thought experiment" demonstrates the necessity of a preferred frame of reference when speaking of motion.

D. The Preferred Frame of Reference

The proposed preferred frame of reference is different from the ether of the last century. Moreover, a distinction must be made between an electromagnetic wave (photon) and a charged particle such as an electron.

The frame of reference, or medium. of an electromagnetic wave is the field of the charged object (e.g. electron) which is the source of the wave. This frame of reference moves along with the charge. Thus, if the charge is moving at a velocity v, the light proceeding from it would have a velocity c + v.

A charged particle, however, is different. Its own field of course, moves with it; but one may think of an ambient field through which it travels. This ambient field is not a mental construct but a physical entity associated with the matter which is at rest with respect to the moving charge.

A little reflection on this matter will show the fundamental difference between speaking of an electron on the earth moving around the sun at a velocity of 18.5 miles per second and speaking of an electron moving in a high-energy particle accelerator at the same velocity, the accelerator as a whole being fixed to the earth.

In the first case the electron is at rest in relation to the ambient field, and no effects of motion would be seen by any observer. This case corresponds to the M-M experiment. In the second case the electron is moving with respect to the ambient field and effects of the motion are observed. This case corresponds to laboratory experiments with high-speed electrons.

It must be remembered, then, that, since the ambient field has its origin in matter, the preferred frame of reference to be considered in a particular case will depend on one's situation in the universe.

IV. An Electromagnetic Model of the Electron

Apart from saving Maxwell's equations, the most important results of Einstein's special theory of relativity were the equivalence of energy and mass, and the prediction of the increase of mass with velocity, as expressed in Equations (1) and (2).

If suitably interpreted, the Lorentz transformations will yield those results; but they do not give any physical insight into the reason why. For that one must look to the theory of elementary particles, as it joins up with electrodynamics. That theory, however, has never been complete. Arnold Sommerfeld pointed out in his work *Electrodynamics*,

> ". . . . In the present volume we must limit ourselves to the *theory of the individual electron.* It is true that the basic question regarding the *nature* of the electron will remain unclarified. *The electron is a stranger in electrodynamics*, as Einstein has said on occasion . . . . The forces which, opposing the Coulomb forces, prevent its explosion are unknown to us . . ."[21]

This paper will now proceed to present a new theory of the electron which explains equations (1) and (2) and which clarified some of the problems mentioned by Sommerfeld.

A. The Static Electron

When at rest the electron is assumed to be a non-rigid sphere of radius a_o with total charge q distributed over the surface. The rest energy of the electron is known to be $.819 \times 10^{-13}$ joules, but of what specifically does this energy consist? The electric field of this electron may be expressed as

$$E = \left[\frac{q}{4\pi\epsilon r^2}\right] u_r \tag{9}$$

The total energy in this electric field, denoted by V, may be found by use of the equation

$$V = \frac{\epsilon}{2}\iiint E^2\, dV \tag{10}$$

In this expression for V, E is the electric field as given by Equation (9) and dV is the volume element for spherical coordinates equal to $r^2 \sin\theta\, dr d\theta d\phi$. Noting this and substituting the necessary limits of integration results in

$$V = \frac{\epsilon}{2}\int_0^{2\pi}\int_0^{\pi}\int_{a_o}^{\infty}\left[\frac{q}{4\pi\epsilon r^2}\right]^2 r^2 \sin\theta\, dr d\theta d\phi \tag{11}$$

which when integrated yields

$$V = \frac{q^2}{8\pi\epsilon a_o} \tag{12}$$

for the total energy in the field of the static electron. Is this quantity, however, the total energy of the electron at rest?

This question may be answered with various considerations. The electric stress (force per unit area) on the surface of the electron due to the electrostatic coulomb repulsion can be shown to be

$$\frac{dF}{dA} = \left[\frac{\epsilon}{2}E^2\right] \mathbf{u}_r \quad (13)$$

which may also be expressed as

$$\frac{dF}{dA} = \left[\frac{q^2}{32\pi^2\epsilon\, a_o^4}\right] \mathbf{u}_r \quad (14)$$

Equation (14) turns out to give approximately 10^{26} lb./in^2 as the pressure seeking to blow the electron apart! If the electron is to remain in stable equilibrium there must exist some force, other than electrostatic, holding it together. With this force, or field, can be associated a binding energy, just as the electrostatic energy, considered above, is associated with the electric field. The binding energy, moreover, can be considered distributed throughout a volume, presumably the volume of the electron, just as the electrostatic energy was in the volume outside the electron. Moreover, it can be calculated by integrating the force, or field, treated suitably, as will be done soon.

It is tempting to speculate whether this binding energy might be like that binding nucleons into an atomic nucleus; but to discuss that question would lead too far afield.

To compute the magnitude of the electron's binding energy U_b, it must be noted that the inward pull of the binding force at the surface must exactly balance the outward tension of the charge. From equation (14), one may express this inward force on an element $dA = a_0^2 \sin\theta d\theta d\phi$ of the electron's surface as

$$dF = -\left[\frac{q^2 a_0^2 \sin\theta d\theta d\phi}{32\pi^2\epsilon\, a_o^4}\right] \mathbf{u}_r \quad (15)$$

The relation just given holds at the surface of the electron; indeed, it must do so for equilibrium. What happens farther in?

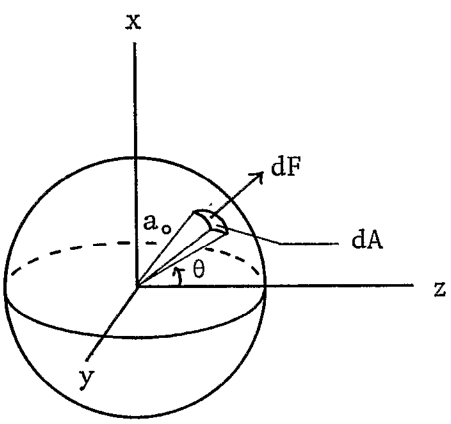

Figure 3. Element of surface charge dq pushes out with a force dF due to electric tension while the binding field pulls in with an equal and opposite force $-dF$. The surface area dA of dq is given by $a_o^2 \sin\theta d\theta d\phi$.

There is no very apparent analogy to guide one here; it will be a matter of speculation, and, eventually, of seeing what will work. Since the binding force has been taken to be proportional to the element of area, one might expect it to vary with r, as r ranges from 0 to a_0, according to:

$$df = -\frac{q^2 a_o^2 \sin\theta d\theta d\phi}{32\pi^2\epsilon\, a_o^4}\left[\frac{r^2}{a_o^2}\right] \mathbf{u}_r \quad (16)$$

So the inward force is proportional to (r^2/a_0^2) as one moves in from the electron's surface toward the center. Note that dF meets the necessary boundary conditions: it is zero at the electron's center and given by (15) at the surface. The binding energy dU_b of each element can therefore be found from the relation

$$dU_b = -\int_0^{a_o} d\mathbf{F} \cdot d\mathbf{r} \quad (17)$$

which after a substitution of equation (16) becomes

$$dU_b = \frac{q^2}{32\pi^2\epsilon\, a_o^4}\left[\int_o^{a_o} r^2 dr\right] \sin\theta d\theta d\phi \quad (18)$$

or, after integration,

$$dU_b = \frac{q^2 \sin\theta d\theta d\phi}{96\pi^2\epsilon\, a_o} \quad (19)$$

To arrive at the total binding energy one must integrate over the angles θ and ϕ; that over r having been done.

$$U_b = \frac{q^2}{96\pi^2\epsilon\, a}\int_0^{2\pi}\int_0^{\pi} \sin\theta d\theta d\phi \quad (20)$$

This gives:

$$dU_b = \frac{q^2}{24\pi^2\epsilon\, a_o} \quad (21)$$

The total rest energy of the electron, U_0, is therefore a combination of the electrostatic field energy, (12), and the binding energy (21):

$$U_o = V + U_b = \frac{q^2}{6\pi\epsilon\, a_o} \quad (22)$$

Since the rest energy of the electron is known to be .819 $\times 10^{-13}$ joules, one may easily solve for the electrostatic radius a_0 which turns out to be 1.87×10^{-15}m. Note that the binding energy (21) is one-fourth of the total energy U_0—this is not surprising in view of the tremendous forces opposing the electron's equilibrium.

B. The Dynamic Electron at Low Velocities

Consider a slow-moving electron with a velocity much less than the speed of light: $v << c$. Its total energy may be expressed as

$$U = V + U_b + T \quad (23)$$

where T is the magnetic field energy (like kinetic energy) induced as a result of the electron's motion. The electric field energy V and the binding energy U_b will remain essentially unaltered at low velocities.

The magnetic field energy T may be computed from the relation

$$T = \frac{\mu}{2}\int\int\int H^2\, dV \quad (24)$$

H is of magnitude $v\epsilon E \sin\theta$; also $\mu = 1/\epsilon c^2$ and $dA = r^2 \sin\theta r \theta d\phi$, so equation (24) becomes

$$T = \frac{1}{2\epsilon c^2}\int_o^{2\pi}\int_o^{\pi}\int_{a_o}^{\infty}[v\epsilon E \sin\theta]^2\, r^2 \sin\theta dr d\theta d\phi \quad (24')$$

With the value of E from equation (9), this expression for T results in

$$T = \frac{1}{2}\left[\frac{q^2}{6\pi\epsilon a_o c^2}\right] v^2 \tag{25}$$

From expressions (12), (21), and (25) equation (23) becomes

$$U = \frac{q^2}{6\pi\epsilon a_o} + \frac{1}{2}\left[\frac{q^2}{6\pi\epsilon\, a_o c^2}\right] v^2 \tag{26}$$

In classical mechanics, the total energy U of a slow-moving body must be equal to the sum of its rest of potential energy and kinetic energy. In other words,

$$U = U_o + \frac{1}{2} m_o v^2 \tag{27}$$

A comparison of equations (26) and (27) gives

$$m_o = \frac{q^2}{6\pi\epsilon a_o c^2} \tag{28}$$

for the rest mass of the electron and

$$U_o = \frac{q^2}{6\pi\epsilon\, a_o} \tag{29}$$

for the rest energy of the electron. Equation (29) is identical to equation (22) as would naturally be expected. A simple algebraic manipulation of (28) and (29) yields

$$U_o = m_o c^2 \tag{30}$$

the equivalence of energy and mass!

Upon examination of equations (25) and (26) one may note that for a slow electron the magnetic field energy and the kinetic energy are equivalent. This is reasonable; since by definition, the kinetic energy is the added energy which results from motion; and the only added energy for a slow electron due to its motion is that of the magnetic field induction energy. In other words, the mass of the electron is entirely of electromagnetic origin.

An alternative proof of equation (28) for the mass of the electron may be arrived at by computing the electromagnetic field momentum of a slow moving electron. Denoting **G** as the electromagnetic field momentum, one must make use of the following expression:

$$\mathbf{G} = \frac{1}{c^2} \int\int\int [\mathbf{E} \times \mathbf{H}]\, dV \tag{31}$$

Assuming the electron's velocity to be in the z direction, this equation becomes

$$\mathbf{G} = \frac{v\epsilon}{c^2} \int\int\int [E_x^2 + E_y^2]\, dV \tag{32}$$

Since $E_x = E \sin\theta \cos\phi$, $E_y = E \sin\theta \sin\phi$, and $E = -q/4\pi\epsilon r^2$ equation (32) may be written as

$$\mathbf{G} = \frac{q^2 v}{16\pi^2 \epsilon c^2}\left[\int_{a_o}^{\infty} \frac{dr}{r^2}\right]\left[\int_0^{\pi} \sin^3\theta d\theta\right] \tag{32'}$$

$$\left[\int_0^{2\pi} \cos^2\phi d\phi + \int_0^{2\pi} \sin^2\phi d\phi\right]$$

which reduces to

$$\mathbf{G} = \frac{q^2 v}{6\pi\epsilon a_o c^2} \tag{33}$$

Assuming the total momentum of the electron itself to be possessed by the field one finds $\mathbf{G} = q^2 v/6\pi\epsilon a_0 c^2 = \mathbf{p} = m_0 \mathbf{v}$, so that

$$m_o = \frac{q^2}{6\pi\epsilon a_o c^2} \tag{34}$$

in agreement with (28).

C. The Equivalence of Energy and Mass

Equation (30) of the last section gave the famous result of mass and energy equivalence. In the previously expressed interpretation of the Michelson-Morley experiment it was noted that light may be considered an electromagnetic wave in the field of an accelerated charge. A photon may therefore be thought of as a "wave packet" or "bundle of energy" which moves at speed c with respect to the charge which was its source.

Accordingly, a photon has a mass equivalence, but no rest mass since it has no rest; i.e., if it stops (i.e., is absorbed) it ceases to exist. An electron, on the other hand, is different. When it stops it does not cease to exist since its charge and binding energy can still be thought of as a separate entity localized in space. Thus there is a fundamental distinction between the mass-energy relationships of the photon and the electron.

D. The Dynamic Electron at High Velocities

In this section the state of the electron will be considered for speeds v close to that of light. The results will be the most interesting and also the most general since they will reduce to the same outcome of sections A. and B. in the proper limits of v.

In Figure 4 the electron is shown to have a velocity v in the z-direction. The expression for the electric field of a moving electron, as previously noted, may be written

$$\mathbf{E} = \frac{q^2}{4\pi\epsilon r^2}\left[\frac{1}{\gamma^2(1 - \beta^2 \sin^2\theta)^{3/2}}\right] \mathbf{u}_r \tag{35}$$

where $\beta = v/c$ and $\gamma = (1 - \beta^2)^{-1/2}$. The electric stress (force per unit area) on the surface of the electron is

$$\frac{dF_e}{dA} = \left[\frac{\epsilon E^2}{2}\right] \mathbf{u}_r \tag{36}$$

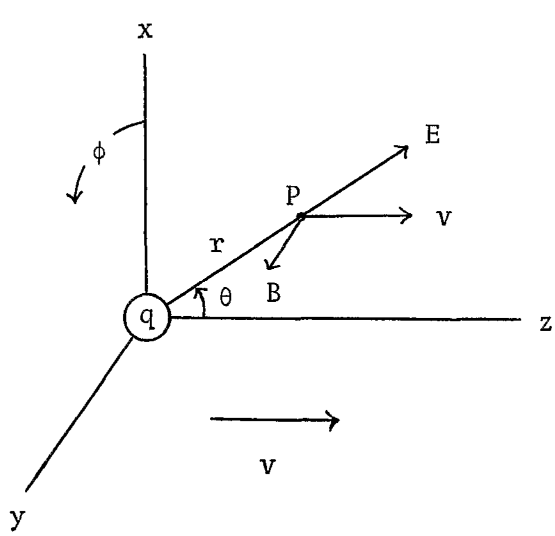

Figure 4. The electron, an elementary charge q, is here shown to have a velocity v in the z-direction.

as before; only E is now given by (35) instead of by (9). At high speeds there also exists a magnetic "pinch-effect" on each element of surface charge dq so that in addition to the electric stress there is also a magnetic stress which may be represented by the equation.

$$\frac{dF_b}{dA} = -\beta^2 \sin\theta \left[\frac{\epsilon}{2}E^2\right] \mathbf{i} \qquad (37)$$

where $\mathbf{i}$ is a unit vector in the x-direction as illustrated in Figure 5. Due to azumuthal symmetry one may arbitrarily consider a particular point P (for a given angle θ)on the electron's surface on the x-z plane; although the results are valid in general.

If the electron is to remain in stable equilibrium as in the static case, the inward pull $\mathbf{dF}$ of the binding force at the surface must exactly balance the electric and magnetic stress forces. Thus, for each unit area $dA = a^2 \sin\theta d\theta d\phi$ on the electron's surface the following equation must hold for the inward pull of the binding field:

$$\mathbf{dF} = -\frac{\epsilon}{2}E^2[\mathbf{u}_r - \beta^2 \sin\theta\ \mathbf{i}]\ a^2 \sin\theta d\theta d\phi \qquad (38)$$

Due to the transformed electric tension, the added magnetic stress, and the altered binding energy the shape of the electron is changed. Suppose that the change is given by:

$$a = \frac{a_o}{\gamma\sqrt{1 - \beta^2 \sin^2\theta}} \qquad (39)$$

i.e., the radius a is now a variable function of v and θ. This makes the electron an oblate speroid for velocities approaching the speed of light; although for velocities $v << c$ it is for all practical purposes a perfect sphere. Substitution of equations (35) and (39) into (38) results in

$$\mathbf{dF} = -\frac{q^2 a^2 \sin\theta d\theta d\phi}{32\pi^2 \epsilon a_o^4 (1 - \beta^2 \sin^2\theta)}[\mathbf{u}_r - \beta^2 \sin\theta\ \mathbf{i}] \qquad (40)$$

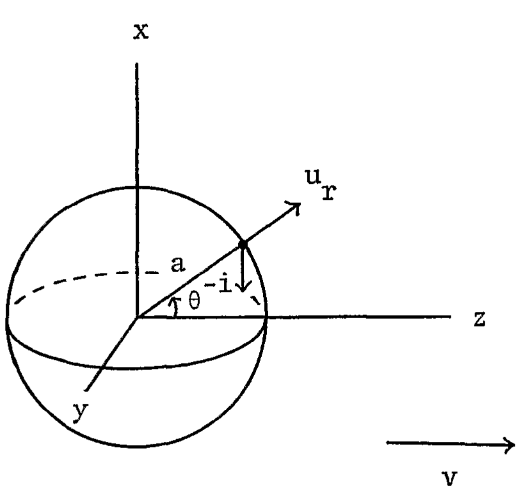

Figure 5. Directions of the electric and magnetic stress on the surface of the electron.

for the inward-pulling force of the binding field at the surface of the electron. The force $\mathbf{dF}$ on each element due to the binding energy is proportional to the factor r^2/a^2 so that in general,

$$\mathbf{dF} = -\frac{q^2 r^2 \sin\theta d\theta d\phi}{32\pi^2 \epsilon a_o^4 (1 - \beta^2 \sin^2\theta)}[\mathbf{u}_r - \beta^2 \sin\theta\ \mathbf{i}] \qquad (41)$$

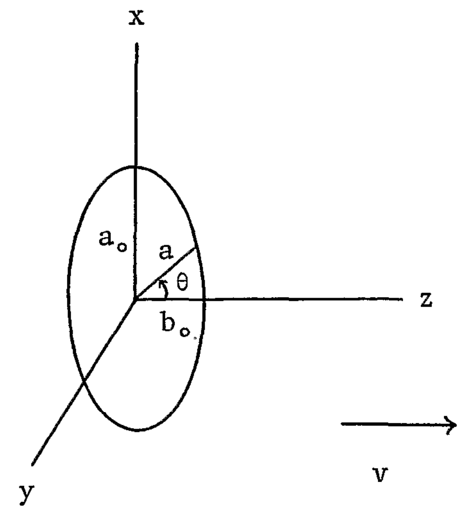

Figure 6. Elliptical cross section of the electron in the x-z plane with constant velocity v = .83c. The semi-minor axis $b_0 = a_0/\gamma$ and thus contracts with velocity while the semi-major axis a_0 remains constant.

where r is the distance from the center of the electron. Note that dF in (41) is zero at the center and agrees with (40) at the surface. The total energy dU_b in each element due to the binding energy may therefore be found from the equation

$$dU_b = -\int_o^a \mathbf{dF} \cdot \mathbf{dr} \qquad (42)$$

Since $[\mathbf{u}_r - \beta^2 \sin\theta \mathbf{i}] \cdot \mathbf{dr} = (1 - \beta^2 \sin^2\theta)dr$, equation (42) becomes, after substitution of (41),

$$dU_b = \frac{q^2}{32\pi^2 \epsilon a_o^4}[\int_o^a r^2 dr] \sin\theta d\theta d\phi \qquad (43)$$

Integrating this expression and noting the value for a as given in (39) results in

$$dU_b = \frac{q^2 \sin\theta d\theta d\phi}{96\pi^2 \epsilon a_o \gamma^3 (1 - \beta^2 \sin^2\theta)^{3/2}} \qquad (44)$$

The total binding energy U_b may therefore be found by integrating the energies dU_b of all the elastic elements (as in the static case). Doing this yields

$$U_b = \frac{q^2}{96\pi^2 \epsilon a_o \gamma^3} \int_o^{2\pi} \int_o^{\pi} \frac{\sin\theta d\theta d\phi}{(1 - \beta^2 \sin^2\theta)^{3/2}} \qquad (45)$$

or after integration over ϕ:

$$U_b = \frac{q^2}{48\pi \epsilon a_o \gamma^3} \int_o^{\pi} \frac{\sin\theta d\theta}{(1 - \beta^2 \sin^2\theta)^{3/2}} \qquad (46)$$

Since the integral in (46) is equal to $2\gamma^2$ the final expression for the binding energy is

$$U_b = \frac{q^2}{24\pi \epsilon a_o \gamma} \qquad (47)$$

Note that the binding energy actually diminishes with velocity by the factor $1/\gamma$. As would be expected, equation (47) reduces to (21) in the static case.

Now that the binding energy U_b has been calculated, the next step is to compute the general expressions for the electric field energy V, the magnetic field energy T, the total energy U, and the electromagnetic momentum $\mathbf{G}$.

To find V, one may substitute equation (35) into the general expression for the electric field energy, equation (10). This results in

$$V = \frac{q^2}{32\pi^2\epsilon\gamma^4}\int_0^{2\pi}\int_0^{\pi}\int_a^{\infty}\frac{\sin\theta dr d\theta d\phi}{r^2(1-\beta^2\sin^2\theta)^3} \quad (48)$$

which easily reduces to

$$V = \frac{q^2}{16\pi\epsilon\gamma^4}\int_0^{\pi}\int_a^{\infty}\frac{\sin\theta dr d\theta}{r^2(1-\beta^2\sin^2\theta)^3} \quad (49)$$

Since a (one of the limits of r) is a function of θ, one must perform the integration over r before the integration over θ, and this gives

$$V = \frac{q^2}{16\pi\epsilon\gamma^4}\int_0^{\pi}\left[\frac{1}{a}\right]\frac{\sin\theta d\theta}{(1-\beta^2\sin^2\theta)^3} \quad (50)$$

which from equation (39) becomes

$$V = \frac{q^2}{16\pi\epsilon a_o\gamma^3}\int_0^{\pi}\frac{\sin\theta d\theta}{(1-\beta^2\sin^2\theta)^{5/2}} \quad (51)$$

Since

$$\int_0^{\pi}\frac{\sin\theta d\theta}{(1-\beta^2\sin^2\theta)^{5/2}} = \frac{2\gamma^4}{3}(3-\beta^2) \quad (52)$$

the final expression for the electric field energy turns out to be

$$V = \gamma\frac{q^2}{6\pi\epsilon a_o}\left[\frac{3}{4}-\frac{\beta^2}{4}\right] \quad (53)$$

As was previously noted, the magnetic field energy may be written as

$$T = \frac{\mu}{2}\int\int\int H^2\, dV \quad (24)$$

Since $H = v\epsilon E\sin\theta$, $\mu = 1/\epsilon c^2$, and $dV = r^2\sin\theta dr d\theta d\phi$; (24) becomes, after substitution of the proper limits of integration,

$$T = \frac{1}{2\epsilon c^2}\int_0^{2\pi}\int_0^{\pi}\int_a^{\infty}[v\epsilon E\sin\theta]^2\, r^2\sin\theta dr d\theta d\phi \quad (54)$$

After substituting equation (35) and integrating over ϕ and r, (54) becomes

$$T = \frac{q^2v^2}{16\pi\epsilon a_o c^2\gamma^3}\int_0^{\pi}\frac{\sin^3\theta\, d\theta}{(1-\beta^2\sin^2\theta)^{5/2}} \quad (55)$$

The integral in (55) is $(4/3)\gamma^4$; and since $\beta = v/c$ the magnetic field energy turns out to be

$$T = \gamma\frac{q^2}{6\pi\epsilon a_o}\left[\frac{\beta^2}{2}\right] \quad (56)$$

The total energy U of the electron may now be computed from the relation

$$U = U_b + V + T \quad (57)$$

which from equations (47), (53), and (56) becomes

$$U = \gamma\frac{q^2}{6\pi\epsilon a_o}\left[\frac{1}{4\gamma^2}+\frac{3}{4}-\frac{\beta^2}{4}+\frac{\beta^2}{2}\right] \quad (58)$$

which easily reduces to

$$U = \gamma\left[\frac{q^2}{6\pi\epsilon a_o}\right] \quad (59)$$

From equation (22), (59) may also be expressed as

$$U = \gamma U_o \quad (60)$$

so that the total energy of the electron increases with velocity by the factor γ. If mass and energy are equivalent then one would immediately expect the rest mass m_0 to also increase with velocity by the factor γ. This indeed turns out to be the case!

The electromagnetic momentum **G** may be computed from the previously utilized expression

$$\mathbf{G} = \frac{1}{c^2}\int\int\int[\mathbf{E}\times\mathbf{H}]\, dV \quad (61)$$

The velocity was assumed to be in the z-direction, Equation (61) therefore becomes

$$\mathbf{G} = \frac{\epsilon v}{c^2}\int_0^{2\pi}\int_0^{\pi}\int_{a_o}^{\infty}[E_x^2 + E_y^2]\, r^2\sin\theta dr d\theta d\phi \quad (62)$$

In going through the integration one must be careful to integrate over r *before* θ; the expression (62) turns out to be

$$\mathbf{G} = \gamma\left[\frac{q^2}{6\pi\epsilon a_o c^2}\right]\mathbf{v} \quad (63)$$

Assuming again that the total momentum p of the electron itself is equal to the electromagnetic momentum of the field one arrives at

$$\mathbf{P} = m\mathbf{v} = \mathbf{G} = \gamma\left[\frac{q^2}{6\pi\epsilon a_o c^2}\right]\mathbf{v} \quad (64)$$

Solving (64) for the electron's mass m results in

$$m = \gamma\left[\frac{q^2}{6\pi\epsilon a_o c^2}\right] \quad (65)$$

which from equation (28) may be written as

$$m = \gamma m_o = \frac{m_o}{(1-v^2/c^2)^{1/2}} \quad (66)$$

This shows the increase of the electron's rest mass with velocity by the factor γ! From equations (59), (65), and (66) it follows that

$$U = mc^2 = \gamma m_o c^2 \quad (67)$$

As would logically be expected, the energy and mass of the electron are equivalent regardless of the electron's velocity. The increase of mass with velocity according to equation (66) is therefore an electromagnetic effect, that is, the field energy of the electron increases by a tremendous amoung at high velocities and this shows up experimentally as an increase of its mass equivalent, or inertia. Experiments performed in 1939 by Rogers, McReynolds, and Rogers seem to have confirmed this mass-velocity relationship,[22] and also the results of others, e.g. Kaufmann and Bucherer about the turn of the century.

E. In Retrospect

Thus we have completed the development of a new, classical theory of the electron. Is this model the final truth, the utmost picture, of what an electron really is? Perhaps not. The electron can not be seen; one can only hunt for models which fit what can be observed. As Alfred Romer stated with regard to atomic theory in general:

"Do not think for a moment, though, that you know the 'real' atom. The atom is an idea, a theory, a hypothesis; it is whatever you need to account for the facts of experience .... A good deal will happen in the future and the changes in the atom will continue. An idea in science, remember, lasts only as long as it is useful."[23]

At any rate, the results obtained for the electron are very encouraging in view of the comments made by John Slater and Nathaniel Frank:

"A simple model of an electron, which was supposed before the quantum theory to represent it actual structure, was a sphere of radius R, on the surface of which the charge is distributed .... The total electrical energy is the volume integral of $(e^2/32\pi^2\epsilon_0)$ $(1/r^4)$ over all space outside the sphere . . . $(e^2/8\pi\epsilon_0 R)$.

"In the classical theory of the electron, which we have mentioned, it is this quantity which is interpreted as being the actual constitutive energy of the electron, though a correction must be made of an additional energy of a nonelectromagnetic nature that is required to keep the sphere in equilibrium. Neglecting this correction, we can compute the mass of the electron .... Now, if this electron moves, it will produce a magnetic field, as a current would, and hence will have a certain magnetic energy. Since the magnetic field is proportional to the velocity (or the current), the magnetic energy is proportional to the square of the velocity. This can be shown to be the kinetic energy. Further, there will be a Poynting vector, pointing in general in the direction of travel of the electron, and representing the flow of energy associated with the electron. All these relations prove on closer examination to be more complicated than they seem at first sight, but they are suggestive in pointing one possible way to an eventual theory of the structure of the electron, which even the present quantum theory is unable to supply completely."[24]

V. Conclusion

This paper began be reviewing the special relativistic approach to electrodynamics and modern physics. It was found that the experimental side of the issue is open to question while several fundamental fallacies in the theory actually appear to exist. If these fallacies cannot be reconciled, then the entire special theory of relativity must be rendered untenable.

The latter portion of this treatise dealt with the presentation of an alternative theory in which the previously mentioned fallacies are resolved. This new approach was found to yield most of the same useful theoretical results as the special theory of relativity. In addition, a new theory of the electron based upon classical concepts has been unveiled.

VI. Acknowledgements

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References

[1]Jackson, J. D. 1975. Classical electrodynamics. Second Edition . John Wiley & Sons, pp. 505, 506.
[2]Richardson, O. W. 1914. The electron theory of matter. Cambridge University Press, pp. 8, 9, 268.
[3]Wallbank. T. W.; A. M. Taylor, and N. M. Bailkey, 1971. Civilization past and present. Fourth Edition. Scott, Foresman, and Company, p. 794.
[4]Acosta, V; C. L. Cowan,; and B. J. Graham, 1973. Essentials of modern physics. Harper and Row, p. 92.
[5]Shadowitz, Albert. 1968. Special relativity. W. B. Saunders, p. 168.
[6]Jackson, *op. cit.*, p. 521.
[7]Essen, L., 1977. Atomic clocks coming and going. *Creation Research Society Quarterly* 14 (1):46.
[8]French. A. P. 1968. Special relativity. The M.I.T. Introductory Physics Series, W. W. Norton and Co., New York, pp. 97-104.
[9]Kantor, Wallace. 1976. Relativistic propagation of light. Coronado Press: Lawrence, Kansas, p. 101.
[10]DeYoung, Don B. 1976. The precision of nuclear decay rates, *Creation Research Society Quarterly* 13 (1):38-41.
[11]Jackson, *op. cit.*, pp. 512 & 514.
[12]*Ibid.*, p. 514.
[13]Kantor, *op. cit.*, pp. 118 & 119.
[14]*Ibid.*, p. 142.
[15]Dingle, Herbert. 1972. Science at the crossroads. Martin Brian & O'Keefe, London.
[16]*Ibid.*, p. 61.
[17]French, *op.cit.*, p. 88. This statement is from the book The Evolution of Physics (1938) co-authored by Einstein and Infeld.
[18]This definition is in keeping with the sense of the word as used by Acosta, Cowan, and Graham, *op. cit.*, pp. 28, 66, & 67.
[19]Jackson, *op. cit.*, pp. 555 & 556.
[20]Barnes, T. G., R. R. Pemper, and H. L. Armstrong, 1977. A classical foundation for electrodynamics. *Creation Research Society Quarterly* 14 (1):38-45.
[21]Sommerfeld, Arnold. 1952. Electrodynamics. Academic Press, New York. pp. 236 & 278.
[22]Semat, Henry. 1966. Fundamentals of physics. Fourth edition. Holt, Rinehart, and Winston, Inc., pp. 618 & 619.
[23]Williams, Emmett L., and George Mulfinger, Jr., 1974. Physical science for Christian schools. Bob Jones University Press, Greenville, South Carolina, pp. 62 & 63.
[24]Slater, John C., and Nathaniel H. Frank, 1969. Electromagnetism. Dover Publications, New York. pp. 101 & 102. (Originally published by McGraw-Hill, 1947.)