APPENDIX 1

“The experts in a particular field can become so indoctrinated and so committed to the current paradigm that their critical and imaginative powers are inhibited and they cannot see ‘see beyond their own noses’. In these circumstances, scientific progress may come to a halt – knowledge may even regress – until intellectual intruders come through the interdisciplinary frontiers and look at the field without preconceptions”.

Joseph Ziman, *Reliable Knowledge: An Explanation of the Grounds for Belief in Science*, Cambridge University Press (1978), p. 134.

A COMPARISON OF SOME EQUATIONS IN CLASSICAL, RELATIVISTIC AND RADIATIONAL ELECTRODYNAMICS

There are now three systems of electrodynamics that happen to be applicable under different situations. Classical electrodynamics is applicable to electrically charged particles moving at very low speeds compared to the speed of light, relativistic electrodynamics is for charged particles moving at speeds comparable to that of light and quantum electrodynamics is for atomic particles moving at high speeds. Radiational electrodynamics is a consistent system of electrodynamics applicable to all charged particles moving at speeds up to that of light, with emission of radiation and the mass of a moving particle remaining constant. A comparison of some important equations in A classical, B relativistic and C radiational electrodynamics is given in the Table below.

(***Vectors*** are indicated in **boldface** type and *scalars* in ordinary type)

A. CLASSICAL ELECTRODYNAMICS	**B. RELATIVISTIC ELECTRODYNAMICS**	**C. RADIATIONAL ELECTRODYNAMICS**
1. Mass *m* of a particle is independent of its speed *v* at time *t*: $m = m_o$ where m_o is the rest mass (at speed $v = 0$, with respect to an observer).	**1.** Mass *m* of a particle increases with its speed *v* at time t: $m = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}} = \gamma m_o$ *m* becomes ∞ at $v = c$	**1.** Mass *m* of a particle is independent of its speed *v* at time *t*: $m = m_o$ where m_o is the rest mass (at peed $v = 0$, with respect to an observer)

2 Magnitude of electric charge q is independent of its speed v at time t: $q = q_o$ (rest charge)	**2.** Magnitude of electric charge q independent of its speed v at time t: $q = q_o$ (rest charge)	**2.** Magnitude of electric charge q independent of its speed v at time t: $q = q_o$ (rest charge)
3. NEWTON'S 2nd LAW OF MOTION: **Force** $\mathbf{F} = m\frac{d\mathbf{v}}{dt}$, ***v*** is the velocity and $\frac{d\mathbf{v}}{dt}$ the acceleration of constant mass m, at time t.	**3.** NEWTON'S 2nd LAW OF MOTION: **Force** $\mathbf{F} = \frac{d}{dt}(m\mathbf{v})$, ***v*** is the velocity and $(m\mathbf{v})$ the momentum of mass m, which depends on velocity at time t	**3.** NEWTON'S 2nd LAW OF MOTION: **Force** $\mathbf{F} = m\frac{d\mathbf{v}}{dt}$, ***v*** is the velocity and $\frac{d\mathbf{v}}{dt}$ the acceleration of constant mass m, at time t.
4. COULOMB'S LAW ON A MOVING CHARGED PARTICLE **4.1** A particle of charge q and mass m, moving with velocity ***v***, at time t, under the acceleration *(d**v**/dt)* of electrostatic field of intensity ***E***...... For a stationary source charge Q, accelerating force ***F***, is $\mathbf{F} = \frac{Qq}{kZ^2}\hat{\mathbf{u}} = \mathbf{E}q$ $\mathbf{E} = \frac{Q}{kZ^2}\hat{\mathbf{u}}$ is the field. where k is a constant, Z is the distance between the charges (Q and q) and **û** a unit vector in the direction of force of repulsion and $\mathbf{F} = \mathbf{E}q = m\frac{d\mathbf{v}}{dt}$	**4.** COULOMB'S LAW ON A MOVING CHARGED PARTICLE **4.1** A particle of charge q and mass m, moving with velocity ***v***, at time t, under the acceleration *(d**v**/dt)* of an electrostatic field of intensity ***E***........ For a stationary source charge Q, accelerating force ***F***, is: $\mathbf{F} = \frac{Qq}{kZ^2}\hat{\mathbf{u}} = \mathbf{E}q$ $\mathbf{E} = \frac{Q}{kZ^2}\hat{\mathbf{u}}$ is the field. where k is a constant, Z is the distance between the charges (Q and q) and **û** a unit vector in the direction of force of repulsion and $\mathbf{F} = \mathbf{E}q = \frac{d}{dt}(m\mathbf{v})$	**4.** COULOMB'S LAW ON A MOVING CHARGED PARTICLE **4.1** A particle of charge q and mass m, moving with velocity ***v***, at time t, under the acceleration *(d**v**/dt)* of an electrostatic field of intensity ***E***..................... For a stationary source charge Q, accelerating force ***F***, is: $\mathbf{F} = \frac{Qq}{ckZ^2}(\mathbf{c} - \mathbf{v}) =$ $E = \frac{Q}{kZ^2}$ the magnitude of the electrostatic field. where k is a constant, Z is the distance between the charges (Q and q), **c** is the velocity of light at the aberration angle and $\mathbf{F} = \frac{Eq}{c}(\mathbf{c} - \mathbf{v}) = m\frac{d\mathbf{v}}{dt}$

In rectilinear motion ***E*** and ***v*** are collinear and $Eq = m\frac{dv}{dt}$. For motion in a uniform electrostatic field of intensity *E* with $m = m_o$ as a constant, **Speed**: $v = at$ where $a = \frac{Eq}{m}$ is a constant and speed *v* = *0* at time *t* = *0*. Maximum attainable speed, as $t \to \infty$, is infinitely large, contrary to observation on accelerated particles.	In rectilinear motion, ***E*** and ***v*** are collinear and $Eq = \frac{d}{dt}(mv)$ For motion in a uniform field of intensity *E* with *m* dependent on speed *v*, **Speed**: $v = \frac{at}{\sqrt{1+\left(\frac{at}{c}\right)^2}}$, where $a = \frac{Eq}{m_o}$ is a constant and *v* = *0* at *t* = *0*. Speed of light *c* is the maximum attainable, as time $t \to \infty$	In rectilinear motion, ***c*** and ***v*** are collinear so that $\frac{Eq}{c}(c-v)\hat{\mathbf{u}} = m\frac{dv}{dt}\hat{\mathbf{u}}$ $Eq(1-\frac{v}{c}) = m\frac{dv}{dt}$, For motion in a uniform field of intensity *E* with $m = m_o$ as a constant. **Speed**: $v = c\left(1-e^{\frac{-at}{c}}\right)$ where $a = \frac{Eq}{m}$ is a constant and *v* = *0* at *t* = *0*. Speed of light *c* is the maximum attainable, as time $t \to \infty$
4.2 For a particle of charge *q* and mass *m* decelerated from the speed of light *c* by a uniform electrostatic field ***E***, the decelerating force ***F***, with velocity ***v*** at time *t*, is: $\mathbf{F} = \mathbf{E}q = -m\frac{d\mathbf{v}}{dt}$ For rectilinear motion: $Eq = -m\frac{dv}{dt}$ **Speed:** $v = c - at$ with $a = \frac{Eq}{m}$ constant. Maximum speed as time $t \to \infty$, is minus infinity ($-\infty$), contrary to observations	**4.2** For a particle of charge *q* and mass *m* decelerated from the speed of light *c* by a uniform electrostatic field ***E***, the decelerating force ***F***, with velocity ***v*** at time t, is: $\mathbf{F} = \mathbf{E}q = -\frac{d}{dt}(m\mathbf{v})$ For rectilinear motion, $Eq = -\frac{d}{dt}(mv)$ *m* dependent on speed. **Speed:** $v = c$ A particle moving at the speed of light *c*, cannot be stopped by any finite force. It continues to move with the speed c.	**4.2** For a particle of charge *q* and mass *m* decelerated from the speed of light *c* by a uniform electrostatic field of intensity ***E***, the decelerating force ***F*** is: $\mathbf{F} = \frac{Eq}{c}(\mathbf{c}+\mathbf{v}) = m\frac{d\mathbf{v}}{dt}$ where ***v*** is velocity at time t and ***c*** is velocity of light at the aberration angle. For rectilinear motion: $Eq(1+\frac{v}{c}) = -m\frac{dv}{dt}$ **Speed**: $v = c\left(2e^{\frac{-at}{c}} - 1\right)$ Speed as $t \to \infty$, is $-c$

5. NEWTON'S UNIVERSAL LAW OF GRAVITATION Force of attraction **F** between two bodies is proportional to the product of their masses M_1 and M_2, inversely proportional to the square of their separation *Z* in space and independent of their relative velocity. $\mathbf{F} = -G\frac{M_1 M_2}{Z^2}\hat{\mathbf{u}}$ where *G* is the gravitational constant and **û** a unit vector in the direction of force of repulsion.	**5.** NEWTON'S UNIVERSAL LAW OF GRAVITATION $\mathbf{F} = -G\frac{M_1 M_2}{Z^2}\hat{\mathbf{u}}$ **5.1** In the Theory of General Relativity (Einstein's theory of gravitation), gravitation is the result of curvature, warping or distortion of (four-dimensional) *space-time continuum* due to the presence of matter. Bodies move along a path of least resistance, a straight line in (four-dimensional) *space-time*, but, in reality, a curved trajectory in (three-dimensional) *space*.	**5.** NEWTON'S UNIVERSAL LAW OF GRAVITATION $\mathbf{F} = -G\frac{M_1 M_2}{Z^2}\hat{\mathbf{u}}$ **5.1** The electrostatic forces of repulsion and attraction between the electric charges in two (neutral) masses M_1 and M_2, cancel out exactly. **5.2** The mass M_1 or M_2 of a body is proportional to the sum of squares of the constituent charges **5.3** Gravitational force between two masses M_1 and M_2, being proportional to product of the sum of squares of the constituent electric charges, remain positive and attractive.
6. Relative velocity ***w*** between two bodies moving with velocities ***u*** and ***v*** (relative to a frame of reference), is: $\mathbf{w} = \mathbf{u} - \mathbf{v}$ where ***u*** and ***v*** are vectors in any direction.	**6.** Relative velocity ***w*** between two bodies moving with velocities ***u*** and ***v*** (relative to a frame of reference), is: $\mathbf{w} = (\mathbf{u} - \mathbf{v})\left(1 - \frac{uv}{c^2}\right)^{-1}$ ***u*** and ***v*** are collinear.	**6.** Relative velocity ***w*** between two bodies moving with velocities ***u*** and ***v*** (relative to a frame a reference), is: $\mathbf{w} = \mathbf{u} - \mathbf{v}$ ***u*** and ***v*** are vectors in any direction.
7. Velocity of light ***z*** from a source moving with velocity ***u***, as seen by an observer moving with velocity ***v*** (relative to a frame of reference), is: $\mathbf{z} = \mathbf{c} + (\mathbf{u} - \mathbf{v})$ where ***c*** is the velocity of	**7.** Velocity of light ***z*** from a source moving with velocity ***u***, as seen by an observer moving with velocity ***v*** (relative to a frame of reference), is: $\mathbf{z} = \mathbf{c}$ where ***c*** is the velocity of	**7.** Velocity of light ***z*** from a source moving with velocity ***u***, relative to an observer moving with velocity ***v***, is: $\mathbf{z} = \mathbf{c} + (\mathbf{u} - \mathbf{v})$ where ***c*** is the velocity of light relative to the source.

light relative to the source. **7.1** Velocity of propagation of an electrostatic force is ∞ (infinite) **7.2** Velocity of transmission of electrostatic force, relative to a charged particle moving with velocity **v**, is: ∞ of infinite magnitude	light in a vacuum, an absolute constant. **7.1** Velocity of propagation of an electrostatic force is ∞ (infinite) **7.2** Velocity of transmission of electrostatic force, relative to a charged particle moving with velocity **v**, is: ∞ of infinite magnitude	**7.1** Velocity of propagation of an electrostatic force is **c** **7.2** Velocity of transmission of electrostatic force, relative to a charged particle moving with velocity **v**, is: $\mathbf{s} = \mathbf{c} - \mathbf{v}$ **7.3** Velocity of light ***c*** is a vector quantity of constant magnitude $c = 2.998 \times 10^8$ *m/s*, relative to the source.
8. Kinetic energy *K* of a body of mass $m = m_o$ moving with speed *v*, is: $K = \frac{1}{2}mv^2$ (Classical mechanics does not reckon with the internal energy content of a body of mass m)	**8.** Total energy E_m of a body of rest mass m_o moving at speed *v*, is: $E_m = mc^2 = \frac{m_o c^2}{\sqrt{1 - \frac{v^2}{c^2}}}$ where *c* is the speed of light in a vacuum.	**8.** Total energy E_m of a body of mass $m = m_o$ moving at speed *v*, is: $E_m = \frac{1}{2}m(c^2 + v^2)$ where *c* is the speed of light, which is a constant relative to the source only. Energy content $E = 1/2\, mc^2$
9. Radiation reaction force $\mathbf{R}_f$ due to a particle of charge *q* moving with velocity ***v*** and acceleration ***a***, at time *t*. $\mathbf{R}_f = \frac{q^2}{6\pi\varepsilon_o c^3}\frac{d\mathbf{a}}{dt}$ *(Abraham-Lorentz formula)* *where c is* the speed of light in a vacuum. {There should be no radiation force in circular motion with constant speed as (d**a**/dt) = 0	**9.** THE FORMULA FOR RADIATION REACTION FORCE, IN RELATIVISTIC ELECTRODYNAMICS, HAS SOME DIFFICULTIES. See David Griffith, *Introduction to Electrodynamics*, Prentice-Hall Inc., New Jersey, 1981, p. 382 Without radiation force, there should be no radiation power	**9.** Radiation reaction force $\mathbf{R}_f$ due to a particle of charge *q* moving with speed *v* in the direction of an electrostatic field of intensity ***E***: $\mathbf{R}_f = -\frac{qv}{c}\mathbf{E} = -Eq\frac{\mathbf{v}}{c}$ *where c* is the speed of light, which is a constant relative to the source only. (At the speed of light, a moving charged particle takes the form of light radiation)

10. RADIATION POWER **10.1** Radiation power R_p of a particle of charge *q* moving with speed *v* and acceleration a, is: $R_p = \frac{q^2 a^2}{6\pi\varepsilon_o c^3}$ *(Larmor formula)* where *c* is the speed of light (*v* « *c*) in a vacuum. **10.2** Radiation power R_p of a particle of charge *q* moving with speed *v* *and* centripetal acceleration $a = v^2/r$, in a circle of radius *r*, is $R_p = \frac{q^2 v^4}{6\pi\varepsilon_o r^2 c^3}$ *(Larmor formula)* (This formula influenced physics, early in the 20th century, leading to Bohr's quantum theory of the hydrogen atom).	**10.** RADIATION POWER **10.1** Radiation power R_p of a particle of charge *q* moving with speed *v* and acceleration *a* in the same direction, is: $R_p = \frac{q^2 a^2 \gamma^4}{6\pi\varepsilon_o c^3}$ *(Lienard formula)* where *c* is speed of light and $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$ **10.2** Radiation power R_p of a particle of charge *q* moving with speed *v and* acceleration $a = v^2/r$, in a circle of radius *r*, is $R_p = \frac{q^2 v^4 \gamma^4}{6\pi\varepsilon_o r^2 c^3}$ *(Lienard formula)* (Radiation power R_p explodes at speed *v* = *c*).	**10.** RADIATION POWER **10.1** Radiation power of particle of charge *q* moving with velocity ***v***, is the scalar product: $R_p = -\mathbf{v}.\mathbf{R}_f$ For collinear motion ***v, E*** and $\boldsymbol{R_f}$ are in the same direction and radiation power is: $R_p = Eq\frac{v^2}{c}$ Radiation power R_p is 0 if ***v*** is orthogonal to ***E*** and $\boldsymbol{R_f}$ as in circular motion of an electron round a nucleus. **10.2** Radiation power of a particle of charge q revolving with speed *v* and acceleration $a = v^2/r$, in a circle of radius *r*, is zero (Rutherford's nuclear model of the hydrogen atom is, therefore, stable without recourse to Bohr's quantum theory).
11. Potential energy *P* lost by an electron, of mass $m = m_o$, accelerated from rest to speed *v* by an electrostatic field: $P = \frac{1}{2}mv^2$	**11.** Potential energy *P* lost by an electron, of rest mass m_o, accelerated from rest to speed *v* by a field. $P = \frac{m_o c^2}{\sqrt{1-\frac{v^2}{c^2}}} - m_o c^2$	**11.** Potential energy *P* lost by an electron of mass $m = m_o$, accelerated from rest to speed *v* by an electrostatic field: *P* = $-mc^2 \ln\left(1-\frac{v}{c}\right) - mcv$

11.1 Kinetic energy K gained $K = \frac{1}{2}mv^2 = P$ **11.2** Energy radiated: *R = P – K = 0* *(There must always be energy radiation)*	**11.1** Kinetic energy gained is *K = P* **11.2** Energy radiated: *R = P – K = 0* *(There must always be energy radiation)*	**11.1** Kinetic energy *K* gained is: $K = \frac{1}{2}mv^2$ **11.2** Energy radiated: *R = P – K > 0* *(There must always be energy radiation)*
12. Potential energy *P* gained by an electron, of *mass m = m_o*, decelerated, by an electrostatic field, from the speed of light *c* to speed *v is*: $P = \frac{1}{2}m(c^2 - v^2)$ **12.1** Kinetic energy K lost is: $K = \frac{1}{2}m(c^2 - v^2)$ **12.2** Energy radiated: *R = K – P = 0* *(There must always be energy radiation)*	**12.** An electron moving at the speed of light *c* (with infinite kinetic energy), cannot be stopped by any decelerating field; it continues to move at the same speed of light, gaining potential energy *P* without losing kinetic energy. **12.1** Kinetic energy lost is *K = 0*: **12.2** Energy radiated: *R = 0 – P = –P?* *(The energy radiated, must always be positive)*	**12.** Potential energy *P* gained by an electron, of *mass m = m_o*, decelerated, by an electrostatic field, from the speed of light *c* to speed *v is*: $P = mc^2 \ln\frac{1}{2}\left(1+\frac{v}{c}\right) + mc^2\left(1-\frac{v}{c}\right)$ **12.1** Kinetic energy K lost, is: $K = \frac{1}{2}m(c^2 - v^2)$ **12.2** Energy radiated: *R = K – P > 0* *(There is energy radiation)*
13. Potential energy *P* gained by an electron, of mass *m = m_o*, decelerated by an electrostatic field, from the speed of light *c* to rest is: $P = \frac{1}{2}mc^2$ **13.1** Kinetic energy *K* lost is: $K = \frac{1}{2}mc^2$	**13.** An electron moving at the speed of light *c* (with infinite kinetic energy), cannot be stopped by any decelerating field; it continues to move at the same speed of light, gaining potential energy *P* without losing kinetic energy. **13.1** Kinetic energy *K* lost is *K = 0*	**13.** Potential energy *P* gained by an electron, of mass *m = m_o*, decelerated by an electrostatic field, from the speed of light *c* to rest *(v = 0)*, is: $P = mc^2 \ln\frac{1}{2} + mc^2$ *$P = mc^2(1 - 0.693)$* *$P = 0.307mc^2$* **13.1** Kinetic energy *K* lost is: $K = \frac{1}{2}mc^2$

13.2 Energy radiated: *R = K – P = 0* *(There must always be energy radiation)*	**13.2** Energy radiated: *R = 0 – P = –P?* *(R is always positive)*	**13.2** Energy radiated: *R = K – P = 0.193*mc^2 *(There must always be energy radiation)*
14. Classical **r**adius *r* of revolution of an electron of charge –*e* and mass $m = m_o$ moving with speed *v* in a radial electrostatic field of magnitude *E* due to a positively charged nucleus: $r = \frac{mv^2}{eE} = r_o$ Mass $m = m_o$ **Mass *m* is independent *of* speed *v of a charged particle such as an electron.***	**14.** Relativistic **r**adius *r* of revolution of an electron of charge –*e* and mass *m* moving with speed *v* in a radial electrostatic field of magnitude *E* due to a positively charged nucleus: $r = \frac{m_o v^2}{eE\sqrt{1-\frac{v^2}{c^2}}} = \gamma r_o$ $m = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}} = \gamma m_o$ $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$ **Mass *m* of a charged particle such as an electron, depends on γ, mass becoming infinitely large at $\gamma = \infty$ or $v = c$.**	**14.** Radiational **r**adius *r* of revolution of an electron of charge –*e* and mass $m = m_o$ moving with speed *v* in a radial electrostatic field of magnitude *E* due to a positively charged nucleus: $r = \frac{mv^2}{eE\sqrt{1-\frac{v^2}{c^2}}} = \gamma r_o$ Mass $m = m_o$ Radius *r* can become infinitely large as is the case in rectilinear motion. **For a charged particle such as an electron, the variation of radius of circular revolution *r*, with γ, was mistaken, in Special Relativity, as being the result of mass *m* depending on γ** **For circular revolution of a charged particle such as an electron, Relativistic and Radiational Electrodynamics are in agreement but for different reasons.**