Under what conditions is the energy of a photon proportional to its frequency?

Yefim Bakman bakmanyef@gmail.com

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Abstract. When an artificial intelligence (AI) model was asked the question in the title, the answer was "Under all conditions." This response is understandable because, in the dominant paradigm, photons have no size, structure, or mass, and consequently, there is no photon model, but there is spin. When asked about spin, the AI model replied that spin is not the rotation of matter in space, but rather a representation of the Lorentz group. Planck's formula is a postulate, not the result of a physical consequence. The answer to the question in the title can be found within the framework of a new paradigm built on Tesla's insight. In this new paradigm, photons have size, structure, non-zero mass, and spin; thus, compared with the dominant paradigm, the new paradigm provides a closer match to classical physics.

Here, based on this photon model, we derive a generalized formula for the energy and frequency of a photon, in which Planck's formula is a special case.

Keywords: Planck's formula, photon model, Tesla, new paradigm, gravitational field, Sjödin's insight on general relativity.

1. Introduction

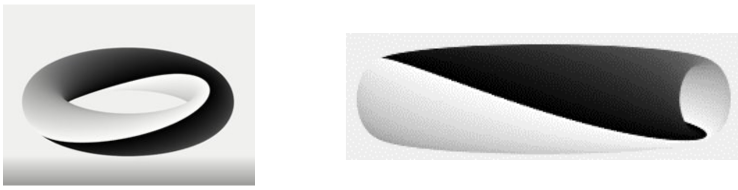
To determine the limits of applicability of Planck's formula, a physical model of the photon is needed. The dominant paradigm lacks such a model: photons are massless, point-like particles without structure.

A physical model of a free photon was proposed in a new physical paradigm (Bakman, A New Physical Paradigm, 2020). This model is based on Tesla's primary substance, a continuous fundamental medium, from which all matter is made (Tesla, 1908). In this model, elementary particles, atoms, and molecules are stable vortices of primary substance.

The new paradigm has already solved 22 unsolvable problems in physics (Bakman, A List of Unresolved Problems in Physics, Solved by the New Paradigm, 2024).

2. Photon model

According to the presented model, a photon is a stretched toroid, along which a density wave of primary substance circulates (Fig. 1). The wave closes on itself, and a cycle is formed.



a) b)

Fig. 1. Elementary particles and atoms are stable vortices of primary substance: a) an electron vortex; b) a photon vortex. The photon has a toroidal shape similar to that of an electron but is highly elongated.

A counter question immediately arises: Why did the Michelson–Morley experiment not detect motion relative to the primary substance?

The traditional interpretation of the Michelson–Morley experiment overlooked a subtle kinematic effect (Marmet, 2000). When a beam is reflected from a moving semi-transparent mirror, the reflection angle differs slightly from that of a stationary mirror — analogous to a ping-pong ball rebounding differently from a moving paddle.

Accounting for this angular correction removes the apparent contradiction and reconciles the null result with the hypothesis of an absolute reference frame.

In our work (Bakman, What makes a photon move? A paradigm shift in physics, 2017), the linear dimensions of a free photon *R, a, b* (Fig. 2) were calculated in terms of its wavelength λ.

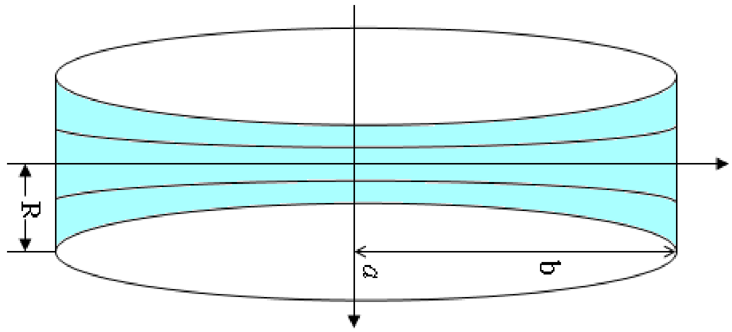


Fig. 2. Cross-section of a photon in free flight, according to its proportions.

Free photons are similar: they have the same shape, with the corresponding dimensions being proportional (related by a scale factor) and the corresponding angles being equal.

Let us consider a free photon with energy E and diameter D at the center.

The energy of the photon is contained in the compression of its vortex — if the photon is compressed by a factor of n, its energy will increase by a factor of n.

Consequently, the product of E and D remains constant for free photons of different energies:

$$E \cdot D = const \qquad (1)$$

The period T of a photon's revolutions equals

$$T = \pi\, D/u$$

where u is the transverse component of the vortex wave velocity (see Fig. 3).

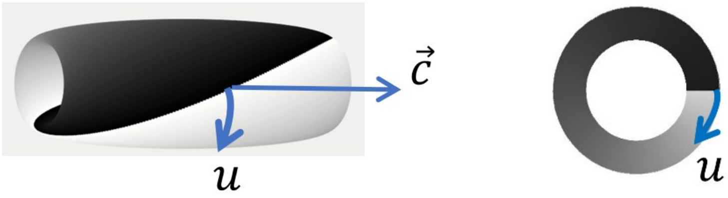


Fig. 3. The two components of the wave front velocity (left) and the photon's cross-section perpendicular to its velocity $\vec{c}$ (right). $\vec{c}$ is also the longitudinal component of the wave front velocity.

The photon's frequency depends on its size and the speed of the vortex wave:

$$\nu = \frac{1}{T} = \frac{u}{\pi\, D} \tag{2}$$

We obtain

$$h = \frac{E}{\nu} = \frac{E\, \pi\, D}{u} \tag{3}$$

If we assume that the vortex wave velocity u is constant under all conditions, then we obtain Planck's formula by taking into account Eq. (1).

However, in the new paradigm, the vortex wave velocity depends on the medium. In particular, in a gravitational field, the vortex wave slows down, and the proportionality between E and ν is violated.

In Section 4, we will calculate the value $h = E/\nu$ on the Sun and will compare this value with the Planck constant on the Earth. However, instead of using the general relativity (GR) tensor, we will apply insight from Sjödin.

3. Sjödin's insight into GR

In 1990, Torgny Sjödin published a paper (Sjödin, 1990) in which a gravitational field is described by a scalar: a refracting index ρ is ascribed to every point in space. Then, the velocity of light c is given by

$$c = \frac{c_0}{\rho}$$

where c_0 is the speed of light at infinity.

If ρ is not constant, then the vacuum is inhomogeneous, and a gravitational field is present.

Sjödin provided a clear understanding of the underlying principles of GR. In a gravitational field, rods bend, and the frequencies of atomic clocks change with altitude. These effects lead to distortions in measurements. Einstein adopted the approach of using such instruments for measurements.

In GR, the 4-tensor field with 10 independent components at each point in spacetime represents a cumbersome mechanism for overcoming measurement distortions.

Moreover, the GR tensor was developed while taking into account the distortions of atomic clocks. However, other types of clocks exist—for example, pendulum clocks slow down at increasing altitude, whereas atomic clocks speed up. Therefore, to account for the distortions of other clocks, a different theory with its own curved spacetime and tensor is needed.

This line of reasoning indicates that the spacetime of GR does not represent a physical reality, but rather a mathematical device with many variations.

In contrast, Sjödin chose an approach in which measurements are performed by a class of measuring rods whose dimensions do not change in a gravitational field. These rods measure Euclidean geometry by definition. Analogically, time intervals are measured by standard clocks, with no need to correct the measurement results.

Sjödin showed that his approach can replace the tensor formalism of GR while reproducing its observational predictions if we calculate the speed of light in a static, spherically symmetric gravitational field using the formula

$$c = c_0 \exp\left(-\frac{m}{R}\right) \qquad (4)$$

where m is the Schwarzschild radius of the gravitating body and R is the distance to its center.

Using Euclidean geometry and absolute time with a variable speed of light, Sjödin derived all four classical tests of GR in a mathematically simpler way than invoking curved spacetime.

These two theories collided in practice in the Global Positioning System (GPS). The cesium atomic clock of GPS is tuned so that its microwave oven frequency provides resonant absorption of the oven radiation by cesium atoms. The oven pulses serves as clock ticks (Global Positioning System, 2026).

The first satellite was launched without the clock adjustment built into subsequent satellites. This clock ran 38 μs/day faster than those on the Earth. In later versions, the clock adjustment was built in so that the clock readings coincided with the Earth standard time, as required by Sjödin's approach.

Sjödin’s theory is a part of the new paradigm.

4. Calculation of Planck's constant on the Sun

As shown in Eq. (3), the value of h is inversely proportional to the component u of the vortex wave velocity. Because the angles are equal for similar shapes, u and c are directly proportional:

$$\frac{h_{sun}}{h_{Earth}} = \frac{u_{Earth}}{u_{sun}} = \frac{c_{Earth}}{c_{sun}} \qquad (5)$$

Here, Sjödin's approach provides valuable insight. We substitute the speed of light from Eq. (4) into Eq. (5) and obtain

$$\frac{h_{sun}}{h_{Earth}} = c_0 \exp\left(-\frac{m_{Earth}}{R_{Earth}}\right) / c_0 \exp\left(-\frac{m_{sun}}{R_{sun}}\right)$$

$$\frac{h_{sun}}{h_{Earth}} = \exp\left(\frac{m_{sun}}{R_{sun}} - \frac{m_{Earth}}{R_{Earth}}\right) \qquad (6)$$

We substitute the values of *m* and *R* for the Earth and the Sun:

Earth radius = 637,1000 m

Schwarzschild radius of the Earth = 0.00887 m

Sun radius = 695,700,000 m

Schwarzschild radius of the Sun = 2950 m

ratio of *h* on the Sun to *h* on the Earth $\frac{h_{sun}}{h_{Earth}} = 1.00000423$

h_{Earth}=6.62607015×10^{-34} J·s

$h_{sun} =$ 6.62609824×10^{-34} J·s

Conclusions

When a physical model of the photon is presented, it is possible to derive a formula connecting the photon energy to its frequency. The formula derived in this work shows that a gravitational field is a factor that violates the proportionality between E and ν. Our calculations show that the difference between the *h* values for the Earth and the Sun is three orders of magnitude greater than the measurement error of h_{Earth}.

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