Relativity and absolute laws

Jean Louis Van Belle, *Drs*, *MAEc*, *BAEc*, *BPhil*

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Email: jeanlouisvanbelle@outlook.com

Summary: This paper adds some thoughts on relativity theory and geometry to our one-cycle photon model. We basically highlight what *exactly* we should think of as being relative in this model (energy, wavelength, and the related force and field values), as opposed to what is absolute (the geometry of spacetime and the geometry of the photon).

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The speed of light

Of all of the foundational contributions to physics – or to science in general, I'd say – Einstein's special relativity theory stands out. Its name is not very appropriate. It is generally referred to as being special because it makes abstraction of gravity.[1] However, I feel that is *not* a very compelling reason to do so: Einstein's so-called special relativity theory deals with the very common concepts of mass and energy and, as such, should not be thought of as being special. More importantly, Einstein's relativity theory is, essentially, not about things being relative, but about the one thing that is *absolutely absolute*: the speed of light. Now, that is a *very* weird thing. As Feynman puts it, with his usual disdain for the philosophers:

> "One will find few philosophers who will calmly state that it is self-evident that if light goes 186,000 mi/sec inside a car, and the car is going 100,000 mi/sec past an observer on the ground, that the light also goes 186,000 mi/sec past the observer on the ground."[2]

Because you are reading this, we must assume that you are already familiar with the basic *results* and relativistic *equations* that come out of this astonishing *fact*: relativistic length contraction, time dilation and relativistic mass. In fact, we must assume you are so familiar with these concepts that you have accepted we do not really *understand* these things: we simply *accept* them as being, somehow, *true*—despite being as astonished as the philosophers. Probably more because, to paraphrase Feynman once more, we are *not* like "these philosophers, who are always with us, struggling in the periphery to try to tell us something, but never really understanding the subtleties and depths of the problem."[3]

Let's go back to the light. We know the light beam in the car will consist of *photons*: light *quanta*, or *particles* of light—but we'd better talk of wavicles or use some other innovative term, because particles can refer to (almost) anything in physics, and so we should probably think of the term as being non-precise and, therefore, non-scientific. Einstein studied these too, and actually got his Nobel Prize in Physics for the photoelectric effect—*not* for his relativity theory.[4] So what *are* these photons?

We mentioned we don't think the term 'particle' is accurate and, therefore, useful. Willis Lamb, another Nobel Prize winner[5], went much further and actually claimed that even the concept of a photon is a "bad concept" with "no scientific justification" and that it is, therefore "high time to give up its use."[6] He wrote this when he was over 80 years old and, hence, we attribute the exaggerated boldness in this statement to old age. Having said that, we do acknowledge the point he wanted to make: we should think of photons as an electromagnetic *wave*, rather than as a particle. At the same time,

[1] See, for example, the entry on relativity theory on Wikipedia: https://en.wikipedia.org/wiki/Theory_of_relativity.
[2] Richard Feynman, *Lectures on Physics*, p. I-16-2.
[3] Richard Feynman, *Lectures on Physics*, p. I-16-1.
[4] Back in 2012, astronomy journalist Stuart Clark wrote a rather brilliant and oft-quoted article on that for the Guardian newspaper. See: https://www.theguardian.com/science/across-the-universe/2012/oct/08/einstein-nobel-prize-relativity. We warmly recommend reading it!
[5] You may or may not have heard of the so-called Lamb shift, which is a tiny energy difference between the $^2S_{1/2}$ and $^2P_{1/2}$ orbitals in the hydrogen atom. See: https://en.wikipedia.org/wiki/Lamb_shift.
[6] W.E. Lamb, Jr., *Anti-Photon*, in: Appl. Phys. B 60, 77-84 (1995).

electromagnetic radiation does come in packets, and there is no reason whatsoever to not refer to these as photons. Even if we do not want to think of these photons as, somehow, being 'particle-like', they do have momentum and energy, which are properties one does usually associate with particles. More importantly, they come in *discrete* lumps. In short, they are, effectively, the *quanta* of light. In case you wonder, the term 'photon' is said to combine the Greek *phōs* or *phōt,* which just means 'light', and the ending of the term 'electron'. However, if this is correct, then we should, perhaps, refer to it as a 'phot*r*on.'

The Martian story

The single most important difference between photons and proper particles – we could call them *matter*-particles but that's also confusing – is that photons do *not* carry any charge. All other *matter* as we know it, carry (electric) charge—think of protons, electrons or even neutrons[7] here: photons do *not*.[8] That's why 'photon' sounds better than 'photron'—to me, at least. But, if it is *not* charge, then *what* defines a photon as a discrete 'particle' or 'packet' of energy? The (preliminary) answer is: Planck's quantum of action.[9] The photon's energy and wavelength are both *relative* but they are related through that other fundamental constant in nature: *h* or, in its so-called *reduced* form, *h-bar* (ħ).[10] So here is our first formula—the Planck-Einstein relation:

$$E = h \cdot f = \hbar \cdot \omega$$

Planck's quantum of action is *not* relative—in contrast to the energy and the frequency, which depend on our reference frame: am I the observer on the ground in Feynman's little story, or am I sitting in that car? When thinking about relativity, we should think of an obvious question: the frequency and the energy of our photon will depend on the reference frame but is there – by some chance – some reference for the reference? I tend to answer that question positively: we happen to live in *this* Universe here, where our Earth orbits the Sun, and where our Sun happens to be part of the Milky Way, which is part of the *Local Group*, which – in turn – is part of the Virgo Supercluster, etcetera.[11] In short, there is a *structure* here which we can use as an *anchor* for our physics.

That is why Feynman's digressions on (broken) symmetries and anti-matter do not make all that much sense. He basically argues there is no way to distinguish up and down, and left and right, from *physical experiments only*.[12] In case you don't remember the line of argument here, Feynman basically imagines

[7] Neutrons are neutral but they do have a measurable magnetic moment. Hence, we think neutrons must, somehow, combine positive and negative charge. We will come back to this later.

[8] Some authors are popularizing the idea that a photon would, somehow, combine both negative and positive charge. See, for example, Richard Gauthier (https://richardgauthier.academia.edu/research). This idea is intuitively attractive because of the phenomenon of electron-positron pair production out of photons. However, we do not concur with the idea: pair production requires the presence of a nucleus and we, therefore, think something else is going on. We will come back to this later but – in case you'd want something on this right now and right here – see my entry on *protons and neutrons* on viXra.org (http://vixra.org/abs/2001.0104).

[9] As we will see in a moment, we will also involve Planck's quantum of action in our model of an electron. That's why we inserted 'preliminary' in our answer.

[10] We'll explain the meaning of the reduced and non-reduced form of Planck's constant in a moment.

[11] For a brief description of where we are, see the Wikipedia article on our surroundings: https://en.wikipedia.org/wiki/Milky_Way.

[12] See: *Feynman's Lectures*, Volume I, Chapter 52 (*Symmetry in Physical Laws*).

we somehow manage to make contact with a 'Martian': some advanced *being* somewhere 'out there' whom we can communicate with but can't relate all those spatial binary concepts (front/back, up/down, left/right) to ours. He or she or it – whatever, let's be *male* and use 'he' – understands we're talking some *direction* in 3D space but we're just not sure he's got it right—and, likewise, he's not sure *we* got it right.

To make a long story short, mankind basically gives the mike to Feynman and – of course there is good translation – Feynman walks the Martian through all of the physics we know of. To be more specific, Feynman explains him all of his lectures on conservation laws, mirror reflections, polar and axial vectors in physics and, importantly, the weird phenomenon of CP-*a*symmetry, or the non-conservation of *parity*. The Martian gets it but – just to make sure – he wants Feynman to send him something that illustrates the concept of left and right. Unfortunately, that's the one thing we can*not* do in this imaginary experiment. As Feynman puts it:

> "We are not allowed to send him any actual samples to inspect; for instance, if we could send light, we could send him right-hand circularly polarized light and say, "That is right-hand light—just watch the way it is going." But we cannot give him anything, we can only talk to him. He is far away, or in some strange location, and he cannot see anything we can see. For instance, we cannot say, "Look at Ursa major; now see how those stars are arranged. What we mean by 'right' is …" We are only allowed to telephone him."[13]

That's the flaw of the whole argument. Because it's the final chapter in Feynman's first volume of lectures in a series that is designed to 'save the more advanced and excited student by maintaining his enthusiasm'[14], I've come to think of this thought experiment as Feynman at his worst, which, paradoxically, doesn't diminish my admiration for him as 'the Great Teacher'—not at all, actually.[15] Any case, to make a long story short, Feynman basically concludes we cannot be sure our Martian friend lives in the same Universe. It all boils down, in the end, to the difference of matter and anti-matter:

> "So if our Martian is made of antimatter and we give him instructions to make this "right" handed model like us, it will, of course, come out the other way around. What would happen when, after much conversation back and forth, we each have taught the other to make spaceships and we meet halfway in empty space? We have instructed each other on our traditions, and so forth, and the two of us come rushing out to shake hands. Well, if he puts out his left hand, watch out!"

It's a funny story and, at the same time, it's not: Feynman just keeps the 'mystery' alive here. He doesn't answer any of the obvious questions. We know those famous words of Minkowski, which he wrote in following in 1907, shortly after he had re-formulated Einstein's special relativity theory in terms of four-dimensional space-time: "*Henceforth space by itself, and time by itself, are doomed to fade away into*

[13] For a full discussion, see my posts on time reversal and CP-asymmetry on my blog on Feynman's *Lectures* (https://readingfeynman.org/2014/05/11/time-reversal-and-cpt-symmetry-iii/).
[14] See Feynman's Preface to his *Lectures*.
[15] Feynman's biggest achievement with this *Lectures* series is that he does make you think for yourself, which he said he would do.

mere shadows, and only a kind of union of the two will preserve an independent reality." However, it's equally true that "**the underlying geometry of Minkowskian space-time remains absolute**."[16]

The geometry of a photon

So what *is* a photon then? I've detailed that in previous papers so I will just present the basics here.[17] It is, effectively, just a point-like electromagnetic oscillation. I refer to it as the one-cycle photon model. The argument is as follows.

Angular momentum comes in units of $\hbar$. When analyzing the electron orbitals for the simplest of atoms (the one-proton hydrogen atom), this rule amounts to saying the electron orbitals are separated by a amount of *physical action* that is equal to $h = 2\pi\cdot\hbar$. 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:

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

To focus our thinking, let us consider the transition from the second to the first level, for which the $1/1^2 - 1/2^2$ factor is equal 0.75. Hence, the energy of the photon that is being emitted will 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:

$$\mathrm{E}\cdot\mathrm{T} = h \Leftrightarrow \mathrm{T} = \frac{h}{\mathrm{E}} \approx \frac{4.135\times 10^{-15}\mathrm{eV}\cdot\mathrm{s}}{10.2\ \mathrm{eV}} \approx 0.4\times 10^{-15}\ \mathrm{s}$$

This corresponds to a wavelength of $(3\times10^8\ \mathrm{m/s})\cdot(0.4\times10^{-15}\ \mathrm{s}) = 122$ nm, which is 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.[18]

Let us quickly insert another calculation here. If we think of an electromagnetic oscillation – as a beam or, what we are trying to do here, as some *quantum* – then its energy is going to be proportional to (a) the square of the amplitude of the oscillation and (b) the square of the frequency. Just to make sure, we are *not* thinking of some quantum-mechanical amplitude here: we are talking the amplitude of a *physical* wave. Hence, if we write the amplitude as a and the frequency as ω, then the energy should be equal to $\mathrm{E} = \mathrm{k}\cdot a^2\cdot\omega^2$. The k is just a proportionality factor.

However, relativity theory tells us the energy will have some equivalent mass, which is given by Einstein's mass-equivalence relation: $\mathrm{E} = \mathrm{m}\cdot c^2$. Hence, the energy will also be proportional to this equivalent mass. It is, therefore, very tempting to equate k and m. We can only do this, of course, if c^2 is equal to $a^2\cdot\omega^2$ or – what amounts to the same – if $c = a\cdot\omega$. You will recognize this as a tangential velocity formula, and so you should wonder: the tangential velocity of *what*? Indeed, the a in the $c = a\cdot\omega$ formula is a radius, while the a in the $\mathrm{E} = \mathrm{k}\cdot a^2\cdot\omega^2$ formula that we started off with is an amplitude: so why would

[16] This is a philosophical comment (https://physics.nyu.edu/faculty/sokal/transgress_v2/node2.html) from an author I don't know, so I am not quite sure it means what I think it should mean.
[17] See: *A Classical Quantum Theory of Light* (http://vixra.org/abs/1906.0200).
[18] Just so you can imagine what we are talking about, this is short-wave ultraviolet light (UV-C). It is the light that is used to purify water, food or even air. It kills or inactivate microorganisms by destroying nucleic acids and disrupting their DNA. It is, therefore, harmful. The ozone layer of our atmosphere blocks most of it.

we suddenly think of it as a radius now? I can*not* give you a very convincing answer to that question but – intuitively – we will probably want to think of our photon as having a circular polarization. Why? Because it is a boson and it, therefore, has angular momentum. To be precise, its angular momentum is $+\hbar$ or $-\hbar$. There is no zero-spin state.[19] Hence, if we think of this classically, then we will associate it with circular polarization.

We are now ready for some calculations. If the energy E in the Planck-Einstein relation (E = ħ·ω) and the energy E in the energy equation for an oscillator ($E = m \cdot a^2 \cdot \omega^2$) are the same[20] – and they should be because we are talking about something that has some energy – then we get the following formula for the amplitude or radius *a*:

$$E = \hbar \cdot \omega = m \cdot a^2 \cdot \omega^2 \Leftrightarrow \hbar = m \cdot a^2 \cdot \omega \Leftrightarrow a = \sqrt{\frac{\hbar}{m \cdot \omega}} = \sqrt{\frac{\hbar}{\frac{E}{c^2} \cdot \frac{E}{\hbar}}} = \sqrt{\frac{\hbar^2}{m^2 \cdot c^2}} = \frac{\hbar}{m \cdot c}$$

This is the formula for the Compton radius of an electron ! How can we explain this? What relation could there possibly be between our *Zitterbewegung* model of an electron[21] and the quantum of light? We do not want to confuse the reader too much but things become somewhat more obvious when staring at the illustration below (Figure 1).

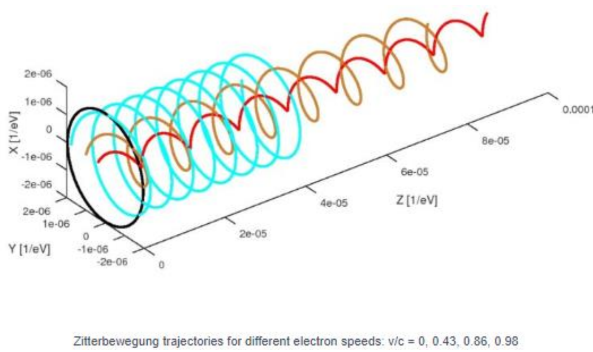


Figure 1: The Compton radius must decrease with increasing velocity

We think of the *Zitterbewegung* of a free electron as a circular oscillation of a pointlike *charge* (with *zero* rest mass) moving about some center at the speed of light. However, as the electron starts moving along some *linear* trajectory at a relativistic velocity (i.e. a velocity that is a *substantial* fraction of *c*), then the

[19] This is one of the things in mainstream quantum mechanics that bothers me. All courses in quantum mechanics spend like two or three chapters on why bosons and fermions are different (spin-one versus spin-1/2) and, when it comes to the specifics, then the only boson we actually know (the photon) turns out to *not* be a typical boson because it can*not* have zero spin. Feynman gives some haywire explanation for this in section 4 of *Lecture* III-17. I will let you look it up (Feynman's *Lectures* are online) but, as far as I am concerned, I think it's really one of those things which makes me think of Prof. Dr. Ralston's criticism of his own profession: "*Quantum mechanics is the only subject in physics where teachers traditionally present haywire axioms they don't really believe, and regularly violate in research*." (John P. Ralston, *How To Understand Quantum Mechanics*, 2017, p. 1-10)
[20] In case the reader would wonder where the ½ factor went, we should mention this is the formula for an oscillation in *two* dimensions. Again, we are talking two *physical* dimensions. For more details on the oscillator model, see our paper on the *Zitterbewegung* electron (http://vixra.org/abs/1905.0521).
[21] See the reference above.

radius of the oscillation will have to diminish – because the tangential velocity remains what it is: *c*. The geometry of the situation shows the circumference – so that's the Compton *wavelength* $\lambda_C = 2\pi \cdot a = 2\pi\hbar/mc$ – becomes a wavelength in this process.

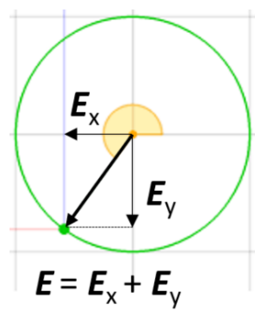
Of course, we should remind ourselves that the m in the $a = \hbar/mc$ equation here is *not* the mass of the electron but the (equivalent) mass of the photon. The Compton radius of a photon is, therefore, different than the Compton radius of an electron. Let us quickly calculate it for our 10.2 eV photon. We should, of course, express the energy in SI units (10.2 eV ≈ 1.634×10^{-18} *J*) to get what we should get:

$$a = \frac{\hbar}{\mathrm{m}\cdot c} = \frac{\hbar}{\mathrm{E}/c} = \frac{(1.0545718 \times 10^{-18}\, J\cdot s)\cdot(3\times 10^{8}\, m/s)}{1.634\times 10^{-18}\, J} \approx 19.4\times 10^{-9}\ \mathrm{m}$$

How does this compare to the Compton radius of an electron? The Compton radius of an electron is equal to about 386×10^{-15} m, so that's about 50,000 times *smaller* than the Compton radius of a photon. Unsurprisingly, that's the ratio between the electron's (rest) energy (about 8.187×10^{-14} *J*) and the photon energy (about 1.634×10^{-18} *J*). It is somewhat counterintuitive that the Compton radius is *inversely* proportional to the (rest) mass or energy, but that's how it is.[22]

Let us now answer the most obvious question: what *is* that amplitude? It's a (rotating) field. We will use the elementary wavefunction to represent the rotating *electric* field vector (see Figure 2). Remembering the $F = q_eE$ equation – with q_e as the unit charge – you can also think of it as a *force* field.

Figure 2: The one-cycle photon



Field calculations

The 'one-cycle photon model' is delightfully simple: the photon is just one single cycle traveling through space and time, which packs one unit of angular momentum ($\hbar$) or – which amounts to the same, one unit of physical action (h). This gives us an equally delightful interpretation of the Planck-Einstein relation ($f = 1/T = E/h$) and we can, of course, do what we did for the electron, which is to express h in two alternative ways: (1) the product of some momentum over a distance and (2) the product of energy

[22] While counterintuitive, the calculation is consistent. The reader can verify this by calculating the Compton radius for highly energetic photons. For example, the X-ray photons in the original Compton scattering experiment had an energy of about 17 keV = 17,000 eV and modern-day experiments will use gamma rays with even higher energies. One experiment, for example, uses a cesium-137 source emitting photons with an energy that is equal to 0.662 MeV = 662,000 eV. One can see these high photon energies bridge the gap with the rest energy of the electron they are targeting.

over some time. We find, of course, that the distance and time correspond to the wavelength and the cycle time:

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

$$h = \mathrm{E} \cdot \mathrm{T} \Leftrightarrow \mathrm{T} = \frac{h}{\mathrm{E}} = \frac{1}{f}$$

Needless to say, the E = mc^2 mass-energy equivalence relation can be written as p = mc = E/c for the photon. The two equations are, therefore, wonderfully consistent:

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

We can also calculate the strength of the electric field. How can we do that? We can do it using the relation between energy and force. Indeed, energy is some force over a distance and, hence, the force must equal the ratio of the energy and the distance. What distance should we use? The force will vary over the cycle and, hence, this distance is a distance that we must be able to relate to this fundamental cycle. Is it the Compton *radius* (*a*) or the wavelength (λ)? They differ by a factor 2π only, so let us just try the radius and see if we get some kind of sensible result:

$$\mathrm{F} = \frac{\mathrm{E}}{a} = \frac{2\pi \cdot \mathrm{E}}{\lambda} = \frac{2\pi \cdot h \cdot f}{\lambda} = \frac{2\pi \cdot h \cdot c}{\lambda^2}$$

Does this look weird? Not really. We get the E·λ = h·c equation from *de Broglie*'s h = p·λ = m·c·λ = E·λ/c equation and the equation above is fully consistent with it:

$$\frac{\mathrm{E}}{a} = \frac{2\pi \cdot h \cdot c}{\lambda^2} \Leftrightarrow \mathrm{E} \cdot \lambda = \frac{2\pi \cdot a \cdot h \cdot c}{\lambda} = h \cdot c$$

Now that we have the force, we can calculate the electric field – which we will write as *E*[23] – is the force per unit charge which, we should remind the reader, is the *coulomb* – *not* the electron charge. Why? Because we use SI units. We, therefore, get a delightfully simple formula for the strength of the electric field vector for a photon[24]:

$$E = \frac{\frac{2\pi hc}{\lambda^2}}{1} = \frac{2\pi hc}{\lambda^2} = \frac{2\pi \mathrm{E}}{\lambda} = \frac{\mathrm{E}}{a}$$

The electric field is the ratio of the energy and the Compton radius. Does this make sense? What about units? We divided by 1 *coulomb* and the physical dimension is, therefore, equal to [*E*] = [E/*a*] *per*

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[23] The *E* and E symbols should not be confused. *E* is the magnitude of the electric field vector and E is the energy of the photon. We hope the italics (*E*) – and the context of the formula, of course! – will be sufficient to help the reader distinguish the electric field vector (*E*) from the energy (E). We chose to *not* use a different symbol so as to not needlessly multiply the number of symbols we are using here.

[24] The *E* and E symbols should not be confused. *E* is the magnitude of the electric field vector and E is the energy of the photon. We hope the italics (*E*) – and the context of the formula, of course! – will be sufficient to distinguish the electric field vector (*E*) from the energy (E).

coulomb. A *joule* is a newton·meter and [E/*a*] is, therefore, equal to N·m/m = N. We're fine. Let us calculate its value for our 10.2 eV photon (using SI units once again, of course):

$$E \approx \frac{1.634 \times 10^{-18}\, J}{19.4 \times 10^{-9}\, m \cdot C} \approx 84 \times 10^{-12}\, \frac{\mathrm{N}}{\mathrm{C}}$$

The amplitude *a* appears as a natural distance unit here: if we use it as a divisor for the energy, then we get the field strength! I would think this is a very nice result.

Needless to say, all of these laws respect relativity theory: the measured values of the energy, the wavelength and, hence, of the field and the force will depend on your reference frame. However, the underlying *geometry* of the photon – the quantum of light – looks pretty absolute. 😊

Jean Louis Van Belle, 18 January 2020