About the Arrow of Time

Cynthia Kolb Whitney
Editor, Galilean Electrodynamics
141 Rhinecliff Street, Arlington, MA 02476-7331
e-mail: Galilean_Electrodynamics@comcast.net

This paper locates the exact point in the development of physics where the phenomenon of irreversibility becomes an inevitable part of the mathematical description of all systems. That point is the appearance of Maxwell's four coupled field equations. Very early, the four coupled field equations were inserted one into another to produce two un-coupled wave equations. This manipulation revealed the finite wave propagation speed c. Compared to Newtonian physics, the finite wave propagation speed was something new in Physics. But it wasn't then tied into the development of irreversibility, because the two wave equations themselves are time reversal invariant. However, the original coupled field equations are *not* time reversal invariant, and from that fact there flows an important story that has implications concerning the status we should attribute to Einstein's Special Relativity Theory (SRT).

1. Introduction

Within the discipline of Physics, there exists a long-standing philosophical mystery concerning the phenomenon of irreversibility. On the one hand, Nature displays increasing entropy, chaos, heat death, *etc.*, all characterized as evidence for what is called the 'Arrow of Time'. On the other hand, we see the apparent time-reversal invariance of Newton's Laws of Mechanics.

How do we respond? It is generally supposed that irreversibility must develop with increasing number of particles in the system described: the idea is that small systems can have time reversal invariance, but for large enough numbers of particles, the evolution of a system must become irreversible. But this idea about irreversibility is qualitative at best, and so invites a search for deeper understanding.

This paper recommends an alternative idea. Let us ask if irreversibility has something to do with finite signal propagation speed. This phenomenon was definitely absent from Newtonian mechanics. The whole theory was about instantaneous action at a distance.

Finite signal propagation speed was always inherent in the Physics of the European continent, which was often about fluids and vortices, *etc.* It became important in England too with the work of Maxwell and his followers. Very early, Maxwell's four coupled field equations were inserted one into another to produce two un-coupled wave equations. This manipulation revealed the existence of the finite wave propagation speed c. Compared to Newtonian physics, this finite wave propagation speed was something new in Physics.

But finite wave propagation speed wasn't immediately tied into the development of irreversibility, because the two uncoupled wave equations themselves are each individually time reversal invariant.

However, Maxwell's original four coupled field equations are *not* time reversal invariant. The next Section shows why. Section 3 then discusses the interpretation of the un-coupled wave equations. Section 4 comments on the status of SRT. Section 5 proposes a better photon model. Section 6 reviews its merits, and Section 7 shows some applications.

2. Maxwell's Coupled Field Equations

In Gaussian units, Maxwell's four coupled-field equations are [1]:

$$\nabla \bullet \mathbf{B} = 0 \tag{1}$$

$$\nabla \bullet \mathbf{D} = 4\pi\rho \tag{2}$$

$$\nabla \times \mathbf{E} + \frac{1}{c}\partial \mathbf{B} / \partial t = 0 \tag{3}$$

$$\nabla \times \mathbf{H} - \frac{1}{c}\partial \mathbf{D} / \partial t = \frac{4\pi}{c}\mathbf{J} \tag{4}$$

Here $\mathbf{B}$ is magnetic field and $\mathbf{E}$ is electric field. In free space $\mathbf{D} = \varepsilon_0 \mathbf{E}$, $\mathbf{H} = \mathbf{B} / \mu_0$, $1 / c = \sqrt{\varepsilon_0 \mu_0}$, and charge density ρ and current density $\mathbf{J}$ are zero.

Let the word 'pulse' be the short reference for a field profile that is rounded on top and sloping on the sides, such as a Gaussian function. Begin with just one spatial variable, x, as the argument for such a pulse. Let a scenario be initiated with such a pulse and follow its development:

1) Begin with one pulse in $\mathbf{E}$, pointing in, say, the y direction. This pulse has two sloping sides, and so generates two pulses in $\mathbf{B}$. They are orthogonal to $\mathbf{E}$ and opposite to each other, in the plus and minus z direction. Energy is conserved, so as these $\mathbf{B}$ pulses grow, the $\mathbf{E}$ pulse shrinks away.

2) The two pulses in $\mathbf{B}$ have altogether three sloping sides, one long one in the middle and two shorter ones on the outsides. So they generate three $\mathbf{E}$ pulses in y directions: a middle one of larger magnitude and opposite sign to the original input one, plus two smaller ones of sign matching the original input one.

3) The three $\mathbf{E}$ pulses present four sloping sides, which generate four $\mathbf{B}$ pulses in z directions, alternating in signs, with the middle two larger in magnitude than the outer two.

4) And so on it goes. A waveform develops, with more and more peaks, of lesser and lesser amplitudes. Individual peaks define the half wavelength.

Observe that this waveform development process is *not* time reversible. The four coupled field equations do *not* allow solutions that are the time reverse of waveform development; *i.e.* waveform collapse.

3. The Un-Coupled Wave Equations

The two un-coupled wave equations in free space are:

$$\nabla^2 \mathbf{E} - \frac{1}{c^2}\partial^2 \mathbf{E} / \partial t^2 = 0 \tag{5}$$

and

$$\nabla^2 \mathbf{B} - \frac{1}{c^2}\partial^2 \mathbf{B} / \partial t^2 = 0 \tag{6}$$

where $1/c^2 = \varepsilon_0 \mu_0$.

Because the time derivatives in the un-coupled wave equations are second order, the sign attributed to time cancels out. So the un-coupled wave equations are invariant under time reversal. This fact means the two un-coupled wave equations are *not equivalent* to the four coupled field equations. The two un-coupled wave equations have a *larger set* of solutions than do the four coupled field equations. So while all solutions to the four coupled field equations will satisfy the two un-coupled wave equations, only some of the solutions of the two un-coupled wave equations will satisfy the four coupled field equations. So some solutions to the two un-coupled wave equations *do not satisfy* the four coupled field equations.

4. On the Status of SRT

When Einstein offered his Second Postulate as the foundation for SRT [2], he was attempting to capture the essence of Maxwell in his concept of a 'signal'. The mental image for an Einstein signal would be a single pulse in $\mathbf{E}$ with an orthogonal single pulse in $\mathbf{B}$, together traveling without dispersion at speed c with respect to whatever detector might ultimately capture them.

But the Second Postulate really captures *only* the essence of the two un-coupled wave equations, and *not* the essence of Maxwell's four coupled field equations. The wave equations can transport $\mathbf{E}$ and $\mathbf{B}$ pulses unaltered over the path from a source to a detector, but the coupled field equations cannot do that. A waveform inevitably develops. So the mental image that attaches to the 'signal' for Einstein's Second Postulate certainly does *not* capture the essence of Maxwell's theory.

So with SRT we have a 'truth in advertising' issue: SRT is *not* what it was advertised to be. It is based on a signal concept that does *not* capture the behavior that Maxwell's four coupled field equations require. That fact doesn't mean that SRT is actually wrong, but it does mean that SRT lacks the foundation that Einstein claimed for it. In fact, SRT has *no* clear foundation in science prior to its own time.

5. A Better Photon / Signal Model

Can we do better? Can we create a more realistic model for a photon, or a signal, starting with $\mathbf{E}$ and $\mathbf{B}$ field pulses? Yes, but we do have to use *more* of them than were mentioned in Sect. 2.

To being with, in order to cause travel we have to initialize with, not only one $\mathbf{E}$ pulse, but also one $\mathbf{B}$ pulse orthogonal to the $\mathbf{E}$ pulse. Then, in order to make for circular polarization, we have to initialize another $\mathbf{E},\mathbf{B}$ pair of pulses a quarter cycle later in time, and in rotated directions, say $z,-y$. That addition makes an $\mathbf{E},\mathbf{B}$ quartet.

And then we have to do something to overcome the ever-increasing waveform spread, with more and more peaks, of lesser and lesser amplitudes, so that something resembling a photon, or a signal, can be captured at a receiver. What might we be able to do?

One of the tools commonly used in applied Mathematics is the application of so-called 'boundary conditions'. Boundary conditions help us select from among the infinite set of possible solutions to a differential equation a lesser set of solutions that, when combined with the right numerical coefficients, sum together to make a particular solution that not only solves the differential equation, but also fits the boundary conditions.

For the photon/signal model, the boundary conditions could, for example, be 'zero $\mathbf{E}$ at the source', and 'zero $\mathbf{E}$ at the receiver'. Because zero $\mathbf{E}$ makes for zero Poynting vector $\mathbf{P} = \mathbf{E} \times \mathbf{B}$, that pair of boundary conditions makes it impossible for energy to escape the space between the source and the receiver. That means we can limit attention to the space between the source and the receiver.

To meet the boundary conditions, we first need to put two more $\mathbf{E},\mathbf{B}$ quartets into the initialization of the problem. Both of these $\mathbf{E},\mathbf{B}$ quartets must propagate in the direction opposite to the first $\mathbf{E},\mathbf{B}$ quartet. One of them begins at the source, and travels further back, and the other one begins double distance beyond the receiver, and travels back. That makes three $\mathbf{E},\mathbf{B}$ quartets – twelve field vectors overall, which is certainly a very complicated solution.

And to be perfectly pedantic, we really have to put even *more* of these additional $\mathbf{E},\mathbf{B}$ field quartets – an infinite series of them, at higher-multiple distances beyond the receiver, and matching distances before the source, each one added to clean up the boundary condition that the one added just before slightly spoiled. You can even write an analytic formula for sums of the series involved in each boundary condition.

But never mind being so pedantic. Nobody has to think in detail about the whole set of field vectors at all locations in space. The only important aspect of the scenario is the evolving profile of the total energy density $u = \frac{1}{2}(\Sigma E)^2 + \frac{1}{2}(\Sigma B)^2$ within the space between the source and the receiver. It goes like this:

1) The scenario starts with a photon / signal energy bump just beyond the source. This bump is a step on its trailing side at the source because the zero $\mathbf{E}$ imposed there makes for double $\mathbf{B}$ there. But the bump is gentle on its leading side, like a Gaussian.

2) The scenario 'middles' with a broader energy bump halfway between the source and the receiver. This bump is symmetric in space, like a Gaussian.

3) The scenario concludes with an even broader energy bump just behind the receiver. This bump is a step on its leading side at the receiver, again because the zero $\mathbf{E}$ imposed there makes for double $\mathbf{B}$ there. And it is really gentle on its trailing side, like a really broad Gaussian.

6. How is the New Model Better?

The fact of being a broader bump at the reception end of the scenario than at the emission beginning of the scenario does make this proposed better photon / signal model reflect the arrow of time that we know exists in physical reality. So that is a clear improvement in realism.

In addition, the proposed better photon / signal model alleviates some other vexing problems. These have to do with relative motion between the source and the receiver. Consider the following example problems:

6.1 What is the Reference for Light Speed c ?

In SRT, the reference for light speed c is any and all observers. Linguistically, this statement seems quite incomprehensible. Fortunately, the proposed better photon / signal model allows a more linguistically normal kind of statement. Consider that the behavior of the signal bump is driven by boundary two conditions. At times soon after the emission, the boundary condition that is numerically more significant is the one demanding zero $\mathbf{E}$ at the source. But at times just before the reception, the boundary condition that is numerically more significant is the one demanding zero $\mathbf{E}$ at the receiver. The consequence is that the bump starts out traveling at c relative to the source, but then arrives traveling at c relative to the receiver. So the SRT Second Postulate is true at the moment of reception, but not generally true at any time before that moment.

6.2 What Does the Old Photon / Signal Model Say?

This issue was addressed long before Einstein, in the late 19th and early 20th century. Many people addressed it, all with the same basic assumption that Einstein later formalized as his Second Postulate. The ones generally cited are A. Liénard and E. Wiechert [3,4]. They worked separately, and got the same results, as did all subsequent investigators. The results are given in every EM book, and are reviewed here next.

Expressed in Gaussian units, the Liénard-Wiechert (LW) scalar and vector potentials at position $\mathbf{r}$ and time t are

$$\Phi(\mathbf{r},t) = e\left[1/\kappa R\right]_{\text{retarded}} \tag{7}$$

and

$$\mathbf{A}(\mathbf{r},t) = e\left[\vec{\beta}/\kappa R\right]_{\text{retarded}} \quad . \tag{8}$$

where $\kappa = 1 - \mathbf{n}\bullet\vec{\beta}$, $\vec{\beta}$ is source velocity normalized by c, and $\mathbf{n} = \mathbf{R}/R$ (a unit vector), and $\mathbf{R} = \mathbf{r}_{\text{source}}(t - R/c) - \mathbf{r}$ (an implicit definition for the terminology 'retarded'). The LW fields obtained from those potentials are then

$$\mathbf{E}(\mathbf{r},t) = e\left[\frac{(\mathbf{n}-\vec{\beta})(1-\beta^2)}{\kappa^3 R^2} + \frac{\mathbf{n}}{c\kappa^3 R}\times\left((\mathbf{n}-\vec{\beta})\times d\vec{\beta}/dt\right)\right]_{\text{retarded}} \tag{9}$$

and

$$\mathbf{B}(\mathbf{r},t) = \mathbf{n}_{\text{retarded}} \times \mathbf{E}(\mathbf{r},t) \,. \tag{10}$$

The LW fields have some interesting properties. The $1/R$ fields are radiation fields, and they make a Poynting vector (energy flow per unit area per unit time) that lies along $\mathbf{n}_{\text{retarded}}$:

$$\begin{aligned}\mathbf{P} &= \frac{c}{4\pi}\mathbf{E}_{\text{radiative}} \times \mathbf{B}_{\text{radiative}} \\ &= \frac{c}{4\pi}\mathbf{E}_{\text{radiative}} \times \left(\mathbf{n}_{\text{retarded}} \times \mathbf{E}_{\text{radiative}}\right) \quad . \\ &= \frac{c}{4\pi}(E_{\text{radiative}})^2 \mathbf{n}_{\text{retarded}}\end{aligned} \tag{11}$$

But the $1/R^2$ fields are Coulomb-Ampère fields, and the Coulomb field does *not* lie along $\mathbf{n}_{\text{retarded}}$ as one might naively expect; instead, it lies along $(\mathbf{n}-\vec{\beta})_{\text{retarded}}$. Assume that $\vec{\beta}$ does not change much over the total field propagation time, in which case $(\mathbf{n}-\vec{\beta})_{\text{retarded}}$ is virtually indistinguishable from $\mathbf{n}_{\text{present}}$. So then the Coulomb field and the radiation are arriving to the observer from different directions. This does *not* sound right!

6.3 How is the New Photon / Signal Model Different?

The proposed better photon / signal model has a tipping point. Exact balance between the two imposed boundary conditions occurs at the temporal midpoint of the scenario. If the photon / signal is to reach the receiver, then its direction of propagation has to be from the source at this mid-point moment to the receiver at the reception moment. That means the concept of retardation has to be implemented differently than it was in the 19th and 20th centuries. Instead of full retardation, to the moment of emission, we need to use half retardation, to the temporal midpoint of the scenario.

6.4 Does the New Photon / Signal Model Work Better?

With the proposed better photon / signal model, the field-direction problem goes away. The scalar and vector potentials become:

$$\Phi(\mathbf{r},t) = e\left[1/\kappa R\right]_{\text{half retarded}} \tag{12}$$

and

$$\mathbf{A}(\mathbf{r},t) = e\left[\vec{\beta}/\kappa R\right]_{\text{half retarded}} \quad . \tag{13}$$

The fields become:

$$\mathbf{E}(\mathbf{r},t) = e\left[\frac{(\mathbf{n}-\vec{\beta})(1-\beta^2)}{\kappa^3 R^2} + \frac{\mathbf{n}}{c\kappa^3 R}\times\left((\mathbf{n}-\vec{\beta})\times d\vec{\beta}/dt\right)\right]_{\text{half retarded}} \tag{14}$$

and

$$\mathbf{B}(\mathbf{r},t) = \mathbf{n}_{\text{half retarded}} \times \mathbf{E}(\mathbf{r},t) \quad . \tag{15}$$

The Poynting vector becomes:

$$\begin{aligned}\mathbf{P} &= \frac{c}{4\pi}\mathbf{E}_{\text{radiative}} \times \mathbf{B}_{\text{radiative}} \\ &= \frac{c}{4\pi}\mathbf{E}_{\text{radiative}} \times \left(\mathbf{n}_{\text{half retarded}} \times \mathbf{E}_{\text{radiative}}\right) \quad . \\ &= \frac{c}{4\pi}(E_{\text{radiative}})^2 \mathbf{n}_{\text{half retarded}}\end{aligned} \tag{16}$$

Observe that now the direction of the Coulomb field is $(\mathbf{n}-\vec{\beta})_{\text{half retarded}} \approx (\mathbf{n}_{\text{present}})_{\text{half retarded}} \triangleq \mathbf{n}_{\text{half retarded}}$ and the direction of the Poynting vector is $\mathbf{n}_{\text{half retarded}}$ too. So now, the

Coulomb field and the Poynting vector are reconciled to the same direction. Now *this* sounds right.

7. Applications

The main applications for the proposed better photon / signal model are in Quantum Mechanics (QM), especially QM concerning atoms. Why are atoms stable at all? Is there a foundation for Schrödinger's equation? Why do electron populations behave as they do? What about Quantum Chemistry?

7.1 The Hydrogen Atom

The stability of the Hydrogen atoms was a really big problem for Maxwell's electromagnetic theory. The simplest atom possible, the Hydrogen atom, appeared to be prone to rapid collapse on account of the radiation that the circulating electron would generate. This Section shows that the supposed radiation problem is balanced by other effects not discoverable without the proposed better photon / signal model.

Recall that the photon / signal model had its three important parts: the main function, and the two boundary conditions. The corresponding Hydrogen atom model also features three important parts. It has not just the familiar radiation, but also an un-familiar internal system torquing, and very un-Newtonaian center of mass motion.

The far-field power radiated (energy loss per unit time) is

$$P_{\text{radiated}} = \int_{4\pi} |\mathbf{P}| R^2 d\Omega = \int_{4\pi} \frac{c}{4\pi} (E_{\text{radiative}})^2 R^2 d\Omega$$
$$= \int_{4\pi} \frac{c}{4\pi} \frac{e^2}{c^2\kappa^6} \left| \mathbf{n} \times \left((\mathbf{n} - \vec{\beta}) \times d\vec{\beta} / dt \right) \right|^2 d\Omega \tag{17}$$

where Ω means 'solid angle'. Because the full 4π of solid angle captures opposing directions of $\mathbf{n}$, contributions to the integral from the vector $\vec{\beta}$ visible in the integrand cancel out. Contributions to the integral that come from the dot product $\mathbf{n} \bullet \vec{\beta}$ that is hidden in the κ^6 factor may not be zero at every moment, but they time-average to zero. So let us simplify the expression for far-field power radiated by setting $\vec{\beta}$ to zero. We have:

$$P_{\text{radiated}} = \frac{e^2}{4\pi c} \int_{4\pi} \left| \mathbf{n} \times \left(\mathbf{n} \times d\vec{\beta} / dt \right) \right|^2 d\Omega \tag{18}$$

It evaluates to the well-known Larmor result [1]:

$$P_{\text{radiated}} = \frac{e^2}{4\pi c} \int_{-1}^{1} d\cos\theta \int_0^{2\pi} d\varphi \left| d\vec{\beta} / dt \right|^2 \sin^2\theta$$
$$= \frac{e^2}{2c} \left| d\vec{\beta} / dt \right|^2 \int_{-1}^{1} d\cos\theta (1 - \cos^2\theta) \tag{19}$$
$$= \frac{e^2}{2c} \left| d\vec{\beta} / dt \right|^2 \left(\cos\theta - \tfrac{1}{3}\cos^3\theta \right) \Big|_{-1}^{1} = \frac{2e^2}{3c} \left| d\vec{\beta} / dt \right|^2$$

The second process that occurs in the Hydrogen atom is a not previously noticed energy gain due to internal torquing. This process occurs because the Coulomb force within the atom is not central; it is along $\mathbf{n}_{\text{half retarded}}$, not $(\mathbf{n} - \vec{\beta})_{\text{retarded}} \approx \mathbf{n}_{\text{present}}$.

The power inflow to the electron is $P_{\text{torquing}} = T_e \Omega_e$, where Ω_e is the electron orbit frequency, and T_e is the magnitude of the torque on the electron, given by $\mathbf{T}_e = \mathbf{r}_e \times \mathbf{F}_e$ where $\mathbf{r}_e$ is the electron orbit radius, and $\mathbf{F}_e$ is the tangential force on the electron. But that is not all. The proton also orbits at frequency Ω_e, and experiences its own torque, given by $\mathbf{T}_p = \mathbf{r}_p \times \mathbf{F}_p$, where $\mathbf{r}_p$ is the proton orbit radius (tiny) and $\mathbf{F}_p$ is the tangential force on the proton (huge), with the result that the magnitude T_p is the same as T_e. The total torque on the system is $T = T_e + T_p = 2T_e$. It is determined by the angle between $\mathbf{r}_e$ and $\mathbf{F}_e$, which is given by $r_p \Omega_e / 2c = (m_e / m_p) r_e \Omega_e / 2c$. So torque $T = (m_e / m_p)(r_e \Omega_e / c) e^2 \big/ (r_e + r_p)$ and power received is

$$P_{\text{torqing}} = \frac{m_e}{m_p} \frac{r_e \Omega_e^2}{c} \frac{e^2}{(r_e + r_p)} = (e^4 / m_p) \big/ c(r_e + r_p)^3 \tag{20}$$

The existence of such a process is why the concept of 'balance' emerges: there can be a balance between gain of energy due to internal torquing and the inevitable loss of energy due to radiation.

But we are not done with radiation yet. The fact that the electron and the proton have such different masses, and orbit at such different radii, means that the EM forces within the atom are not only not central; they are not even balanced. This situation has another major implications: The system as a whole experiences a cyclical **net force.** That means the system center of mass (C of M) can **move**. This sort of effect does not occur in Newtonian mechanics due to the fact that Newtonian mechanics assumes infinite signal propagation speed.

Looking in more detail, the unbalanced forces in the Hydrogen atom must cause the C of M of the whole atom to traverse its own circular orbit, on top of the orbits of the electron and proton individually. This is an additional source of accelerations, and hence of radiation. It evidently makes even *worse* the original problem of putative energy loss by radiation that prompted the development of QM. But on the other hand, the torque on the system is a candidate mechanism to compensate the rate of energy loss due to radiation, even if there is a lot more radiation than originally thought..

The details are worked out quantitatively as follows. First ask what the circulation can do to the radiation. Some 20 years after the advent of SRT, a relevant kinematic truth about systems traversing circular paths was uncovered by L.H. Thomas [5], in connection with explaining the then anomalous magnetic moment of the electron: 1/2 its expected value. He showed that a coordinate frame attached to a particle driven around a circle naturally rotates at half the imposed circular revolution rate.

Applied to the scenario of the electron orbiting the proton, the gradually rotating x, y coordinate frame of the electron means that the electron sees the proton moving only half as fast as an external observer would see it. That fact explained the electron's anomalous magnetic moment, and so was received with great interest in its day. But the fact of Thomas rotation has since slipped to the status of mere curiosity, because Dirac theory has replaced it as the favored explanation for the magnetic moment problem. Now, however, there is a *new* problem in which to consider Thomas rotation: the case of the C of M of a whole Hydrogen atom being driven in a circle by unbalanced forces. In this scenario, the gradually rotating local x, y coordinate frame of the C of M means that the atom system doing its internal orbiting at frequency Ω_e relative to the C of M will be judged by an external observer to be orbiting *twice* as fast, at frequency $\Omega' = 2\Omega_e$ relative to inertial space. This perhaps surprising result can be established in at least three ways: **1)** by analogy to the old electron-magnetic-moment problem; **2)** by construction from Ω_e in the C of M system as the power series $\Omega' = \Omega_e \times (1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + ...) \to \Omega_e \times 2$; **3)** by observation that in inertial space Ω' must satisfy the algebraic relation $\Omega' = \Omega_e + \frac{1}{2}\Omega'$, which implies $\Omega' = 2\Omega_e$.

The relation $\Omega' = 2\Omega_e$ means the far field radiation power, if it really ever manifested itself in the far field, would be even *stronger* than classically predicted. The classical Larmor formula for radiation power from a charge e (e in electrostatic units) is $P = 2e^2a^2 / 3c^3$, where a is total acceleration. For the classical electron-proton system, most of the radiation would be from the electron, orbiting with $a_e = r_e\Omega_e^2$, Ω_e given by the Coulomb force $m_e r_e \Omega_e^2 = F_e = e^2 / (r_e + r_p)^2$. But with $\Omega' = 2\Omega_e$, the effective total acceleration is $a' = a_e \times 2^2$. The total radiation power is then

$$P_{\text{total radiated}} = \underline{2^4}\frac{2e^2}{3c^3}a_e^2 = \left(\underline{2^5}e^6 / m_e^2\right) \Big/ 3c^3(r_e + r_p)^4 \quad . \tag{21}$$

Now posit a balance between the energy gain rate due to the torque and the energy loss rate due to the radiation. The balance requires $P_{\text{torquing}} = P_{\text{total radiated}}$, or

$$(e^4 / m_p) \Big/ c(r_e + r_p)^3 = (2^5 e^6 / m_e^2) \Big/ 3c^3(r_e + r_p)^4 \quad . \tag{22}$$

This equation can be solved for

$$r_e + r_p = 32 m_p e^2 \Big/ 3m_e^2 c^2 = 5.5 \times 10^{-9} \quad . \tag{23}$$

Compare that value to the accepted value $r_e + r_p = 5.28 \times 10^{-9}$ cm. The match is fairly close, running just about 4% high. That means the concept of torque *vs.* radiation does a fairly good job predicting the ground state of Hydrogen.

7.2 Schrödinger's Equation

Schrödinger's equation reads [6, 7]

$$\left[-\frac{\hbar^2}{2m}\nabla^2 + V(\mathbf{r}) \right] \Psi(\mathbf{r}, t) = i\hbar \frac{\partial}{\partial t}\Psi(\mathbf{r}, t) \tag{24}$$

where ψ is called a 'wave function'. The idea is that the wave function is complex, and its phase factor is something like $(\mathbf{p} \cdot \mathbf{r} - E \times t) / \hbar$, where $\mathbf{p}$ is momentum, $\mathbf{r}$ is position, E is total energy and t is time. So the differential operators extract $p^2 / 2m$ and E. The V is the potential energy created by the nucleus, so the equation overall says that classical kinetic energy plus potential energy makes total energy.

But why is the equation about a wave function, and not about a particle? Like Einstein's Second Postulate, Schrödinger's wave function had no clear foundation in the science prior to its own time. But unlike Einstein's Second Postulate, Schrödinger's equation seems unlikely to be wrong, since no test of QM so far achieved has revealed any violation of a prediction, even when we did not understand the meaning of the prediction. So maybe that lack of foundation for Schrödinger's equation can now be successfully addressed, by using the proposed better photon / signal model.

Recall that in its emission / propagation / reception scenario, the photon / signal model naturally displays particle-like localization at the two ends, and wave-like periodicity in the middle. So photon / signal establishes a precedent for asserting equivalence between particles and waves. That paves the way for the Schrödinger wave function Ψ.

The photon / signal model thus helps clarify the mysterious issue of 'duality'. In the past, the word has been used to suggest a simultaneous wave-particle character. The photon / signal model had duality of a more pedestrian type: sequential. The photon signal was emitted and is received in a particle-like state, but in between, it is wave-like.

The photon / signal model also helps explain why Schrödinger's equation, unlike classical physics, necessarily involves complex numbers. Recall that that the photon / signal model everywhere has the second $\mathbf{E}, \mathbf{B}$ vector pairs a quarter cycle out of phase with the first $\mathbf{E}, \mathbf{B}$ vector pairs to make the circular polarization. That sort of phase issue invites the use of complex numbers.

Recall finally that the important output from the proposed better photon / signal model was its energy density, defined in terms of squared electric and magnetic fields. If we represented the fields a quarter cycle out of phase as imaginary numbers, then we would need fields, not just squared, but multiplied by complex conjugate fields. That operation would resemble the familiar $\Psi\Psi^*$ operation for probability density.

7.3 Excited States? Bigger Atoms? Electron Rings?

The Schrödinger equation gives a lot more than just the ground state of Hydrogen. Like Maxwell's equations, it admits an infinite set of solutions. They are currently understood as representing an infinite set of excited states of the Hydrogen atom.

What exactly *are* excited states of the Hydrogen atom? The usual understanding is that they are something like spherical shelves above and arount the nucleus, and that the electron can rest on any one of these shelves, and if it tumbles to a lower one, a photon will be released.

I want to encourage readers to consider also any and all alternative interpretations that may be offered. My own working idea is that the term 'excited state' does *not* refer to an attribute that a single Hydrogen atom can have. The atom is too simple; it has too few degrees of freedom. My mental image of 'excited state' is a system involving, not one, but several, Hydrogen atoms.

The basis for such a candidate interpretation is that a balance between radiation and torquing works out, not only for two charges of opposite sign, but also for two, or more, charges of the same sign – if superluminal orbit speeds will be allowed. And what is there to disallow them? The only factors are Einstein's Second Postulate and his resulting SRT, which together embed a rash denial of the well-known 'arrow of time'. So be prudent; don't *a priori* disallow super-luminal orbit speeds.

Of course the Hydrogen atom is only the first atom to study. There are at least 118 elements to consider. The ones beyond Hydrogen have electron populations with mysterious internal interactions that are evident in data about ionization potentials. These matters can be understood via a model for the electron population that is quite different from the one in current use. The current QM model for an electron population features shells of electrons enclosing the nucleus. The alternative model makes the electron population a rather localized subsystem, orbiting the nucleus, rather than enclosing it. The electron subsystem is composed of electron rings spinning at superluminal speeds, stacked together like little magnets.

This model creates a hierarchy of magnetic confinement levels. Two rings with two electrons each create a 'magnetic bottle', and it can contain up to two geometrically smaller rings with three electrons each. Two such three-electron rings create a stronger 'magnetic thermos jug'. That can contain up to two geometrically smaller rings with five electrons each. Two such five-electron rings create an even stronger 'magnetic Dewar flask'. It is capable of containing up to two geometrically smaller rings with seven electrons each.

The electron state filling sequence is determined by a rather 'fractal' looking algorithm: Always build and store an electron ring for the largest number of electrons possible, where 'possible' means having a suitable magnetic confinement volume available to fit into, and where 'suitable' means created by two electron rings with smaller electron count, and not yet filled with two electron rings of larger electron count. Sometimes only a new two-electron ring is possible, and that is what starts a new period in the Periodic Table.

All of this leads to the formation and development of a computationally convenient approach to Chemistry. [8, 9]

8. Conclusion

Maxwell gave us the opportunity to understand the obvious arrow of time that certainly exists in physical reality. Einstein put that opportunity out of reach for proper attention from several generations of scientists. But we can still reclaim it now. And when we do, we can build a more reasonable SRT, and improve insight into QM, and make a much easier job out of Chemistry [8, 9].

References

[1] J.D. Jackson, **Classical Electrodynamics** 1st Ed., Sect. 14.1 & 2nd Ed., Sect. 11.2 (John Wiley & Sons, Inc., New York, London, 1962 & 1975).

[2] A. Einstein, "On the Electrodynamics of Moving Bodies" (1905), as translated in *The Collected Papers of Albert Einstein*, Vol. 2, 140-171 (Princeton University Press, Princeton NJ, 1989).

[3] A. Liènard, "Champ Electrique et Magnétique produit par une Charge Electrique Concentrée en un Point et Animée d'un Movement Quelconque", L'Eclairage Electrique **XVI** (27) 5-14, (28) 53-59, (29) 106-112 (1898)

[4] E. Wiechert, "Elektrodynamische Elementargesetze", Archives Néerlandesises des Sciences Exactes et Naturelles série II, Tome IV (1901).

[5] L.H. Thomas, "The Kinematics of an electron with an Axis", *Phil. Mag*. S. 7, **3** (13) 1-22 (1927).

[6] A. Messiah, Quantum Mechanics, Vol 1 (John Wiley & Sons, New York, London, 1961)

[7] E. Schrödinger, Ann. Physik **79,** 361 & 489 (1925), **80**, 437 (1926), **81** 109 (1927).

[8] C.K. Whitney, "A New Theory for Important New Technologies", Proceedings of the NPA, Vol 2011.

[9] C.K. Whitney, **Algebraic Chemistry: Applications and Origins** (Nova Science Publishers, forthcoming in 2012).