The electron model and Nature's constants

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Summary

This paper recaps our electron model – including our explanation of the anomaly – and offers some reflections on its relevance and our thinking about Nature's fundamental constants.

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Introduction

The idea of a force combines the idea of a charge and the idea of inertia—resistance to a change of the state of motion. This gives rise to a curious paradox: a charge should have some mass. Why? Because any force on a zero-mass charge would give it infinite momentum. A brief look at the (relativistically correct) force law makes this rather obvious:

$$\mathbf{F} = \mathrm{m}_v \cdot \boldsymbol{a} = \frac{\mathrm{d}(\mathrm{m}_v \cdot \boldsymbol{v})}{\mathrm{d}t} = \frac{\mathrm{d}\mathbf{p}}{\mathrm{d}t}$$

$$\mathrm{m}_v = \gamma \cdot \mathrm{m}_0 = \frac{1}{\sqrt{1 - v^2/c^2}} \cdot \mathrm{m}_0$$

In the *inertial* reference frame – the reference frame of the object we would be looking at – the velocity v is equal to zero: the Lorentz factor is, therefore, equal to $\gamma = 1$, and $m_v = m_0$. Hence, if we have a finite force **F** acting on a zero-mass object, its acceleration $\boldsymbol{a}$ has to be infinite so as to yield a finite $0 \cdot \infty$ product.

It is, therefore, quite nice that our ring current model of an electron yields a non-zero rest mass for the pointlike charge inside of the electron. Let us quickly recap the basics of it.

The anomaly of the electron's radius

Most ring current or *Zitterbewegung* models of an electron assume the pointlike *zbw* charge is whizzing around the center of the *zbw* oscillation *at the speed of light*. We think that assumption is a mathematical idealization. This is why the anomalous magnetic moment is *not* an anomaly: the assumption that the elementary charge has no dimension or structure whatsoever is bound to result in an 'anomaly' between our measurements and these 'good theories' we have about the structure of electrons, photons and protons.[1]

Let us do some calculations. Because $\hbar$ and c have precisely *defined* values since the 2019 revision of SI units, we can calculate the Compton radius from the mass—not approximately, but *exactly*.[2] The CODATA value for the electron mass is equal to:

$$m_{\mathrm{CODATA}} = 9.1093837015(28)\times10^{-31}\ \mathrm{kg}$$

Based on this, we can calculate a theoretical electron radius based on a ring current model of the electron.[3] Interpreting c as the tangential velocity of the *zbw* charge – and also using the Planck-Einstein

[1] Mathematical idealizations are just what they are: we need the math and the mathematical ideas that come with it (including the ideas of nothingness and infinity) to describe reality – math was Wittgenstein's ladder to understanding – but Planck's quantum of action, and the finite speed of light, effectively tell us our mathematical ideas are what they are: idealized notions we use to describe a reality which is, in the end, quite finite. Something that has no dimension whatsoever probably exists in our mind only. As for the notion of a 'good theory', we refer to Dirac's remarks on gauge and renormalization theory.

[2] Note that the radius is inversely proportional to the mass. The Compton radius of a muon-electron or a proton, for example, is much smaller than the Compton radius of an electron.

[3] NIST gives CODATA values for the Compton wavelength of an electron. It also gives a measure of the electron's classical electron radius, which is the Compton radius divided by the fine-structure constant. We will leave it to the reader to verify those values against our calculations and reflect about those results.

and mass-energy equivalence relation – we get the following theoretical value for the ring current radius of an electron:

$$a = \frac{c}{\omega} = \frac{c\hbar}{\mathrm{E}} = \frac{c\hbar}{\mathrm{m}c^2} = \frac{\hbar}{\mathrm{m}c} = \frac{\lambda_C}{2\pi} \approx 0.38616\ \mathrm{pm}$$

We can also calculate the radius from the CODATA value for the magnetic moment[4]:

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

Indeed, the magnetic moment is the product of the current and the area of the loop, and the current is the product of the elementary charge and the frequency. 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:

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

We get a value that is slightly different from the theoretical radius: we have an anomaly. We can confirm this anomaly by re-doing this calculation using the Planck-Einstein relation to calculate the frequency:

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

The approximate 0.38666 and 0.38638 pm values we get out of our radius calculation using the CODATA value for the magnetic moment are slightly *larger* than the theoretical $a = \hbar/\mathrm{m}c$ value we get based on the mass or the Compton wavelength, which is 0.38616 fm—more or less.[5] So, yes, we do have an anomaly. We can use a lot of subscripts here, but they are all the same: subscripts don't matter. The bottom line is this: we will want to think of the radius based on the mass or the Compton wavelength as some kind of *theoretical* radius and so we will put it in the denominator. You can write it like you want, with or without some subscript: $a = a_{\mathrm{CODATA}} = a_{\mathrm{m}} = a_{\lambda} = a_{\mathrm{C}}$. In contrast, we will write the radius based on our calculation using the magnetic moment as a_μ. We can then write the anomaly as[6]:

$$\frac{a_\mu - a}{a} \approx 0.00115965 \Leftrightarrow \frac{a_\mu}{a} = 1.00115965 \dots$$

You will immediately recognize the anomaly. It is, effectively, equal to about 99.85% of Schwinger's factor:

$$\frac{\alpha}{2\pi} = 0.00116141 \dots$$

[4] We should put a minus sign as per the convention but, because we are interested in magnitudes here, we will omit it. It will, hopefully, confuse the reader *less*, rather than more.

[5] We encourage the reader to re-do the calculations so as to arrive at more precise results.

[6] We used the first of the two radii one can calculate from the magnetic moment. The reader can re-do the calculations using the second of the two anomalous radii.

The anomaly of the electron's magnetic moment

Let us, for good order, also recalculate the anomaly of the magnetic moment. We will follow a slightly different presentation than the usual one but you will see the logic is not very different. We first calculate a new *theoretical* value for the magnetic moment using the Compton radius, which we will denote as μ_a. When writing it all out, we get this:

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

We can now calculate the anomaly – against the CODATA value – once more[7]:

$$\frac{\mu_a - \mu}{\mu} = 0.00115965 \ldots$$

We get the same anomaly—not approximately but *exactly*. That is what we would expect: in the *zbw* or ring current model, the anomaly is not only related to the *actual* magnetic moment but to the *actual* radius as well. This should not surprise us: the magnetic moment is, of course, proportional to the radius of the loop.[8] Hence, if the *actual* magnetic moment differs from the theoretical one, then the *actual* radius must also differ from the theoretical one.

At this point, the reader may wonder how we get a theoretical value for the magnetic moment. We get it from the same ring current model. We can just equate the two formulas we presented for the magnetic moment:

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

The reader should note we are not calculating anything new here: everything comes with the ring current model.

The mass of the *zbw* charge

Our assumption is that the anomaly is, somehow, the result of our mathematical idealizations. We cannot *really* assume the pointlike *zbw* charge is whizzing around at the speed of light. It can be very *near c*, but not *quite* equal to *c*. Hence, its theoretical rest mass will also be very close to zero, but not *exactly* zero. Of course, because everything is related to everything in this model, the anomalies also suggest we have some *real* radius *r* that is probably *not quite* equal to the Compton radius $a = \hbar/mc$. Let us write it all out. What should we put where? It is not easy to figure out, but the greater value – based on the greater radius – should be in the denominator, so we write:

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[7] 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!

[8] We have a squared radius in the numerator of the formula for the magnetic moment, and a non-squared radius factor in the denominator.

$$\frac{\mu_r}{\mu_a} = \frac{\frac{q_e}{2m}\hbar}{\frac{q_e v}{2}r} = \frac{\hbar}{m \cdot v \cdot r} = \frac{c \cdot a}{v \cdot r}$$

Note that, from the $v = r \cdot \omega$ and $c = a \cdot \omega$ relations[9], we can also get the following result:

$$\frac{\mu_r}{\mu_a} = \frac{c \cdot a}{v \cdot r} = \frac{\omega \cdot a^2}{\omega \cdot r^2} = \frac{a^2}{r^2} \Leftrightarrow \frac{c}{v} = \frac{a}{r}$$

This helps us to with interpretation of our results: because *v* must be smaller than c, the identity shows the *real* radius *r* must also be slightly *smaller* than $a = \hbar/mc$. If there would be no anomaly – in other words: if our mathematical idealization would match reality – then the formulas just becomes unity (everything is equal to 1). However, we know the anomaly exists, and it is *very* nearly equal to $1 + \alpha/2\pi$. For all practical purposes – we think a 99.85% explanation is pretty good – we will just equate it and re-write the expression above as[10]:

$$1 + \frac{\alpha}{2\pi} = \frac{2\pi + \alpha}{2\pi} = \frac{c \cdot a}{v \cdot r} \Leftrightarrow v \cdot r = \frac{2\pi \cdot c \cdot a}{2\pi + \alpha} = \frac{2\pi \cdot c \cdot \frac{\hbar}{mc}}{2\pi + \alpha} = \frac{h}{m(2\pi + \alpha)}$$

$$\Leftrightarrow L = m \cdot v \cdot r = \frac{h}{2\pi + \alpha}$$

So now we need to answer the question: what is the real velocity *v* and what is the real radius *r* of our *zbw* charge? We will come to that. We first ask the reader to note something quite essential here. Mainstream quantum mechanics assumes angular momentum must come in units of *ħ*, and mainstream physicists think that is a direct implication of – or even an equivalent to – the Planck-Einstein law: $E = h \cdot f = \hbar \cdot \omega$. The calculation above brings some nuance to this statement: angular momentum does *not* come in *exact* units of ħ. There is an anomaly, and we think the anomaly is part and parcel of Nature.

In contrast, we believe the Planck-Einstein relation to be true—not approximately but *exactly*. Hence, we believe that the frequency *f* or ω of the *Zitterbewegung* oscillation is, effectively equal to $f = E/h$ or $\omega = E/\hbar$, *precisely*. If we believe that to be true, then the following relations *explain* the anomaly[11]:

$$\frac{\mu_r}{\mu_a} = 1 + \frac{\alpha}{2\pi} = \frac{c \cdot a}{v \cdot r} = \frac{\omega \cdot a^2}{\omega \cdot r^2} = \frac{a^2}{r^2} \Leftrightarrow$$

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[9] The reader may wonder why we take ω to be a constant. The answer is: we take the energy (or mass) of an electron as a given, and we take the Planck-Einstein relation ($\omega = E/\hbar$) as a given too! The geometry of the situation gives us everything here!

[10] The reader should note that we did use the $a = \hbar/mc$ relation above—as opposed to the $a = 2\hbar/mc$ relation. It makes a very significant difference. When using the $a = 2\hbar/mc$ relation, we get this:

$$1 + \frac{\alpha}{2\pi} = \frac{2\pi + \alpha}{2\pi} = \frac{c \cdot a}{v \cdot r} \Leftrightarrow v \cdot r = \frac{2\pi \cdot c \cdot a}{2\pi + \alpha} = \frac{2\pi \cdot c \cdot \frac{2\hbar}{mc}}{2\pi + \alpha} = \frac{2h}{m(2\pi + \alpha)} \Leftrightarrow L = m \cdot v \cdot r = \frac{h}{\pi + \alpha/2}$$

The difference between $\pi + \alpha/2$ and $2\pi + \alpha$ is, unsurprisingly, equal to a factor 2. Practically speaking, we have two *very* different form factors for the angular momentum of an electron here. We discarded the $a = 2\hbar/mc$ hypothesis because we think the Planck-Einstein relation tells us the angular momentum comes in units of *ħ* (or *very nearly* so), rather than in *twice* that amount ($h/\pi = 2\hbar$).

[11] We are just using the tangential velocity formula here to do the substitution that is being done: $c = a \cdot \omega$ and $v = r \cdot \omega$ and – yes – we assume stable particles respect the Planck-Einstein relation, which we believe to be true—as opposed to the quantum-mechanical theorem in regard to angular momentum which, as mentioned, we believe to be very *nearly true*.

$$r = \frac{a}{\sqrt{1 + \frac{\alpha}{2\pi}}} \approx 0.99942 \cdot \frac{\hbar}{\mathrm{m}c}$$

We can plug this into the β = *v*/*c* = *r*/*a* relation to get the relative velocity:

$$\beta = \frac{v}{c} = \frac{r}{a} = \frac{a}{a \cdot \sqrt{1 + \frac{\alpha}{2\pi}}} = \frac{1}{\sqrt{1 + \frac{\alpha}{2\pi}}} \approx 0.99942$$

We can now calculate the real rest mass of the pointlike *zbw* charge:

$$\mathrm{m}_0 = \sqrt{1 - \beta^2} \cdot \mathrm{m}_\gamma = \sqrt{1 - \beta^2} \cdot \frac{\mathrm{m_e}}{2} = \sqrt{1 - \frac{1}{1 + \frac{\alpha}{2\pi}}} \cdot \frac{\mathrm{m_e}}{2} \approx 0.017 \cdot \mathrm{m_e}$$

Hence, we arrive at the conclusion that the rest mass of the pointlike *Zitterbewegung* charge is equal to a bit less than 2% of the rest mass of the electron. Is this a credible result? We think so, but we will let the reader re-do the calculations.

The fundamental units of physics

These results are wonderful. We will now relate them to a more philosophical question: what is *fundamental* in Nature? In other words, what are *first principles*, and what can be *derived* from them?

Planck's constant (*h*) models a fundamental *cycle* in Nature, and we consider the absolute speed of light (*c*) to be another fundamental *fact*. From these two, we get the idea of a force. Indeed, the physical dimension of Planck's constant is a force over some distance during some time (F·Δ*s*·Δ*t*). Hence, combining *h* and *c*, we could define a natural unit for the force, based on whatever natural unit we would want to choose for distance and time—say, the second for time and the light-second for distance, although smaller units would be much more convenient at the sub-atomic scale.[12]

As mentioned, the idea of a force combines two ideas: it acts on a charge, but the charge must have some *inertia* to a change in its state of motion. Otherwise, we get nonsense—as, hopefully, we managed to convincingly illustrate in our introduction.

The first idea – a force acting on a charge – may be used to define a natural unit for the charge which, in this case, is the electric charge.[13]

[12] The only requirement for a natural distance and time unit is that the speed of light as expressed in these units should equal unity: $c = 1$. Hence, our choice for such units will involve some idea of *scale*. In mathematical terms, these units would all be equivalent because they differ by a proportionality constant only. There is a natural constant relating various scales: the fine-structure constant. We will come back to this.

[13] We wrote about the idea of a strong charge in our previous papers as part of our calculations of the electromagnetic radius of a proton ($4\hbar/\mathrm{m}c \approx 0.841$ fm). Indeed, something must explain the extraordinarily *small* radius and, likewise, the extraordinarily *large* mass of a proton (the radius is *inversely* proportional to the mass in the ring current model). We may, therefore, want to think of a fundamental oscillation of some other charge – a *strong* charge – to explain the extra mass. This idea would lead to a distinction between the idea of an electromagnetic mass and the idea of a strong mass. However, we are very reluctant to engage in such theory because we would like to think of other theoretical models here. We may, for example, want to think that the electromagnetic oscillation might have different *modes* or higher harmonics. We are inspired here by the fact that the ring current model is easily applicable to the heavier variant of the electron—the *muon*.

The second idea would define a natural mass unit. For the first, it is quite obvious that the charge of an electron – which is nothing but the *zbw* charge inside – would be the right choice. For the second, we may briefly wonder whether we shouldn't consider the mass of the *zbw* charge, but the sensible answer here is obvious: we can only measure the mass of the electron and, hence, the mass of the electron should probably be our natural mass unit as well.

Apart from $\hbar$ and c, we also have the fine-structure constant α. How can we *define* it? The answer is: we cannot. We can only *measure* it—from the anomalies and from the finer structure of the hydrogen spectrum. Both are related, even if these relations are, obviously, *not* self-evident.

Of course, while we can (probably) not *define* its numerical value, we may try to explain what it *is*. We have done so using our ring current model – not only for the electron itself but also for electron orbitals. These analyses lead us to characterize the fine-structure constant as a scaling constant but, as evident from our previous papers[14], it scales more than one physical dimension—not only the dimensions in space!

What about the Uncertainty Principle?

Is there any room for the Uncertainty Principle in our analysis? There is. We like to think of Planck's constant as a vector. Indeed, the force in the $F \cdot \Delta s \cdot \Delta t$ must have some direction. This direction may wander around. This is equivalent to saying that the plane of the ring current evolves in time which, of course, also means that the direction of the magnetic moment is changing all of the time. When a magnetic field is being applied, the electron snaps into place, so to speak—and we also think of the Larmor precession as an actual precessional motion, obviously.

However, we have no idea of how *exactly* the angle of the plane of the *Zitterbewegung* or rotary motion of the charge could change: we cannot think of some obvious *clue* here. If we could, we would not hesitate to further develop this paper. However, it is, for us, not a priority to develop some answer to this question. Why not? Because it doesn't matter: we do not need to *explain* anything here. About half of the electrons that are entering a Stern-Gerlach apparatus will have their spin *up*, more or less, and the other half will have it *down*. The magnetic field then, somehow, *snaps* them into place. Of course, the reader will object to such reasoning: there should be some inertia here too, isn't it?

We cannot say much to that, except the obvious: apparently, there is *no* inertia here. Why? We don't know. The question is related to the next.

What keeps the current going?

It is an obvious question: what keeps the ring current going? It is related to the other obvious questions: what keeps the *zbw* charge in its orbit, and why does the energy *not* radiate away?

Here also, we can only provide non-definite answers. Most current ring or *Zitterbewegung* theorists – think of David Hestenes and others – think the ring current generates the magnetic field that keeps it going. As such, they compare it to a superconducting ring of current. We like this comparison and then we do not. We like it because a superconducting ring of current also keeps going without radiating any energy away. However, we also note superconduction is being explained in a very different way in

[14] See our paper on the meaning of the fine-structure constant (https://vixra.org/abs/1812.0273).

mainstream mechanics: the explanation involves *Bose* condensation and (Cooper) *pairs* of electrons. We are quite mystified by that.

At the same time, we did seem to be able to offer common-sense explanations for quite a few quantum-mechanical mysteries now (the physical meaning of the wavefunction, the wavelike behavior and interference of electrons and photons, the anomalous magnetic moment, the proton radius, etcetera). Hence, we may be able to explain superconductivity in some easier way one day too!

However, we have a second objection: it would seem a superconducting ring can have any radius. In contrast, the electron has only one specific Compton radius, and there is nothing that keeps the charge in its orbit. I think of that puzzle as a real 'fine-tuning problem'. So far, we can only make sense of it by assuming our two-dimensional oscillator model[15] is, somehow, more fundamental than what I'll refer to as Hestenes' 'superconduction' model. We get our 'perpetuum mobile' – so to speak – directly from (i) accepting Einstein's mass-energy equivalence relation (E = m·c^2) for what it is, (ii) interpreting *c* as the tangential velocity of the *zbw* charge[16] ($c = a\cdot\omega$), and (iii) the Planck-Einstein relation (E = ħ·ω):

$$a = \frac{c}{\omega} = \frac{c\hbar}{\mathrm{m}c^2} = \frac{\hbar}{\mathrm{m}c} = \frac{\lambda_C}{2\pi} \approx 0.386159268 \ldots \text{ pm}$$

We admit it is still mysterious, but it is the best we've got. All the rest – most of the Standard Model, that is[17] – looks even more mysterious to us. It looks like a remake of the intellectual battle between Ptolemaic and Copernican models: both yield results, but one is significantly simpler than the other.

History will decide which model wins. Until that day, we should just try to heed Wittgenstein's advice:

"*Wovon man nicht sprechen kann, darüber muß man schweigen.*"

Jean Louis Van Belle, 17 February 2020

[15] See: https://vixra.org/pdf/1905.0521v4.pdf.

[16] We also referred to the *zbw* charge as a naked charge: it has no properties except its charge. It has, therefore, zero rest mass and that is why it moves around at lightspeed: the slightest force on it will cause an infinite acceleration.

[17] We think of the Higgs field here, for example. In our model, a charge comes with a (tiny) mass. No need for hocus-pocus!