Principles of Quantum Physics

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Summary

This paper summarizes the basic principles of the common-sense interpretation of quantum physics that we have been exploring over the past few years.

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Principles of quantum electrodynamics

1. The electromagnetic force acts on the (elementary) electric charge. We think of the (naked) charge as being pointlike but not dimensionless. The elementary charge is a fundamental constant and there is, therefore, no uncertainty in its value: it is defined as being equal to $1.602176634 \times 10^{-19}$ C.[1] The elementary charge can be positive or negative.

2. The electron and the proton are matter-particles which carry the elementary charge. The idea of an elementary (matter-)particle combines the idea of a charge and its motion and, therefore, accounts for both the particle- as well as the wave-like character of matter-particles.[2] This motion is essentially circular or elliptical[3] and was – according to Ernest Rutherford's 1921 account of the theory of the electron[4] – first modelled in Parson's magnetic electron model (1915). This oscillatory motion is the same *Zitterbewegung* which Schrödinger found when analysing Dirac's wave equation for an electron in free space (1927).

While Dirac immediately grasped the significance of Schrödinger's discovery, he rather unfortunately confused the concept of the electron as a particle with the concept of the naked charge:

> "It is found that an electron which seems to us to be moving slowly, must actually have a very high frequency oscillatory motion of small amplitude superposed on the regular motion which appears to us. As a result of this oscillatory motion, the velocity of the electron at any time

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[1] There is, likewise, no uncertainty in the velocity of light (c) or, since the 2019 revision of SI units, in Planck's quantum of action (h or its reduced form $\hbar = h/2\pi$), which now also has a *defined* value and is, therefore, considered to be a fundamental rather than a derived constant.

[2] The geometry of the anti-matter counterpart of a particle has a different spacetime signature. Using common-sense language we may say antimatter counterparts of elementary particles are geometrically 'left-handed' or, alternatively, that 'their clock ticks counterclockwise'. These definitions depend on the plane of motion of the elementary charge and, therefore, assume the relation in space between the observer and the particle can be defined. The latter is not an issue when using Wittgenstein's definition of reality: "1. *Die Welt is alles was der Fall ist.* 2. *Was der Fall ist, die Tatsache, ist das Bestehen von Sachverhalten.*" We believe Wittgenstein's seven logical propositions (*Abschnitte*) say all there needs to be said about epistemology in the context of physics. There is no *a priori* reason to assume the positive charge inside of a positron is different from the positive charge inside of a proton. Likewise, there is no reason to assume the negative charge inside of a antiproton differs from the negative charge inside of an electron. Photons carry electromagnetic energy but do not carry any charge.

[3] The (classical) linear motion of an electron adds a linear component to the motion of the pointlike charge which, therefore, becomes elliptical rather than circular, except when the plane of the ring current would be perfectly perpendicular to the linear motion of the electron. There is no reason to assume the latter is the case: the plane of oscillation should be taken to be random or – when an external magnetic field is applied – to correspond to Larmor's precessional motion of the angular momentum vector.

[4] See Ernest Rutherford's remarks on the Parson's '*électron annulaire*' (ring electron) and the magnetic properties of the electron in his lecture on '*The Structure of the Electron*' at the 1921 Solvay Conference.

equals the velocity of light. This is a prediction which cannot be directly verified by experiment, since the frequency of the oscillatory motion is so high and its amplitude is so small. But one must believe in this consequence of the theory, since other consequences of the theory which are inseparably bound up with this one, such as the law of scattering of light by an electron, are confirmed by experiment." (Paul A.M. Dirac, *Theory of Electrons and Positrons*, Nobel Lecture, December 12, 1933)

3. The *Zitterbewegung* of the pointlike charge is possibly chaotic. However, experiments yield results that are statistically regular and, hence, this motion must be statistically regular as well. We can, therefore, model it by the formula for circular velocity:

$$c = a \cdot \omega \Leftrightarrow a = \frac{c}{\omega}$$

Any (regular) oscillation has a frequency and a cycle time $T = 1/f = 2\pi/\omega$. The Planck-Einstein relation ($E = h \cdot f = \hbar \cdot \omega$) relates f and T to the energy (E) through Planck's constant h (or, when using the reduced form of Planck's equation, $\hbar$). This frequency formula then allows us to use the tangential velocity formula to calculate the radius of this orbital motion:

$$a = c/\omega = c\frac{\hbar}{\mathrm{E}} = \frac{\hbar c}{\mathrm{m}c^2} = \frac{\hbar}{\mathrm{m}c}$$

This effectively corresponds – as Dirac suggest – to what we refer to as the Compton *radius* of an electron[5], which, paraphrasing Prof. Dr. Patrick LeClair, we can now understand as "the scale above which the electron can be localized in a particle-like sense."[6]

4. The *Zitterbewegung* or ring current inside of an electron generates the *theoretical* magnetic moment of the electron:

$$\mu_e = \mathrm{I}\pi a^2 = \mathrm{q_e} f \pi a^2 = \mathrm{q_e}\frac{c}{2\pi a}\pi a^2 = \frac{\mathrm{q_e} c}{2} a = \frac{\mathrm{q_e}}{2\mathrm{m}}\hbar \approx 9.27401 \ldots \times 10^{-24}\ \mathrm{J \cdot T^{-1}}$$

The *measured* magnetic moment differs slightly from this theoretical value. Such tiny anomaly in the magnetic moment suggests that the pointlike charge must have some tiny spatial dimension itself. The order of magnitude of this physical dimension is that of the classical electron radius and can be calculated from Schwinger's $\alpha/2\pi$ factor.[7]

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[5] The Compton *radius* is the reduced Compton wavelength. The ring current model interprets the Compton wavelength not as a linear wavelength but as a circumference. Instead of a distance corresponding to a linear length of travel, a circumference measures the circular length of travel. We should, therefore, think of Broglie's concept of the matter-wave as corresponding to orbital rather than linear motion.

[6] See: http://pleclair.ua.edu/PH253/Notes/compton.pdf, p. 10. Note that we can also *measure* the scale of the pointlike charge because of the phenomenon of elastic scattering (*Thomson* scattering): however, while we can measure its effective scattering radius, we cannot precisely *localize* the pointlike charge because of its lightlike velocity.

[7] We think of the anomalous magnetic moment as an experimental answer to a theoretical question: we think objects whose spatial dimension is truly zero do not exist and the pointlike charge must, therefore, have some non-zero dimension itself, which can be calculated from the measured anomaly: we refer the reader to Annex I for the calculation. We also think of photons as having some non-zero size. However, this dimension is linear rather

5. The mass of an electron is the inertia of the electron's state of motion and is given by Einstein's mass-energy equivalence relation ($E = mc^2$). The ring current model, therefore, embodies Archibald Wheeler's 'mass without mass' principle, and the de Broglie relation ($p = h/\lambda = \hbar k$) has a *geometric* interpretation which one can only appreciate by noting that the linear momentum of a particle is a *vector* quantity: it has a magnitude as well as a (linear) direction. When writing the de Broglie relation, one should, therefore, also think of Planck's quantum as a vector quantity:

$$\mathbf{p} = \frac{\boldsymbol{h}}{\lambda}$$

In a similar vein, we think of the reduced Planck constant ($\boldsymbol{\hbar} = \boldsymbol{h}/2\pi$) as a proper angular momentum, which can and should be written as $\boldsymbol{\hbar} = I\cdot\boldsymbol{\omega}$: the product of an *angular mass* (the rotational inertia I) and an orbital angular frequency ($\boldsymbol{\omega}$). This, then, also gives meaning to the concept of *spin* (which is either up or down). As mentioned above, this oscillatory motion thus also generates a classical magnetic moment which – equally classically – will precess in an external electromagnetic field.

6. There is no uncertainty in this model except for the uncertainty in regard to the *plane* of oscillation (which is given by the *direction* of $\boldsymbol{\hbar}$ and $\boldsymbol{\omega}$) in the absence of an external electromagnetic field. We can use the elementary wavefunction (Euler's formula) to represents the motion of the pointlike charge by interpreting $\boldsymbol{r} = a\cdot e^{i\theta} = a\cdot e^{i\cdot(E\cdot t - \mathbf{k}\cdot\boldsymbol{x})/\hbar}$ as its position vector. The relativistic invariance of the argument of the wavefunction is then easily demonstrated by noting that the position of the pointlike particle in its own reference frame will be equal to $x'(t') = 0$ for all t'.

We can then relate the position and time variables in the reference frame of the particle and in our frame of reference by using Lorentz's equations[8]:

$$x' = \frac{x - vt}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{vt - vt}{\sqrt{1-\frac{v^2}{c^2}}} = 0$$

$$t' = \frac{t - \frac{vx}{c^2}}{\sqrt{1-\frac{v^2}{c^2}}}$$

When denoting the energy and the momentum of the electron in our reference frame as E_v and $p = \gamma m_0 v$, the argument of the (elementary) wavefunction $a\cdot e^{i\theta}$ can be re-written as follows[9]:

than circular: see Annex II. One can relate the geometry of the electron and the photon using the concept of the de Broglie wavelength.

[8] We can use these simplified Lorentz equations if we choose our reference frame such that the (classical) linear motion of the electron corresponds to our *x*-axis.

[9] One can use either the general $E = mc^2$ or – if we would want to make it look somewhat fancier – the $pc = Ev/c$ relation. The reader can verify they amount to the same.

$$\theta = \frac{1}{\hbar}(\mathrm{E}_v t - \mathrm{p}x) = \frac{1}{\hbar}\left(\frac{\mathrm{E}_0}{\sqrt{1-\frac{v^2}{c^2}}}t - \frac{\mathrm{E}_0 v}{c^2\sqrt{1-\frac{v^2}{c^2}}}x\right) = \frac{1}{\hbar}\mathrm{E}_0\left(\frac{t}{\sqrt{1-\frac{v^2}{c^2}}} - \frac{\frac{vx}{c^2}}{\sqrt{1-\frac{v^2}{c^2}}}\right) = \frac{\mathrm{E}_0}{\hbar}t'$$

E_0 is, obviously, the rest energy and, because p' = 0 in the reference frame of the electron, the argument of the wavefunction effectively reduces to $E_0t'/\hbar$ in the reference frame of the electron itself.

Besides proving that the argument of the wavefunction is relativistically invariant, this calculation also demonstrates the relativistic invariance of the Planck-Einstein relation when modelling elementary particles.[10] This is why we feel that the argument of the wavefunction (and the wavefunction itself) is more *real* – in a *physical* sense – than the various wave equations (Schrödinger, Dirac, or Klein-Gordon) for which it is some solution.

In any case, a wave equation usually models the properties of the medium in which a wave propagates. We do not think the medium in which the matter-wave propagates is any different from the medium in which electromagnetic waves propagate. That medium is generally referred to as the *vacuum* and, whether or not you think of it as true nothingness or some medium, we think Maxwell's equations – which establishes the speed of light as an *absolute* constant – model the properties of it sufficiently well! We, therefore, think superluminal phase velocities are *not* possible, which is why we think de Broglie's conceptualization of a matter particle as a wave*packet* – rather than one *single* wave – is erroneous.[11]

7. A good theory should respect Occam's Razor—the *lex parsimoniae*: one should not multiply concepts without necessity. The need for new concepts or new principles – such as the conservation of strangeness, or postulating the existence of a new force or a new potential[12] – should, therefore, be continuously questioned. Conversely, when postulating the existence of the positron in 1928 – which directed experimental research to a search for it and which, about five years later, was effectively found to exist – Paul Dirac unknowingly added another condition for a good theory: all of the *degrees of*

[10] The relativistic invariance of the Planck-Einstein relation emerges from other problems, of course. However, we see the *added value* of the model here in providing a *geometric* interpretation: the Planck-Einstein relation effectively models the *integrity* of a particle here.

[11] See our paper on matter-waves, amplitudes and signals.

[12] We are, obviously, referring to the *invention* of the concept of strangeness by Murray Gell-Man and Kazuhiko Nishijima in the 1950s. Feynman's treatment of it in his 1963 *Lectures* on physics shows that the concept of strangeness – and the related conservation law – is a rather desperate assumption to explain the decay of K-mesons (kaons). Unfortunately, the concept of strangeness started a strange life of its own and would later serve as the basis for the quark hypothesis which – for a reason we find even stranger than the concept of strangeness itself – was officially elevated to the status of *a scientific dogma* by the Nobel Prize Committee for Physics.

As for the invention of a new force or a new potential, we are, obviously, referring to the Yukawa potential. This hypothesis – which goes back to 1935 – might actually have been productive if it would have led to a genuine exploration of a stronger short-range force on an electric charge—or, if necessary, the invention of a *new* charge. Indeed, if the electromagnetic force acts on an electric charge, it would be more consistent to postulate some new charge – or some new wave equation, perhaps – matching the new force. Unfortunately, theorists took a whole different route. They invented a new *aether* theory instead: it is based on the medieval idea of messenger or *virtual* particles *mediating* forces.

freedom in the mathematical description should map to a physical *reality*.

It is, therefore, surprising that the mainstream interpretation of quantum mechanics does not integrate the concept of particle spin from the outset because the + or – sign in front of the imaginary unit (*i*) in the elementary wavefunction ($a \cdot e^{-i \cdot \theta}$ or $a \cdot e^{+i \cdot \theta}$) is thought as *a mathematical convention* only. This non-used *degree of freedom* in the mathematical description then leads to the *false* argument that the wavefunction of spin-½ particles has a 720-degree symmetry. Indeed, physicists treat –1 as a *common phase factor* in the argument of the wavefunction.[13] However, we should think of –1 as a complex number itself: the phase factor may be +π or, alternatively, –π: when going from +1 to –1 (or vice versa), it matters how you get there—as illustrated below.[14]

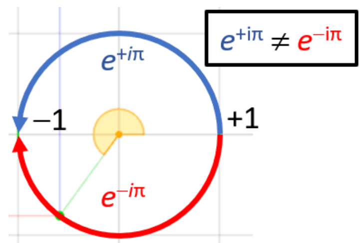

Figure 1: $e^{+i\pi} \neq e^{-i\pi}$

Combining the + and – sign for the imaginary unit with the direction of travel, we get four mutually exclusive structures for the electron wavefunction:

Spin and direction of travel	**Spin up (J = +ħ/2)**	**Spin down (J = –ħ/2)**
Positive *x*-direction	$\psi = \exp[i(kx-\omega t)]$	$\psi^* = \exp[-i(kx-\omega t)] = \exp[i(\omega t-kx)]$
Negative *x*-direction	$\chi = \exp[-i(kx+\omega t)] = \exp[i(\omega t-kx)]$	$\chi^* = \exp[i(kx+\omega t)]$

Table 1: Occam’s Razor: mathematical possibilities versus physical realities (1)

We may now combine this with the properties of anti-matter.

8. We think antimatter is different from matter because of its opposite spacetime signature. The logic here is the following. Consider a particular direction of the elementary current generating the magnetic moment (we effectively define spin as an (elementary) *current*[15]). It is then quite easy to see that the

[13] Mainstream physicists therefore think one can just multiply a set of amplitudes – let us say *two* amplitudes, to focus our mind (think of a beam splitter or alternative paths here) – with –1 and get the same *physical states*.

[14] The quantum-mechanical argument is technical, and I did *not* reproduce it in this book. I encourage the reader to glance through it, though. See: *Euler’s Wavefunction: The Double Life of – 1*. Note that the $e^{+i\pi} \neq e^{-i\pi}$ expression may look like *horror* to a mathematician! However, if he or she has a bit of a sense for geometry and the difference between identity and equivalence relations, there should be no surprise. If you are an amateur physicist, you should be excited: it is, effectively, the secret key to unlocking the so-called mystery of quantum mechanics. Remember Aquinas’ warning: *quia parvus error in principio magnus est in fine*. A small error in the beginning can lead to great errors in the conclusions, and we think of this as a rather serious error in the beginning!

[15] We are aware this may sound shocking to those who have been brainwashed in the old culture. If so, make the switch. It should not be difficult: a magnetic moment – *any* magnetic moment, really – is generated by a current. The magnetic moment of elementary particles is no exception.

magnetic moment of an electron ($\mu = -q_e\hbar/2m$) and that of a positron ($\mu = +q_e\hbar/2m$) would be opposite. We may, therefore, associate a particular direction of rotation with an angular frequency *vector* **ω** which – depending on the direction of the current – will be up or down with regard to the plane of rotation.[16] We can, therefore, associate this with the spin property, which is also up or down. We, therefore, have another table with four mutually exclusive possibilities, which we should combine with the possible directions of travel in Table 1[17]:

Matter-antimatter	**Spin up**	**Spin down**
Electron	$\mu_{-e} = -q_e\hbar/2m$	$\mu_{-e} = +q_e\hbar/2m$
Positron	$\mu_{+e} = +q_e\hbar/2m$	$\mu_{+e} = -q_e\hbar/2m$

Table 2: Occam's Razor: mathematical possibilities versus physical realities (2)

Table 2 shows that (1) the ring current model also applies to antimatter but that (2) antimatter has a different *spacetime* signature. Abusing Minkowski's notation, we may say the spacetime signature of an electron would be + + + + while that of a positron would be + – – –.[18] Table 1 and Table 2, therefore, *complement* each other.

9. Spacetime trajectories – or, to put it more simply, *motions* – need to be described by well-defined functions: for every value of *t*, we should have one, and only one, value of *x*. The reverse, of course, is *not* true: a particle can travel back to where it was (or, if there is no motion, just stay where it is). Hence, it is easy to see that the concepts of motion and time are related because our mind (mathematical logic) imposes the use of the well-behaved functions to describe reality.[19]

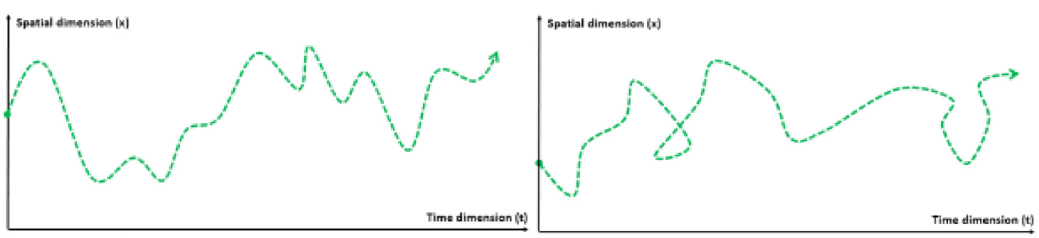

Figure 2: A well- and a not-well behaved trajectory in spacetime[20]

[16] To determine what is up or down, one has to apply the ubiquitous right-hand rule.

[17] The use of the subscripts in the magnetic moment may be confusing, but should not be: we use –e for an electron and +e for a positron. We do so to preserve the logic of denoting the (positive) elementary charge as q_e (without a + or a – in the subscript here).

[18] In case the reader wonders why we associate the + +++ signature with the *positron* rather than with the electron, the answer is: convention. Indeed, if I am not mistaken (which may or may not be the case), it is the + +++ *metric signature* which is the one which defines the usual righthand rule when dealing with the *direction* of electric currents and magnetic forces.

[19] We wish the reader who would want to try using not-so-well-behaved functions to arrive at some kind of description of reality the best of luck.

[20] We actually do not like the concept of spacetime very much: time and space are *related* (through special and general relativity theory, to be precise) but they are *not* the same. Nor are they *similar*. We do, therefore, *not* think

Time, therefore, goes in one direction only.[21] This, then, makes it possible to physically interpret the meaning of conjugates and the breaking of (combined) CP-symmetry: CPT-symmetry models the theoretical reversibility of physical processes and/or phenomena. However, such reversibility is, effectively, *theoretical* only. We can play a movie backwards, but we cannot reverse time. We know that because a movie in which two like charges (say, two electrons) would attract rather than repel each other does not make sense.[22]

10. There is no weak force: a force theory explaining why charges stay together must also explain when and how they separate. A force works through a force field: the idea that forces are *mediated* by virtual messenger particles resembles 19th century aether theory. The fermion-boson dichotomy does not reflect anything real: we have charged and non-charged wavicles (electrons and protons, for example, versus photons). An electron is a wavicle that carries charge. A photon does *not* carry charge: it carries energy between wavicle *systems* (atoms, basically). It can do so because it is an oscillating *field*.[23]

The Planck-Einstein law embodies a (stable) wavicle. A stable wavicle respects the Planck-Einstein relation ($E = h \cdot f$) *and* Einstein's mass-energy equivalence relation ($E = m \cdot c^2$). A wavicle will, therefore, carry energy but it will also pack one or more units of Planck's quantum of action. Planck's quantum of action represents an elementary *cycle* in Nature. An elementary particle embodies the idea of an elementary cycle. The 'particle zoo' is, therefore, a collection of unstable wavicles: they disintegrate because their cycle is slightly off (the integral of the force over the distance of the loop and over the cycle time is not *exactly* equal to (a multiple of) h).

11. The geometry of a matter-particle can be related to the geometry of the photon using the following illustration, which shows how the Compton wavelength (the circumference of the *Zitterbewegung* of the pointlike charge) becomes a linear wavelength as the classical velocity goes from 0 to c: the *radius* of the circulatory motion must effectively diminish as the electron gains speed. [24]

that some 'kind of union of the two' will replace the separate concepts of space and time any time soon, despite Minkowski's stated expectations in this regard back in 1908. Grand statements and generalizations are not often useful in physics.

[21] This intuition contrasts with the erroneous suggestion of Richard Feynman that we may want to think, perhaps, of matter-particles as particles that travel back in time. This suggestion results from *not* associating any particular physical meaning with the + or – sign of the imaginary unit in the wavefunction.

[22] This is a rather technical matter which we do not want to spell out here because a detailed exploration would take up several pages. We must refer the interested reader to our other paper(s) here.

[23] We refer the reader to our photon model for more detail.

[24] We thank Prof. Dr. Giorgio Vassallo and his publisher to let us re-use this diagram. It originally appeared in an article by Francesco Celani, Giorgio Vassallo and Antonino Di Tommaso (*Maxwell's equations and Occam's Razor*, November 2017). Once again, however, we should warn the reader that he or she should imagine the plane of oscillation to rotate or oscillate itself. He should not think of it of being *static* – unless we think of the electron moving in a magnetic field, in which case we should probably think of the plane of oscillation as being *parallel* to the direction of propagation. To be precise, he should think of it as *precessing* in the external field.

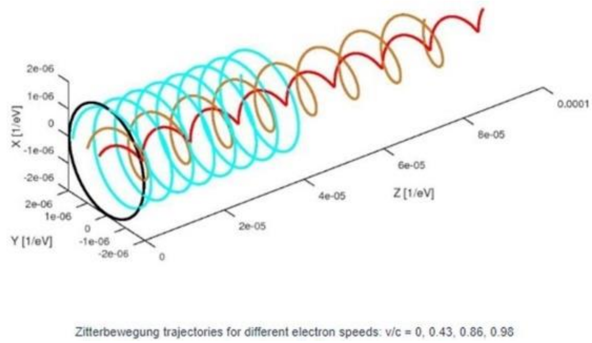

Figure 3: The Compton radius must decrease with increasing velocity

12. We concur with Rutherford's idea of the neutron combining a proton and an electron.[25] As such, one should think of the neutron as carrying not one but *two* charges, which combine to make up an electrically neutral *composite* particle.

The idea of the neutron combining a proton and an electron is consistent with the instability of neutrons outside of the nucleus, their size[26], their energy (or rest mass)[27], the magnetic moment of a neutron, the existence of an anti-neutron, the presence of neutrinos in proton/neutron *Verwandlung*[28] and other common-sensical considerations. We, therefore, think this idea is too evident to be dismissed. We, therefore, have no need for the quark hypothesis to explain the neutron even if we have not worked out the exact *equations of motion* for the proton and electron that make up the neutron.[29]

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[25] See Rutherford's remarks in this regard in his paper on '*The Structure of the Electron*' at the 1921 Solvay Conference.

[26] The Compton wavelength for a neutron is more or less the same as that of a proton:

$$\lambda_{neutron} = 1.31959090581(75)\times10^{-15} \text{ m}$$

$$\lambda_{proton} = 1.32140985539(40)\times10^{-15} \text{ m}$$

The reduced value of these wavelengths is the Compton radius.

[27] The neutron's energy is about 939,565,420 eV. The proton energy is about 938,272,088 eV. Hence, the difference is about 1,293,332 eV. This mass difference, combined with the fact that neutrons spontaneously decay into protons but – conversely – there is no such thing as spontaneous proton decay, is probably the most compelling argument when making the case that a neutron must, somehow, combine a proton and an electron. It is true that the mass of an electron is 0.511 MeV/c^2, which represents only 40% of the energy difference but the kinetic and *binding* energy could make up for the remainder. The reader should note that the mass of a proton and an electron add up to *less* than the mass of a neutron, which is why it is only logical that a neutron should decay into a proton and an electron. Indeed, binding energies – think of Feynman's calculations of the radius of the hydrogen atom, for example (see: https://www.feynmanlectures.caltech.edu/III_02.html#Ch2-S4) – are usually *negative*.

[28] We provide an overview of the equations involving a proton turning into a neutron and, vice versa, neutron decay in our paper on the nature of protons and neutrons.

[29] This is a reference to Dirac's terminology.

We feel the twelve principles above are plain logical. We also think they offer a more common-sense explanation of the structure of an atom[30], the scattering of photons by electrons (and of Compton scattering in general[31]), diffraction or interference, the Lamb shift, the anomalous magnetic moment, one-photon Mach-Zehnder interference or whatever other phenomenon that is said to 'prove' quantum mechanics.

The ring current model also comes with a rather dynamic view of the fields surrounding charged particles. Potential barriers -or their corollary: potential *wells* – should, therefore, not be thought of as static fields: they vary in time. They result from two or more charges moving around and creating some *joint* or superposed field. Hence, a particle breaking through a 'potential wall' or coming out of a potential 'well' probably just uses an opening which corresponds to a classical trajectory.

This should offer a new perspective on the so-called 'new physics' and/or the 'scientific 'revolution' which was started by the younger Heisenberg and his admirers. From an epistemological point of view, this revolution amounts to 'elevating indeterminism to a philosophical and scientific principle', as H.A. Lorentz notes in an untypically brutal remark after Bohr, Born and Heisenberg, Schrödinger and de Broglie had presented their papers on 'the new quantum mechanics' at the occasion of the 1927 Solvay Conference. We are almost 100 years later now and, as far as I can see, this revolution has not added a single *iota* to our understanding of the above-mentioned physical phenomena or processes. Indeed, all these phenomena have alternative common-sense explanations using the Planck-Einstein relation and simple (circular) wave geometry.

Let us now think about what might or might not be happening at an even smaller scale, which is generally referred to as high-energy physics or the QCD sector in the Standard Model. We do not refer to our ideas in this regard as 'principles' because they are speculative. Nevertheless, we think these reflections are rather sound and – in any case – *less* outlandish than mainstream hypotheses.

Thoughts on quantum chromodynamics

1. The electron has *two* heavier versions. Both of them are unstable. The muon energy is about 105.66 MeV, so that is about 207 times the electron energy. Its lifetime is much shorter than that of a free neutron but longer than that of other unstable particles: about 2.2 *micro*seconds (10^{-6} s). That is fairly long as compared to other non-stable particles.[32]

The energy of the tau electron (or tau-*particle* as it is more commonly referred to[33]) is about 1776 MeV, so that is almost 3,500 times the electron mass. However, its lifetime is *extremely* short: 2.9×10^{-13} s

[30] An atom is a system of wavicles. A wavicle system has an *equilibrium* energy state. This equilibrium state packs one unit of *h*. Higher energy states pack two, three,…, *n* units of h. When an atom transitions from one energy state to another, it will emit or absorb a photon that (i) carries the energy difference between the two energy states and (ii) packs one unit of *h*.

[31] Photons may also scatter of protons or of other charged or neutral matter-particles.

[32] This presumed longevity of the muon-electron should not be exaggerated, however: the mean lifetime of charged pions, for example, is about 26 *nano*seconds (10^{-9} s), so that is only 85 times less.

[33] In light of its short lifetime, we prefer to refer to the tau-electron as a resonance. Indeed, we like to reserve the term 'particle' for *stable* particles. Within the 'zoo' of unstable particles, we may refer to longer-living particles as *transients* so as to distinguish them from these *very*-short life *resonances*.

only. Hence, we think of it as some resonance or very *transient* particle. We, therefore, think that – in line with the reasoning we presented in the introduction to our paper – the Planck-Einstein relation does *not* apply: we think the tau-electron quickly disintegrates because its cycle is *way* off. We will, therefore, only deal with the muon here.

2. The calculation of the Compton radius of a muon-electron – i.e. its non-reduced wavelength, which we interpret as the circumference of the *Zitterbewegung* motion of the charge – is equal to:

$$\lambda_C = \frac{2\pi}{2\pi}\cdot\frac{\left(299{,}792{,}458\,\frac{\mathrm{m}}{\mathrm{s}}\right)\cdot(6.62607015\times10^{-34}\mathrm{eV}\cdot\mathrm{s})}{1.6928338\times10^{-11}\,\mathrm{J}} \approx 1.1734441131\ldots\times10^{-14}\ \mathrm{m}$$

This falls within the uncertainty interval of the CODATA value, which is equal to:

$$1.173444110\times10^{-14}\ \mathrm{m}\ \pm 0.000000026\times10^{-14}\ \mathrm{m}$$

The CODATA value is also precise enough to calculate the anomaly, which makes sense as well. We, therefore, think the ring current model works for a muon-electron as well.[34]

3. When applying the $a = \hbar/mc$ radius formula to a proton, we get a value which is about 1/4 of the *measured* proton radius: about 0.21 fm, as opposed to the 0.83-0.84 fm charge radius which was established by Prof. Dr. Pohl and colleagues in 2010, and which was re-confirmed by the PRad research group at JLAB last year.[35] We may, therefore, assume a different *form factor* for the angular momentum and derive the Compton radius for the proton as follows:

$$\left.\begin{matrix}\left.\begin{matrix}\mathrm{E} = \mathrm{m}c^2\\ \mathrm{E} = 4\hbar\omega\end{matrix}\right\} \Rightarrow \mathrm{m}c^2 = 4\hbar\omega\\ c = a\omega \Leftrightarrow a = \dfrac{c}{\omega} \Leftrightarrow \omega = \dfrac{c}{a}\end{matrix}\right\} \Rightarrow \mathrm{m}a^2\omega^2 = 4\hbar\omega \Longrightarrow \mathrm{m}\frac{c^2}{\omega^2}\omega^2 = \frac{4\hbar c}{a} \Leftrightarrow a = \frac{4\hbar}{\mathrm{m}c}$$

The assumption in regard to the form factor is, admittedly, rather *ad hoc* but the rather precise match of the calculation cannot be a coincidence.[36]

4. The ring current model may also be analysed as an oscillator in two dimensions. Indeed, we may think of the sine and cosine *components* of the wavefunction as the (perpendicular) components of the centripetal force. However, instead of a one *linear* oscillation, we get two for the price of one, so to speak. The energies of these two oscillations can be added and offers a geometric explanation of Einstein's $E = mc^2$ relation.[37]

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[34] We will leave it to the reader to repeat the exercise for the tau-electron: he will find the theoretical $a = \hbar/mc$ radius does *not* match the CODATA value for its radius. We think this *indirectly* confirms our interpretation of the Planck-Einstein relation and our reference to the tau-electron as a *resonance* instead of a *transient* or a (stable) particle. CODATA/NIST values for the properties of the tau-electron can be found on the NIST website.

[35] For the exact references and contextual information on the (now solved) 'proton radius puzzle', see our paper on it: https://vixra.org/abs/2002.0160.

[36] In any case, Prof. Dr. Gasparan noted mainstream QCD actually has *no* theory whatsoever in regard to the (theoretical) radius of a proton. Hence, we would think any attempt to model it should be welcomed.

[37] For more detail, we may refer the reader to our paper(s) on the electron as an electromagnetic oscillator. It may be noted that our initial *metaphor* was based on a rather classical linear oscillator model: the sum of the potential

One can analyse these oscillators as *relativistic* oscillators, and the calculations will then involve the concept of the *relativistic* or *effective* mass of the pointlike charge: it is the mass it acquires because it travels at lightspeed (which it can do, of course, because its *rest* mass is equal to zero). When denoting the effective mass as $m_\gamma = m/2$[38], we can calculate the centripetal force as a function of the mass only[39]:

$$\mathrm{F} = \mathrm{m}_\gamma a_\mathrm{c} = \frac{\mathrm{m}}{2} \cdot \frac{\mathrm{m}c^3}{\hbar} = \frac{\mathrm{m}^2 c^3}{2\hbar}$$

We can now calculate the *relative* strength of the force inside of a muon (μ) and an electron (e) as their ratio (F_μ/F_e):

$$\frac{\mathrm{F}_\mu}{\mathrm{F}_\mathrm{e}} = \frac{\frac{\mathrm{m}_\mu^2 c^3}{2\hbar}}{\frac{\mathrm{m}_\mathrm{e}^2 c^3}{2\hbar}} = \frac{\mathrm{m}_\mu^2}{\mathrm{m}_\mathrm{e}^2} \approx 42{,}753$$

This is a rather huge value which may or may not justify us thinking the force inside of a muon must be some strong(er) *mode* of the electromagnetic oscillation. To put it simply, we may want to think of it as the strong force.

5. Because muon decay involves the emission of neutrinos, we think of neutrinos as carriers of the strong force. Indeed, a muon decays into an electron while emitting not one but *two* neutrinos—one with relatively low energy, which is referred to as an electron neutrino, and another with very high energy, which is referred to as a muon neutrino. Hence, the decay goes like this:

$$\mu^- \rightarrow e^- + \nu_e + \nu_\mu$$

---

and kinetic energy in *one* linear oscillator effectively add up to $E = m \cdot a^2 \cdot \omega^2/2$ and it is, therefore, logical to think of *two* perpendicular oscillators to explain Einstein's mass-energy equivalence relation geometrically. However, we do use relativistically correct equations (the *relativistic* oscillator) in our later calculations.

[38] The subscript (gamma) may remind the reader of the symbol that is often used for a photon but we should remind the reader the only commonality here is lightspeed: a photon does *not* carry any charge. In contrast, our pointlike *Zitterbewegung* charge *is* a charge. As for the rather obvious question as to where we can find the other half of the electron mass, the answer here must be that of David Hestenes: half of the energy of the electron is kinetic, and the other half is in the electromagnetic field that is generated by this charge in motion and which may or may not keep it in place (the answer as to the question of what keeps the charge in place has not conclusively answered). The argument of Hestenes is based on the energy equipartition theorem. We derive the ½ factor from more formal geometric calculations.

[39] The a_c in this formula is *not* the Compton radius but the centripetal acceleration:

$$a_\mathrm{c} = \frac{v_\mathrm{t}^2}{r} = \frac{c^2}{\hbar/\mathrm{m}c} = \frac{\mathrm{m}c^3}{\hbar}$$

The reader can double-check the force calculation by using the tangential velocity formula for the Compton radius *a* or *r*:

$$\mathrm{F} = \mathrm{m}_\gamma r \omega^2 = \frac{\mathrm{m}}{2} \cdot \frac{\hbar}{\mathrm{m}c} \cdot \frac{\mathrm{E}^2}{\hbar^2} = \frac{\mathrm{m}}{2} \cdot \frac{\hbar}{\mathrm{m}c} \cdot \frac{\mathrm{m}^2 c^4}{\hbar^2} = \frac{\mathrm{m}^2 c^3}{2\hbar}$$

When actually *calculating* the force, one gets a value of about 0.106 N for an electron. This force is equivalent to a force that gives a mass of about 106 gram an acceleration of 1 m/s per second. This is a rather enormous value considering the sub-atomic scale. For a muon, one gets a force that is equal to 4,532 N.

The muon's anti-matter counterpart decays into the positron, of course:

$$\mu^+ \rightarrow e^+ + \nu_e + \nu_\mu$$

This raises two questions. The first is: why *two* neutrinos? We assume there must be two neutrinos because energy *as well as angular momentum* must be conserved, and a single neutrino would not be able to do that trick.

The second question is: should or should we not distinguish between neutrinos and anti-neutrinos?[40] We do not think so. Neutrinos may have opposite spin, but the idea of anti-matter involves a charge, and neutrinos – just like photons – do *not* carry charge.[41]

6. The two-dimensional oscillator model proton implies the following value for the centripetal force inside of a proton:[42]

$$\mathrm{F_p} = \frac{1}{2}\mathrm{m_p}a\omega^2 = \frac{1}{2}\mathrm{m_p}a\frac{c^2}{a^2} = \frac{1}{2}\frac{\mathrm{m_p}c^2}{a} = \frac{1}{2}\frac{\mathrm{m_p}^2\mathrm{c}^3}{4\hbar} = \frac{1}{8}\frac{\mathrm{m_p}^2\mathrm{c}^3}{\hbar} \approx 89{,}349\ \mathrm{N}$$

We can now take ratio of the forces in a proton, an electron, and a muon respectively:

$$\frac{\mathrm{F_p}}{\mathrm{F_e}} = \frac{\mathrm{k_p}}{\mathrm{k_e}} = \frac{\frac{1}{8}\cdot\frac{\mathrm{m_p}^2c^3}{\hbar}}{\frac{1}{2}\cdot\frac{\mathrm{m_e}^2c^3}{\hbar}} = \frac{1}{4}\cdot\frac{\mathrm{m_p}^2}{\mathrm{m_e}^2} \approx 842{,}864 \approx \frac{1}{4}\cdot 1.836^2$$

$$\frac{\mathrm{F_p}}{\mathrm{F_\mu}} = \frac{\mathrm{k_p}}{\mathrm{k_\mu}} = \frac{\frac{1}{8}\cdot\frac{\mathrm{m_p}^2c^3}{\hbar}}{\frac{1}{2}\cdot\frac{\mathrm{m_\mu}^2c^3}{\hbar}} = \frac{1}{4}\cdot\frac{\mathrm{m_p}^2}{\mathrm{m_\mu}^2} \approx 19.71 \approx \frac{1}{4}\cdot 8.88^2$$

$$\frac{\mathrm{F_\mu}}{\mathrm{F_e}} = \frac{\mathrm{k_\mu}}{\mathrm{k_e}} = \frac{\frac{1}{2}\cdot\frac{\mathrm{m_\mu}^2c^3}{\hbar}}{\frac{1}{2}\cdot\frac{\mathrm{m_e}^2c^3}{\hbar}} = \frac{\mathrm{m_\mu}^2}{\mathrm{m_e}^2} \approx 42{,}753 \approx 206.77^2$$

The numbers on the right-hand side are squared mass ratios. There are no surprises there: the proton is about 8.88 times more massive than the muon, which, in turn, is almost 207 times more massive than an electron. The proton is, therefore, 1,836 times more massive than an electron. For the rest, it is difficult to make sense of these ratios. We should probably understand these oscillations, frequencies, and forces as higher modes of some *fundamental* frequency. However, such rather vague statements should be detailed, of course—and we are not (yet) in a position to do so.

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[40] The reader will note that, in contrast to mainstream theorists, we did *not* denote one of the two neutrinos as an anti-neutrino.

[41] We mention this because we think of the question of the (non-existence of the) anti-neutrino as one of those mysteries which mainstream physicists religiously (but wrongly) worship. The reader may also note we have thought of some *strong* charge which the strong force may or may not act upon. See our paper on our neutrino hypothesis and the nature of the strong force.

[42] We apply a factor of 1/4 (rather than 1/2) to calculate the effective mass of the proton here. It has to do with the specific assumptions.

The other notable *particularity* about the proton-muon and the proton-electron ratio is the ¼ factor which, as mentioned above, we may relate to a different *form factor* in the formula for the angular momentum. Because we know the academic reader will cry wolf here and insist that protons, muons and electrons must all be spin-1/2 particles, we will show he or she is actually right here but – possibly – not in the sense he or she might expect. We must talk about g-ratios at this point, which we will do now.

7. If we accept the modified Planck-Einstein relation for a proton (E = 4ħω), we can re-write this equation in terms of energy (E) and cycle time (T):

$$\mathrm{E} = 4\hbar\omega = 4hf \Leftrightarrow \frac{\mathrm{E}}{f} = \mathrm{E} \cdot \mathrm{T} = 4h$$

This way of writing shows that physical action may come as a multiple of *h*.[43] To be precise, in the case of a proton, it comes in units of *four times h*! Dividing by 2π, that means its angular momentum must also be equal to *four units of ħ*! It means we may think of our proton as a spin-1/2 particle after all! Why? Because its g-ratio is, effectively, equal to ½[44]:

$$\frac{\mu_\mathrm{p}}{\mathrm{L_p}} = \frac{\frac{2\mathrm{q_e}}{\mathrm{m_p}}\hbar}{4\hbar} = \mathrm{g_p} \cdot \frac{\mathrm{q_e}}{\mathrm{m_p}} \Leftrightarrow \mathrm{g_p} = \frac{1}{2}$$

This, then explains, the meaning of this mysterious spin-1/2 property: the ratio of (1) the product of the mass and the magnetic moment and (2) the product of the charge and the angular momentum is equal to 1/2. Indeed, you can easily verify this in general now, or more in particular for an electron, for a muon, and for a proton:

$$\frac{\mu}{\mathrm{L}} = \mathrm{g} \cdot \frac{\mathrm{q}}{\mathrm{m}} = \frac{1}{2} \cdot \frac{\mathrm{q}}{\mathrm{m}} \Leftrightarrow \frac{\mathrm{m} \cdot \mu}{\mathrm{q} \cdot \mathrm{L}} = \frac{1}{2}$$

$$electron: \frac{\mathrm{m_e} \cdot \mu_\mathrm{e}}{\mathrm{q_e} \cdot \mathrm{L_e}} = \frac{\mathrm{m_e} \cdot \frac{\mathrm{q_e}\hbar}{2\mathrm{m_e}}}{\mathrm{q_e} \cdot \hbar} = \frac{1}{2}$$

$$muon: \frac{\mathrm{m_\mu} \cdot \mu_\mu}{\mathrm{q_e} \cdot \mathrm{L_\mu}} = \frac{\mathrm{m_\mu} \cdot \frac{\mathrm{q_e}\hbar}{2\mathrm{m_\mu}}}{\mathrm{q_e} \cdot \hbar} = \frac{1}{2}$$

[43] This should not surprise us as we have encountered the E = *n·h* relation in the context of the Bohr model of an atom or, more generally, in the context of a *system* of elementary particles, which is what an atom actually is.

[44] For the calculation of the magnetic moment of the proton, we must refer the reader to our paper on the mass, radius and magnetic moment of protons and electrons, in which we corrected the CODATA value for precession in a magnetic field by inserting a $\sqrt{2}$ factor. We contacted Prof. Dr. Pohl in this regard (besides being expert in so many fields, he is also a member of the CODATA Task Group for Fundamental Constants) but we did not get any reply. We think our argument is rather solid but it triggers an obvious question: why is there no such factor for the CODATA value of the magnetic moment of an electron? Prof. Dr. Randolf Pohl should surely know more in this regard.

$$proton: \frac{m_p \cdot \mu_p}{q_e \cdot L_p} = \frac{m_p \cdot \frac{2q_e\hbar}{m_p}}{q_e \cdot 4\hbar} = \frac{1}{2}$$

We may, therefore, say that the only *meaningful* g-factor that can be defined is, effectively, Bohr's (1/2)·q/m *magneton*.[45]

Conclusions

We think we were able to explain – to a large extent, at least – all of the intrinsic properties of a proton without any need for the quark hypothesis.[46] We effectively do not think very highly of the *invention* of the concept of strangeness by Murray Gell-Man and Kazuhiko Nishijima in the 1950s.[47] We actually think Feynman's treatment of it in his 1963 *Lectures* on physics shows that the concept of strangeness – and the related conservation law – is a rather desperate assumption to explain the decay of K-mesons (kaons) which – in our not-so-humble opinion – should probably not be explained in terms of a weak force but in terms of non-equilibrium states.

We have, however, not advanced much in our thinking here and we will, therefore, conclude our paper with a quote that was written quite a while ago but still rings very true today:

> "Quantum mechanics may be defined as the application of equations of motion to particles. […] The domain of applicability of the theory is mainly the treatment of electrons and other charged particles interacting with the electromagnetic field—a domain which includes most of low-energy physics and chemistry.
>
> Now there are other kinds of interactions, which are revealed in high-energy physics and are important for the description of atomic nuclei. These interactions are not at present sufficiently well understood to be incorporated into a system of equations of motion. Theories of them have been set up and much developed and useful results obtained from them. But in the absence of equations of motion these theories cannot be presented as a logical development of the principles set up in this book. We are effectively in the *pre-Bohr era* with regard to these other interactions.
>
> *It is to be hoped that with increasing knowledge a way will eventually be found for adapting the high-energy theories into a scheme based on equations of motion, and so unifying them with those of low-energy physics*." (Paul A.M. Dirac, *The Principles of Quantum Mechanics*, 4th edition (1958), p. 312)

[45] The reader will want to verify any other definition he or she may come across that physicists have used to explain the not-so-mysterious spin-1/2 property of matter-particles.

[46] Our paper on the proton radius also explains its magnetic moment, including first-order calculations (or *estimates*, at least) of its anomaly based on the PRad measurement.

[47] Unfortunately, the concept of strangeness started a strange life of its own and would effectively later serve as the basis for the quark hypothesis which – for a reason we find even stranger than the concept of strangeness itself – was officially elevated to the status of *a scientific dogma* by the Nobel Prize Committee for Physics.

Annex I: The non-anomalous magnetic moment of an electron

Before discussing the magnetic moment itself, we would like to draw the attention of the reader to the *physicality* of the model by calculating the actual current inside of an electron:

$$\mathrm{I} = \mathrm{q_e}f = \mathrm{q_e}\frac{\mathrm{E}}{h} \approx (1.6 \times 10^{-19}\ \mathrm{C})\frac{8.187 \times 10^{-14}\ \mathrm{J}}{6.626 \times 10^{-34}\ \mathrm{Js}} \approx 19.8\ \mathrm{A}$$

This is a household-level current at the sub-atomic scale. One also gets very large values when calculating the field strength and the centripetal force that must hold the electron together (0.106 N)[48]. We think these values make sense because the associated energy and mass *densities* are still very much *below* the threshold that would trigger well-founded worries about the effects of such mass/energy densities on the curvature of spacetime.

However, we do admit that, because of gravity (read: general relativity theory), Maxwell's equations may not hold *exactly* when going down to the tiniest scales. Electron models which incorporate gravity are, therefore, very interesting and our simple calculations may, therefore, not be fully exact.[49] Such models should also answer Dr. Burinskii's quintessential remark and question on the simple ring current: "*What keeps the charge in its circular orbit*?"[50] We cannot delve into this question here and so we will return to the simple ring current model again.

Despite the simplicity of the model we are able to explain the anomaly in the magnetic moment of an electron in very simple classical terms. We must be able to do, of course, because the experimental measurements and the theoretical calculations of the anomalous magnetic moment are usually hailed as the 'high-precision test' of *mainstream* quantum mechanics. The Wikipedia article on this describes this as follows:

> "The most precise and specific tests of QED consist of measurements of the electromagnetic fine-structure constant, α, in various physical systems. Checking the consistency of such measurements tests the theory. Tests of a theory are normally carried out by comparing experimental results to theoretical predictions. In QED, there is some subtlety in this comparison, because theoretical predictions require as input an extremely precise value of α, which can only be obtained from another precision QED experiment. Because of this, the comparisons between theory and experiment are usually quoted as independent determinations of α. QED is then confirmed to the extent that these measurements of α from different physical sources agree with each other. The agreement found this way is to within ten parts in a billion (10^{-8}), based on the comparison of the electron anomalous magnetic dipole moment and the Rydberg constant from atom recoil measurements as described below. This makes QED one of the most accurate physical theories constructed thus far."[51]

[48] For more detail, see our paper on classical quantum physics.

[49] We must refer the interested reader here to, for example, Prof. Dr. Alexander Burinskii's explorations of Dirac-Kerr-Newman electron models.

[50] Email exchange between the author and Dr. Burinskii dated 22 December 2018.

[51] See: https://en.wikipedia.org/wiki/Precision_tests_of_QED, accessed on 10 March 2020.

Oliver Consa's seminal February 2020 article on the actual history of this theory and the measurements suggests a huge scientific scam fuelled by the need to keep the funds flowing for upgrades of technological infrastructure such as high-value particle accelerators and other prestigious projects costing hundreds of millions of dollars.[52] We think it is a good point to make: applying for grants by saying physics is basically dead because all problems have been solved is not a great business strategy. Besides custom, fame, fashion or perceived wisdom, academics may also have other motives for keeping the mystery alive, such as religious ones, perhaps.[53]

Whatever the reasons for mainstream physicists *not* looking into classical solutions for tricky problems may be, we must make abstraction of them and show how the ring current model explains the anomalous magnetic moment. The logic goes like this:

1. From Maxwell's Laws, one can easily derive the formula the magnetic moment: it is equal to the current times the area of the loop.[54] The theoretical value for the magnetic moment generated by a pointlike charge *zittering* around at lightspeed is, therefore equal to:

$$\mu_a = \mathrm{I}\pi a^2 = \mathrm{q_e} f \pi a^2 = \mathrm{q_e}\frac{c}{2\pi a}\pi a^2 = \frac{\mathrm{q_e} c}{2} a = \frac{\mathrm{q_e}}{2\mathrm{m}}\hbar \approx 9.27401 \ldots \times 10^{-24}\ \mathrm{J \cdot T^{-1}}$$

The CODATA value – which is supposed to be based on measurements[55] – is slightly different:

$$\mu_{\mathrm{CODATA}} = 9.2847647043(28)\times 10^{-24}\ \mathrm{J{\cdot}T^{-1}}$$

The difference is the so-called anomaly, which we can easily calculate as follows[56]:

$$\frac{\mu_{\mathrm{CODATA}} - \mu_a}{\mu_a} = 0.00115965 \ldots$$

The reader will recognize this value: it is equal to about 99.85% of Schwinger's factor: $\alpha/2\pi$ = 0.00116141…

2. We do not think of the anomaly as an anomaly. We see an immediate perfectly rational explanation for it: we think the *zbw* charge has some very tiny (but non-zero) spatial dimension. As a result, we

[52] Oliver Consa, *Something is Rotten in the State of QED*, February 2020 (https://vixra.org/abs/2002.0011).

[53] If God exists, we do not think He or She will choose to hide in modern-day versions of medieval metaphysical principles such as the *aether* or some metaphysical uncertainty principle. Such hypotheses all amount to thinking of God as being the ultimate 'hidden variable' which, to us, comes across as being quite irrational.

[54] For a straightforward derivation of this formula, we refer – once again – to the *Great Teacher*: Richard Feynman (https://www.feynmanlectures.caltech.edu/II_14.html#Ch14-S5). In case the reader wonders: our reference to Richard Feynman as a great teacher is somewhat ambiguous: we feel he is part of the group of post-WW II physicists which I now think of *mystery Wallahs*.

[55] One reason why we think Oliver Consa's criticism of both the (mainstream) theory as well as the measurements of the anomalous magnetic moments is justified is that the US National Institute of Standards and Technology (NIST) – which is the institution which publishes these CODATA values – is not very clear about how they *weigh* the various experimental results to arrive at some *weighted* average that, by some magic, then sort of corresponds to the theoretical two-, three- or *n*-loop calculations based on quantum field theory.

[56] You should watch out with the minus signs here – and you may want to think why you put what in the denominator – but it all works out!

should distinguish between its *effective* and theoretical (tangential) velocity. The *effective* velocity – which we will denote as *v* – is *very near* but not exactly equal to *c*. Likewise, we should distinguish between an effective radius – which we will denote as *r* – versus its theoretical radius $a = ħ/mc$.

3. We hasten to add that this does *not* imply that we doubt the accuracy of the Planck-Einstein relation here. On the contrary, we think the Planck-Einstein relation is valid, *always*! All that we are saying here is that the idea of a pointlike charge *with absolutely no spatial dimension* whatsoever is probably what common-sense tells us it should be: a mathematical idealization. We, therefore, think we should not only distinguish between a theoretical and an actual (i.e. experimentally determined) magnetic moment but also between a theoretical and an actual radius of the ring current. To be precise, based on the *measured* value of the magnetic moment (i.e. the CODATA value), we can calculate the anomaly of the *radius* of the presumed ring current. Indeed, the frequency is, of course, the velocity of the charge divided by the circumference of the loop. Because we assume the velocity of our charge is equal to *c*, we get the following radius value:

$$\mu = \mathrm{I}\pi a^2 = \mathrm{q_e} f \pi a^2 = \mathrm{q_e}\frac{c}{2\pi a}\pi a^2 = \frac{\mathrm{q_e} c}{2}a \Leftrightarrow a = \frac{2\mu}{\mathrm{q_e} c} \approx 0.38666\ \mathrm{fm}$$

This too is a value that is slightly different from the theoretical $a = c/\omega = ħ/mc$ radius, which is equal to 0.38616… pm. We, therefore, have an anomaly, indeed! We can confirm this anomaly by re-doing this calculation using the Planck-Einstein relation to calculate the radius:

$$\mu = \mathrm{I}\pi a^2 = \mathrm{q_e} f \pi a^2 = \frac{\mathrm{q_e}\omega a^2}{2} \Leftrightarrow a = \sqrt{\frac{2\mu}{\mathrm{q_e}\omega}} = \sqrt{\frac{2\mu\hbar}{\mathrm{q_e E}}} = \sqrt{\frac{2\mu\hbar}{\mathrm{q_e m}c^2}} \approx 0.38638\ \mathrm{fm}$$

We again get a slightly different value. How can we explain this? By doing the calculations.

4. Let us first re-confirm the theoretical value for the magnetic moment by equating the two formulas for the radius that we have presented so far. Both are based on a different *physical* concept of the frequency of the oscillation. While *different*, we can only have one radius, of course. We, therefore, get this:

$$\left.\begin{aligned} a &= \sqrt{\frac{2\mu\hbar}{\mathrm{q_e m}c^2}} \\ a &= \frac{2\mu}{\mathrm{q_e}c} \end{aligned}\right\} \Leftrightarrow \sqrt{\frac{2\mu\hbar \mathrm{q_e^2} c^2}{4\mu^2\mathrm{q_e m}c^2}} = \sqrt{\frac{\hbar \mathrm{q_e}}{2\mu \mathrm{m}}} = 1 \Leftrightarrow \mu = \frac{\mathrm{q_e}}{2\mathrm{m}}\hbar$$

5. Now, we know that a magnetic moment is generated by a current in a loop and, from experiment, we *know* that the *actual* magnetic moment is slightly higher than the above-mentioned value. We can, therefore, calculate the *effective* radius – using one of the two formulas above – from the *actual* magnetic moment. Using the $f = c/2\pi a$ formula[57], we get the value we calculated above already:

[57] This formula is easier to use than a formula involving a square root, but the reader can verify the two calculations would amount to the same.

$$r = \frac{2\mu}{q_e c} \approx 0.3866 \ldots \text{fm}$$

We effectively get a *larger* value than the Compton radius (0.38616 fm—more or less). We can now calculate the anomaly based on these two radii:

$$\frac{r-a}{a} \approx 0.00115965 \Leftrightarrow \frac{r}{a} = 1.00115965 \ldots$$

We get the same thing here: the anomaly of the *radius* is, once again, equal to about 99.85% of Schwinger's factor: $\alpha/2\pi = 0.00116141\ldots$

6. As mentioned above, we think the anomaly is not an anomaly at all. We get it because of our mathematical idealizations: we do not *really* believe that pointlike charge are, effectively, pointlike and, therefore, dimensionless. In other words, we think the assumption that the electron is just a pointlike or dimensionless charge is non-sensical: when thinking of what might be going on at the smallest scale of Nature, we should abandon these mathematical idealizations: an object that has no physical dimension whatsoever does – quite simply – not exist.

We should, therefore, effectively distinguish the effective radius *r* and the effective velocity *v* from the theoretical values *a* and *c*. We can write this:

$$\frac{\mu_r}{\mu_a} = \frac{\frac{q_e v r}{2}}{\frac{q_e}{2m}\hbar} = \frac{v \cdot r}{c \cdot a} = \frac{\omega \cdot r^2}{\omega \cdot a^2} = \frac{r^2}{a^2} \approx 1 + \frac{\alpha}{2\pi} \Leftrightarrow r = \sqrt{1 + \frac{\alpha}{2\pi}} \cdot a \approx 1.00058 \cdot \frac{\hbar}{mc}$$

There is a crucial step here: we equated the anomaly to $1 + \alpha/2\pi$. Is that a good approximation? In a first-order approximation, it is. In fact, the reader will probably have heard that Schwinger's $\alpha/2\pi$ factor explains about 99.85% of the anomaly, but it is actually better than: the μ_r/μ_a ratio is about 99.99982445% of $1 + \alpha/2\pi$.[58]

7. We can now also calculate the effective velocity by using the fact that the *v/c* and *r/a* ratios must be the same, as we can see from the tangential velocity formula:

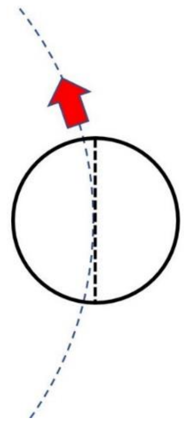
$$1 = \frac{\omega}{\omega} = \frac{v/r}{c/a} \Leftrightarrow \frac{v}{c} = \frac{r}{a}$$

We can, therefore, calculate the relative velocity as:

$$1 = \frac{\omega}{\omega} = \frac{v/r}{c/a} \Leftrightarrow v = \frac{r}{a} \cdot c = \frac{\sqrt{1 + \frac{\alpha}{2\pi}} \cdot a}{a} \cdot c = \sqrt{1 + \frac{\alpha}{2\pi}} \cdot c \approx 1.00058 \cdot c$$

Great ! We are done ! The only thing that is left to explain is… Well… How can the effective radius be *larger* than the theoretical one? And how can the effectively velocity be *larger* than *c*? This is easily explained by thinking of the *physicality* of the situation—as depicted below.

[58] Needless to say, for μ_r, we use the CODATA value.



If the *zbw* charge is effectively whizzing around at the speed of light, and we think of it as a charged sphere or shell, then its effective *center of charge* will *not* coincide with its center. Why not? Because the ratio between (1) the charge that is outside of the disk formed by the radius of its orbital motion and (2) the charge inside – note the triangular areas between the diameter line of the smaller circle (think of it as the *zbw* charge) and the larger circle (which represent its orbital) – is slightly *larger* than 1/2.

It all looks astonishingly simple, doesn't it? *Too* simple, perhaps? We do not think things can be *too* simple, but we will let you – the reader – judge, of course!

8. To conclude this digression, we should add one more formula. It is an interesting one because it brings an important *nuance* to the quantum-mechanical rule that angular momentum should come in units of $\hbar$. Indeed, our calculation shows the *actual* angular momentum of an electron must be slightly *larger* than $\hbar$[59]:

$$1+\frac{\alpha}{2\pi}=\frac{v\cdot r}{c\cdot a}\Leftrightarrow v\cdot r=\left(1+\frac{\alpha}{2\pi}\right)\cdot c\cdot a=\left(1+\frac{\alpha}{2\pi}\right)\cdot c\cdot\frac{\hbar}{\mathrm{m}c}=\left(1+\frac{\alpha}{2\pi}\right)\frac{\hbar}{\mathrm{m}}$$
$$\Leftrightarrow \mathrm{L}=\mathrm{m}\cdot v\cdot r=\left(1+\frac{\alpha}{2\pi}\right)\cdot\hbar=\hbar+\frac{\alpha}{2\pi}\hbar$$

Unsurprisingly, the difference is, once again, given by Schwinger's $\alpha/2\pi$ factor.

We invite the reader to perform the same calculations for the muon-electron using CODATA values for the actual muon radius[60] and magnetic moment: we are confident he (or she) will be able to get the same results.

The reader may also want to think through a possible explanation for the higher-order factors.[61]

[59] In case the reader how the use of a *full* unit of $\hbar$ here fits with our spin-1/2 property, the ½ factor is explained by the concept of the effective mass, which is half of the total mass of the electron. The other half is in the electromagnetic field that is generated by the charge in motion and which may or may not keep it in place.

[60] The reader should calculate the radius from the Compton wavelength.

[61] If he or she would need some inspiration in this regard, we offer some reflections on that in our paper(s) too.

Annex II: The size and shape of a photon

1. Photons carry energy, just like matter-particles, but, unlike matter-particles, they do not carry the (electric) charge. When an electron goes from one state to another – from one electron orbital to another, to be precise – it will absorb or emit a photon. Dirac's description of photons as the particles of light is very apt:

> "We have, on the one hand, the phenomena of interference and diffraction, which can be explained only on the basis of a wave theory; on the other, phenomena such as photo-electric emission and scattering by free electrons, which show that light is composed of small particles. These particles, which are called photons, have each a definite energy and momentum, depending on the frequency of the light, and appear to have just as real and existence as electrons, or any other particles known in physics. A fraction of a photon is never observed." (Paul A.M. Dirac, *Principles of Quantum Mechanics*, p. 2)

Any light – visible light, low-energy radio waves, or high-energy X- and γ-rays – consists of waves that, when we look really close, are effectively made up of photons whose *integrity as a particle* is captured by the same Planck-Einstein relation that models an electron or other *matter*-particles. We just need to specify what energy concept we are using, *exactly*. This is easy enough. However, before we do so, we should make a few notes on the concept of a field.

2. Saying photons carry electromagnetic *energy* is something else than saying they carry the electromagnetic *force* itself. A force always acts on a charge: a photon carries no charge. So, what *are* they then? How should we *think* of them? Think of it like this: a photon is an *oscillating* electromagnetic field. We describe this field by an electric and a magnetic field vector **E** and **B**.

Field vectors do not take up any space: think of them as a force without a charge to act on. Indeed, a non-zero field at some point in space and time – which we describe using the (x, y, x, t) coordinates – tell us what the force *would* be *if* we would happen to have a unit charge at the same point in space and in time. You know the formula for the *electromagnetic* force. It is the Lorentz force $\mathbf{F} = q\cdot(\mathbf{E} + \boldsymbol{v}\times\mathbf{B})$. Hence, the electromagnetic force is the sum of two (orthogonal) *component* vectors: $q\cdot\mathbf{E}$ and $q\cdot\boldsymbol{v}\times\mathbf{B}$.

The velocity vector $\boldsymbol{v}$ in the equation shows *both* of these two component force vectors depend on our frame of reference. Hence, we should think of the separation of the electromagnetic force into an 'electric' (or electrostatic) and a 'magnetic' force *component* as being somewhat artificial: the *electromagnetic* force is (very) *real* – because it determines the *motion* of the charge – but our cutting-up of it in two separate components depends on our frame of reference and is, therefore, (very) *relative*.[62]

3. We think the photon is pointlike because the **E** and **B** vectors that describe it will be zero at each and every point in time *and* in space *except if our photon happens to be at the* (x, y, z) *location at time t.*

[62] At this point, we should probably also quickly note that both amateur as well as professional physicists often tend to neglect the magnetic force in their analysis because the *magnitude* of the magnetic field – and, therefore, of the force – is $1/c$ times that of the *electric* field or force. Hence, they often think of the magnetic force as a tiny – and, therefore, negligible – *fraction* of the electric force. That is a *huge* mistake, which becomes very obvious when using natural time and distance units so as to ensure Nature's constant is set to unity ($c = 1$).

At the same time, we know a photon is defined by its *wavelength*. So how does that work? What is the *physical* meaning of the wavelength? It is, quite simply, the distance over which the electric and magnetic field vectors will go through a full *cycle* of their oscillation. Nothing more, nothing less. That distance is, of course, a *linear* distance: to be precise, it is the distance Δs between two points (x_1, y_1, z_1) and (x_2, y_2, z_2) where the **E** and **B** vectors have the same value. The photon will need some time Δt to travel between these two points, and these intervals in time and space are related through the (constant) velocity of the wave, which is also the velocity of the pointlike photon.

That velocity is, effectively, the speed of light, and the time interval is the cycle time T = 1/*f*. The distance interval is the wavelength, of course. We, therefore, get the equation that will be familiar to you:

$$c = \frac{\Delta s}{\Delta t} = \frac{\lambda}{\mathrm{T}}$$

We can now relate this to the Planck-Einstein relation.

4. Any (regular) oscillation has a frequency and a cycle time T = 1/*f* = 2π/ω. The Planck-Einstein relation relates *f* and T to the energy (E) through Planck's constant (*h*):

$$\mathrm{E} = h \cdot f = \hbar \cdot \omega \Leftrightarrow \mathrm{E} \cdot \mathrm{T} = h$$

The Planck-Einstein relation applies to a photon: think of the photon as *packing* not only the energy E but also an amount of *physical action* that is equal to *h*. *Physical action* is a concept that is not used all that often in physics: physicists will talk about energy or momentum rather than about physical action.[63] However, we find the concept as least as useful. In fact, we like to think physical action can *express* itself in two ways: as some energy over some time (E·T) or – alternatively – as some momentum over some distance (p·λ). For example, we know the (pushing) momentum of a photon[64] will be equal to p = E/*c*. We can, therefore, write the Planck-Einstein relation for the photon in two equivalent ways:

$$\mathrm{E} \cdot \mathrm{T} = \frac{E}{c} \cdot c\mathrm{T} = h \Leftrightarrow \mathrm{p} \cdot \lambda = h$$

We could jot down many more relations, but we should not be too long here.[65] We said the photon *packs* an energy that is given by its frequency (or its wavelength or cycle time through the $c = \lambda f$ relation) through the Planck-Einstein relation. We also said it packs an amount of *physical action* that is equal to *h*. So how should we think of that? We will come to that: let us, effectively, connect all of the dots here.

[63] The German term for physical action – *Wirkung* – describes the concept much better, we feel.

[64] For an easily accessible treatment and calculation of the formula, see: *Feynman's Lectures*, Vol. I, Chapter 34, section 9 (https://www.feynmanlectures.caltech.edu/I_34.html#Ch34-S9).

[65] We may refer the reader to our manuscript (https://vixra.org/abs/1901.0105) or various others papers in which we explore the nature of light (for a full list, see: https://vixra.org/author/jean_louis_van_belle). We just like to point out one thing that is quite particular for the photon: the reader should note that the E = mc^2 mass-energy equivalence relation and the p = m*c* = E/*c* for the photon are *mathematically* equivalent. This is no coincidence, of course.

5. The Planck-Einstein relation does not only apply to a photon, but it also applies to electron orbitals—but in a different way. When analysing the electron orbitals for the simplest of atoms (the one-proton hydrogen atom), the Planck-Einstein rule amounts to saying the electron orbitals are separated by an amount of *physical action* that is equal to $h = 2\pi\cdot\hbar$.[66] Hence, when an electron jumps from one level to the next – say from the second to the first – then the atom will lose one unit of h. The photon that is emitted or absorbed will have to pack that somehow. It will also have to pack the related energy, which is given by the Rydberg formula[67]:

$$\mathrm{E}_{n_2} - \mathrm{E}_{n_1} = -\frac{1}{{n_2}^2}\mathrm{E}_R + \frac{1}{{n_1}^2}\mathrm{E}_R = \left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right)\cdot \mathrm{E}_R = \left(\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right)\cdot \frac{\alpha^2 \mathrm{m}c^2}{2}$$

To focus our thinking, let us consider the transition from the second to the first level, for which the $1/1^2 – 1/2^2$ is equal 0.75. Hence, the photon energy should be equal to $(0.75)\cdot\mathrm{E}_R \approx 10.2$ eV. Now, if the total action is equal to h, then the cycle time T can be calculated as:

$$\mathrm{E}\cdot\mathrm{T} = h \Leftrightarrow \mathrm{T} = \frac{h}{\mathrm{E}} \approx \frac{4.135\times10^{-15}\mathrm{eV}\cdot\mathrm{s}}{10.2\ \mathrm{eV}} \approx 0.4\times10^{-15}\ \mathrm{s}$$

This corresponds to a wave train with a length of $(3\times10^8$ m/s$)\cdot(0.4\times10^{-15}$ s$) = 122$ nm. It is, in fact, the wavelength of the light ($\lambda = c/f = c\cdot\mathrm{T} = \mathrm{h}\cdot c/\mathrm{E}$) that we would associate with this photon energy.

Is the photon *structure* really as simple as this? It is. Of course, simple models may have rather subtle consequences: we did not discuss polarization, for example, which would be essential in a classical explanation of, say, one-photon Mach-Zehnder interference. However, we dealt with that in other papers.[68]

[66] The model of the atom here is the Bohr model. It does *not* take incorporate the finer structure of electron orbitals and energy states. That finer structure is explained by differences in magnetic energies due to the *spin* (angular momentum) of the electron. We refer the reader who would want to look up more details in this regard to our paper on the Lamb shift.

[67] The detail of these calculations can be found in most textbooks but, for ease of reference, we may also refer the reader to Chapter VII of the manuscript we had originally prepared for the WSP/IOP publishing houses: *The Emperor Has No Clothes: A Realist Interpretation of Quantum Mechanics*. We withdrew this manuscript after their first reviewer accused of 'casually connecting formulas' and – more importantly – noted our lack of academic credentials in the field of physics. We prefer peer review by *our* colleagues now, who are (other) amateur physicists rather than academics. If we are left with sufficient time and energy, we may or may not try to transform our writings into one or more journal articles. For the time being, however, we must admit we do not bother too much.

[68] See, for example, the Annex to our paper on the difference between a theory, a calculation and an explanation.