WAVE-PARTICLE DUALITY ©

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INTRODUCTION

Before working into the deterministic atom, there is one other property of the electron that is so important to the whole field of modern physics that a short, separate digression is required. After 1910, it gradually became clear that there were *frequencies* associated with *particles* as well as with *waves*. Except for the behavior of atoms, none of the observations of the related phenomena had been made before 1924 when de Broglie first proposed "matter waves". Unfortunately, the current explanations using the quantum mechanical approach are both inaccurate and non-intuitive, because the de Broglie waves described in modern textbooks are fictitious. *What is needed is a physical wave description, based on real wave properties of the particle.* That is the subject of this Note.

LONGITUDIINAL WAVES

Examination of the behavior of electrons under various conditions makes it clear that when e/p pairs are formed the particles are endowed not only with implicit spin, but also with continuous, real *longitudinal* waves. They run *radially* into the positron and out of the electron, and are a permanent part of the particles' structure until the latter are annihilated. These ℓ-waves are similar in some ways to the transverse t-waves of electromagnetic theory, which are generated by moving charged particles. However, t-waves carry energy in two forms; antenna and photon radiation. Although no longitudinal *radiation* appears in electromagnetic theory, ℓ-waves are more prevalent and potent than t-waves. The sometimes strange physical effects they produce are not yet recognized as being caused by ℓ-waves; and the theory of ℓ-waves is sadly lacking any large experimental base. *Since all energy transfer by waves is presently observed to be carried by t-waves, the ℓ-waves appear to be energyless*; which accounts for their lack of direct observability. The velocities of ℓ-waves and t –waves are the same, and equal to the velocity of light.

Figure 1 illustrates the condition of a constant velocity electron as described in Notes 1 and 2. The first half of the figure indicates the

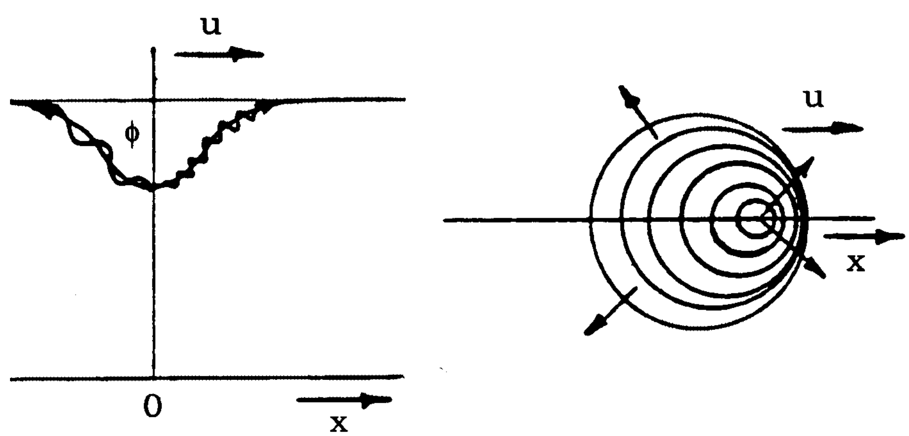

Figure 1. A constant velocity electron

outgoing ℓ-waves, whereas the second part is a plot of their wave-fronts at any particular time, say t = 0. Without going into great detail, the waves can be described in terms of sines and cosines of the form,

$$C = \cos\frac{\omega_e}{\gamma}\left(t \mp \frac{\mathcal{R}}{c_0}\right) \quad , \quad S = \sin\frac{\omega_e}{\gamma}\left(t \mp \frac{\mathcal{R}}{c_0}\right) \quad , \qquad (1)$$

where,

$$x^* = \gamma(x - ut) \ , \ r^* = \sqrt{x^{*2} + R^2} \ , \ \mathcal{R} = \gamma(r^* \pm \beta x^*) \ , \ \beta = \frac{u}{c_0} \quad , \qquad (2)$$

γ is the familiar motion factor, $1\Big/\sqrt{1-u^2/c_0^2}$, and $\omega_e = 2\pi\nu_e$, the electron's ℓ – wave rest frequency found from the Rydberg constant.

SPECTRUM FREQUENCIES AND THE RYDBERG CONSTANT

Because spectral observations are the fundamental method for measuring atomic processes, they deserve a somewhat deeper examination. When an electron produces a photon, by dropping from an initial orbit to a final, lower energy orbit, the photon frequency is,

$$\nu = \frac{E_i - E_f}{h} \quad . \tag{3}$$

Substituting the energy equation from Note 4, the frequency can be expressed as (Heaviside-Lorentz Units),

$$\nu = \frac{e^4}{8 m_0^2 c_0^6} \nu_e^3 \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right) \quad ; \tag{4}$$

or in the more usual form of the inverse wavelength,

$$\bar{\nu} = \frac{1}{\lambda} = R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right) \quad , \tag{5}$$

where,

$$R_H = \frac{e^4}{8 m_0^2 c_0^7} \nu_e^3 \quad . \tag{6}$$

The measured values of $\bar{\nu}$ from many transitions, including microwaves from free hydrogen in outer space, provide a value for R_H, the Rydberg constant, *one of the most accurately measured constants known*. It is found to be,

$$R_H = 1.0973731572 \times 10^5 \ \text{cm}^{-1} \quad . \tag{7}$$

Inverting Eq.(6),

$$\nu_e = \sqrt[3]{\frac{8 m_0^2 c_0^7}{e^4} R_H} = 1.2355898 \times 10^{20} \ \text{cyc/sec} \quad . \tag{8}$$

This is essentially a measured value for ν_e.

From Eqs.(1) and(2), the wave fronts are specified by the phase angle,

$$\delta = \frac{2\pi\nu_e \mathcal{R}}{\gamma c_0} \quad ; \tag{9}$$

and $\mathcal{R}$ can be found along the x axis, where,

$$\mathcal{R} = \begin{cases} \dfrac{x}{1-\beta} & , \quad x > 0 \\ \dfrac{|x|}{1+\beta} & , \quad x < 0 \end{cases} \quad . \tag{10}$$

Substituting these values into the phase δ, the frequency along the x axis is found to be changed to,

$$\begin{aligned} \nu_f &= \frac{\nu_e / \gamma}{1-\beta} \quad , \quad x > 0 \\ \nu_b &= \frac{\nu_e / \gamma}{1+\beta} \quad , \quad x < 0 \end{aligned} \quad . \tag{11}$$

This change is exactly equivalent to the ordinary Doppler shift of a source or sink of sound; and, the electron's being a source of the waves, the front edge frequency is increased and the back is decreased, which is the opposite of the positron (sink).

For a free electron, the only effect of these changes is the adjusted oblate shape described in Notes 1 and 2. *However, when interacting with another particle, the effect produced on the outcome is related to the difference between the front and back frequencies*. For this reason, *the difference frequency assumes a significance of major importance*. Combining the frequencies of Eqs.(11), the difference frequency is,

$$\nu_d = \nu_f - \nu_b = \frac{\nu_e}{\gamma}\left(\frac{1}{1-\beta} - \frac{1}{1+\beta}\right) \quad ,$$

which can be manipulated into the form,

$$\nu_d = 2\gamma\beta\nu_e \quad . \tag{12}$$

To bring the derivation more in line with the conventional approach, the momentum and Eq.(12) can be used to write,

$$pc_0 = \gamma m_0 u c_0 = \frac{m_o c_0^2}{\nu_e} \frac{\nu_d}{2} \quad , \tag{13}$$

which shows that the momentum and the difference frequency vary linearly because,

$$h = \frac{m_0 c_0^2}{\nu_e} \tag{14}$$

is a constant. When ν_e, m_0 and c_0 are substituted into Eq.(14), the value of the **derived** constant h is found to be,

$$h = 6.6260759 \times 10^{-27} \quad , \quad \text{erg-sec} \tag{15}$$

the well known Planck's constant. With this in mind, Eq.(13) can be written as the de Broglie difference frequency[1],

$$\nu_d = 2c_0 \frac{p}{h} \quad . \tag{16}$$

The customary way of writing the corresponding quantum expression is,

$$\lambda = \frac{h}{p} \quad , \qquad \text{WRONG} \tag{17}$$

and this relationship is called a "quantum mechanical" equation; but it is simply another way of writing Eq.(16) which comes from the Doppler shift of the electron's ℓ-wave. *Physically there* <u>*is*</u> *a difference* ***frequency***. However, *the Eq.(17) is probably better not used, because there is* <u>*no*</u> *difference* ***wave***, so the wavelength λ is nothing more than the inverse of Eq.(16) expressed in different units. The proper way to invert Eq.(16) is to write,

$$\Lambda_d = \frac{2c_0}{\nu_d} = \frac{h}{p} \quad . \tag{18}$$

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1. Although the author has chosen to call ν_d the de Broglie frequency, it should not be confused with $\nu_{db} = E/h$, a fictitious frequency of a fictitious wave $\left(\nu_d = 2\frac{u}{c_0}\nu_{db}\right)$.

Λ_d is **not** the wave length of a mysterious wave that travels along curved paths. It is determined by real, longitudinal waves that emanate and propagate radially from the electron's center. It has nothing to do directly with the wavelength of any wave. Instead it is simply *the distance the* *electron* *travels during* $2/\beta$ *cycles of the difference frequency*. The conventional de Broglie frequency, $\nu_{db} = E/h$, of a wave that travels along *in the direction of the electrons' velocity* does not represent a real, physical wave in the same sense that t-waves represent real physical waves. On the other hand, the radial $\ell -$ waves are just as real as the t-waves. This essentially completes the description of the innate properties of the electron.

WAVE-PARTICLE DUALITY

Using the energy, momentum, and force equations derived for electrons in *fields*, and extrapolated to all leptons and baryons in *fields*, the exchanges of energy and momentum in elastic collisions between particles are considered to be well understood. The discovery of the Compton effect in the collision between a photon and an electron, i.e. the particle like behavior of the photon, has led to the conventional point of view about wave-particle duality that light is "neither" particle nor wave.[1] From the present author's point of view, it is "both", with no confusion. Formal description of the Compton effect is so well covered in the available literature that it need not be reproduced here.[2] Simply, it is the collision of two different particle *types*, an electron and a photon (the photon is a long, needle-like particle; see later Notes). The electron's $t -$ waves, ℓ-waves and bulk structure interact with the photon's

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1. R.P.Feynman, R.B.Leighton, M.Sands, Lectures on Physics, **3**, p 1-1, Addison-Wesley Publ. Co., Reading, MA (1965).
2. R.L.Armstrong & J.D.King, The Electromagnetic Interaction, p 3O2 ff, Prentice-Hall Inc. N.J. (1973). K.H.Spring, Photons and Electrons, Ch-3, Methuen & Co. Ltd, London (1950).

$t-$waves, ℓ-waves and bulk structure to deflect both particles; but energy, momentum, and spin, are conserved, while both particles change direction and make adjustments in their wave structures. The best possible deterministic description of any particle is a "wave-particle duality".

As long as particle-particle collisions involve only a relatively weak field interaction, the exchange of energy and momentum is *elastic* and can be handled in the customary fashion. However, if enough energy is involved, the collision may be *inelastic*; i.e. the two particles may merge and splatter. This is a more difficult problem, formally, because the exact structure of most of the particles is not yet available. This is one of the many gaps yet to be filled, in both QM and Main-Line physics. It will be taken up in subsequent Notes.