Photon's Spin, Diffraction, and Radius The One-Photon Hypothesis, and Stopped Photon

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Abstract The Photon's Spin is a negligible fraction of $\hbar$.

We present a ring model for the photon to approximate its spin, explain its diffraction, approximate its radius, and explain a stopped photon. The model leads to our ***One-Photon Hypothesis***: that *photon colors are different energy states of one single photon*.

We assume that a photon ϕ is composed of two radiation particles of opposite charges, subphotons, moving along a circle of radius r_ϕ at light speed c, $\frac{c}{2\pi r_\phi} = \nu_\phi$ times per second.

This harmonic motion associates with the photon a wave of length $\lambda_\phi = 2\pi r_\phi$, *and explains photon's interference, diffraction, and polarization*.

For $\lambda_\phi = 5 \cdot 10^{-7}\mathrm{m}$, the photon's radius is $r_\phi = \frac{\lambda_\phi}{2\pi} \approx 8 \cdot 10^{-6}$.

The photon's frequency, mass, and energy are proportional to $\frac{1}{r_\phi}$

$$\nu_\phi = \frac{c}{2\pi r_\phi},$$

$$m_\phi = \frac{h}{2\pi r_\phi c} + \frac{\frac{1}{2}+\frac{1}{\pi}}{18\cdot 10^7}\frac{e^2}{r_\phi} \approx \frac{h}{2\pi r_\phi c}$$

$$h\nu_\phi = \underbrace{-\frac{\frac{1}{2}+\frac{1}{\pi}}{18\cdot 10^7}\frac{e^2}{r_\phi}c^2}_{\text{Rotation and Binding}} + \underbrace{m_\phi c^2}_{Translation} \approx m_\phi c^2.$$

In the ring model, if the mass of a Subphoton is δ_1,

the Photon's Spin is $2\delta_1 c r_\phi$, *which is close to* $4\times 10^{-21}\hbar$

For $\lambda_\phi = 5\cdot 10^{-7}\,\mathrm{m}$, the Subphotons mass is the order of $10^{-4} m_\phi$.

The Photon Ring Model leads to our ***One-Photon Hypothesis***

Each photon's radius r_ϕ *determines a different color* ν_ϕ, *and is considered a different photon. But what appears as a different photon is only a different energy state with energy* $h\nu_\phi$, *of one single photon.*

A ***Stopped Photon*** *has zero translation energy,* $\frac{1}{2}m_\phi c^2$, *but exists with its rotation and binding energy,* $-\frac{\frac{1}{2}+\frac{1}{\pi}}{18\cdot 10^7}\frac{e^2}{r_\phi}c^2$, *which is its Rest Energy.*

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Contents

The Photon's Spin is not $\hbar$

0.1 $m_\phi c r_\phi = \hbar$ ***is not a Photon Spin***

In the absence of structure, the photon's spin is taken to be

$$m_\phi c r_\phi = m_\phi c \frac{c}{2\pi\nu_\phi}$$

$$= \frac{1}{2\pi} \underbrace{m_\phi c^2}_{\approx h\nu_\phi} \frac{1}{\nu_\phi}$$

$$= \frac{h}{2\pi} = \hbar .$$

But $m_\phi c r_\phi$ is the Angular Momentum of a point mass m_ϕ circulating a center at a distance r_ϕ.

The photon has no such structure, and $m_\phi c r_\phi = \hbar$ is not the Spin of any photon.

1.

Fractional Charges

In 1928, J. J. Thomson presented in [Thomson,p.33], experimental evidence that the electron is a composite particle.

> "*…the properties of the electron recently discovered lead to the view that the electron…has itself a structure, being made up of smaller parts which carry charges of electricity*."

Later, Millikan presented in [Millikan, p. 161] evidence from his experiments for the existence of Subelectrons.

> "*…Ehrenhaft and Zerner even analyze our report on oil droplets and find that these also show in certain instances indications of* ***sub-electrons****, for they yield in these observers' hands too low values of e, whether computed from the Brownian movement or from the law of fall*."

These statements were made long before it has been established that the proton, and the neutron are composed of subparticles with fractional charges.

The evidence for subelectrons had to lead to a planetary model for the electron. Just to balance the electric forces on them, the Subelectrons must be moving, and since they are not going anywhere, the motion is in a closed orbit.

The existence of fractional charges, and subelectrons, is now well-established. For instance, [Wagoner, pp. 541-5].

2.

Diffraction and De Broglie Longitudal Wave

Diffraction of light had to lead to harmonic motion of subphotons within the photon. That harmonic motion manifests itself in a physical wave.

Without the subphotons circulating within the boundaries of the photon, the transversal wave implicated by the diffraction of photons remains a puzzle.

2.1 De Broglie Longitudal Wave

De Broglie wave is based on the speculation that like the photon ϕ which is a particle with speed c, and a Longitudal wavelength

$$\lambda_\phi = \frac{c}{\nu_\phi} = \frac{hc}{h\nu_\phi} = \frac{hc}{m_\phi c^2} = \frac{h}{m_\phi c},$$

any particle p with speed v_p, has an associated wavelength

$$\lambda_p = \frac{h}{m_p v_p}.$$

The diffraction of electrons that must be due to harmonic motion of their subparticles, was erroneously interpreted as support for a wiggling electron.

Then, the De Broglie Longitudal wave was adopted to explain the wave motion of the photon, although it is impossible to visualize a photon wiggling along it path.

The De Broglie Longitudal wave is inconsistent with the transversal classical electromagnetic wave that the photon is supposed to represent.

Instead, a property called wave particle duality was invented.

Even De Broglie realized that his wave represents the uncertainty in the particle location, [Dan].

Thus, the denial of subphotons eliminated the transversal wave that underlies their harmonic motion, and the photon remained a puzzle as to whether it is a wave or a particle.

It remained unclear

- What is the meaning of the frequency ν in the photon's energy?
- Which harmonic motion is taking place while the light particle is moving along a line at speed c?
- Can photon energy lead to an explanation of diffraction, and interference?

2.2 The Transversal Harmonic Motion

The diffraction and polarization of light indicate harmonic motion transversal to the direction of the propagation.

The circular motion of Subphotons about the center, projects a harmonic motion that appears as a propagating wave.

3.

Subphotons' Origin

3.1 Subphotons

The frequency ν in the Radiation Energy

$$h\nu,$$

suggests a harmonic motion associated with the photon.

Subphotons-two radiation particles of opposite signs-are more likely than a spinning sphere of energy.

Then, the centripetal forces of repulsion will balance the Lorentz magnetic and electric forces of attraction, to yield a stable structure.

If we'll assume that the photon is a current-ring of radius r_ϕ, composed of two Subphotons that encircle its center at light speed, the assumed harmonic motion takes place in the photon's interior.

3.2 Subphotons release in annihilation

In the merging of an electron-positron pair, mass energy transforms into radiation energy

$$m_e c^2 + m_e c^2 \to h\nu + h\nu,$$

with frequency

$$\nu = \frac{m_e c^2}{h}.$$

It is likely that similarly to the proton, the electron is a composite particle made of

- one Subelectron with charge $-\frac{1}{3}e$, and mass ε_1
- two Subelectrons with charges $\frac{2}{3}e$, and masses ε_2.

The breakup of the electron-positron pair supplies subparticles that may combine to

- a photon made of $-\frac{1}{3}e$, and $\frac{1}{3}e$ charges
- a photon made of $-\frac{2}{3}e$, and $\frac{2}{3}e$ charges

Thus, the subphotons are likely to have equal masses, and opposite signs.

3.3 Subphotons release in Antenna Radiation

In the acceleration of electrons by an alternating voltage of frequency ν along an antenna, the electrons radiate photons of energy $h\nu$.

Since an electron at rest does not radiate, the subelectrons encircle its center at one non-radiating orbit.

Thus, the source of the subphotons may be subelectrons torn off the electrons that are pounded by the vibrations at frequency ν. If so, the torn subelectrons will be moving at light speed c, because of the absence of a process to accelerate them to light speed.

Some subelectrons will merge with their anti-particles into a circle, and encircle a center at the vibrations frequency ν to become photons of energy $h\nu$. The frequency of the harmonic motion along the circle should be identical to the frequency of the generating vibrations.

4.

Subphotons' Motion

4.1 Closed Orbit

To stay within the photon boundaries,

the subphotons should have a closed orbit.

4.2 Central Force

By [Routh, p. 274], a closed orbit results from a central force that is proportional to the inverse square of the distance,(such as the Coulomb electric force) or directly to the distance(such as the centripetal force).

Opposite sign charges supply the electric force to close the orbit.

4.3 Orbit Stability

By [Routh, p.280] Central Force orbits are stable. That is, they are bounded in a ring between two circles. The stability of the photon indicates such orbits.

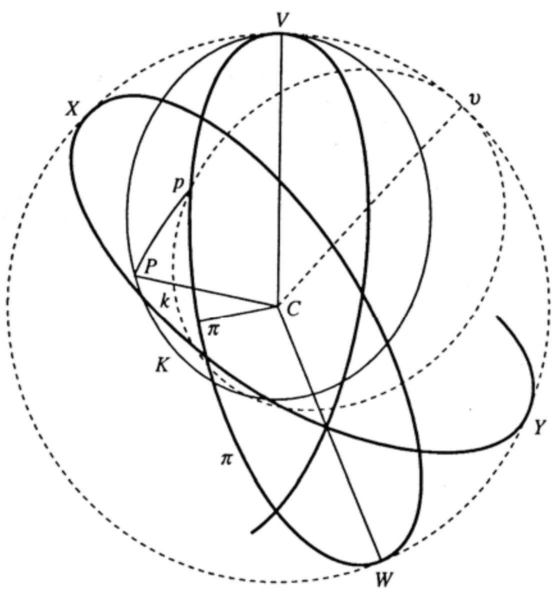
Diffraction implies harmonic motion along a circular path.

4.4 Planar Motion

Since the electric force is inverse squared law force, *both orbits will be in the same plane,*

and not on a sphere

The plane of motion of the particle turns around to generate a sphere <u>only under a non-inverse squared law force.</u>



[Chandrasekhar, p. 195].

Polarization of light confirms that

the plane's orientation, and direction in space are fixed.

Since the subphotons' masses are equal, the orbits' radii will equal, and

the two subphotons will be on the same circle of radius r_ϕ

4.5 Subphotons' Speed

Since the Subphotons are radiation particles, they move at light speed c. Thus,

The Circle's Center propagates along a line at speed c.

Also,

The Subphotons' tangential speed along the circle must be c.

Thus,

the subphotons orbit the center $\nu_\phi = \dfrac{c}{2\pi r_\phi}$ *times per second.*

4.6 The Photon Radius r_ϕ.

The Subphotons circulate the vortex center at light speed

$$c = \underbrace{\lambda_\phi}_{2\pi r_\phi} \nu_\phi = r_\phi \underbrace{2\pi\nu_\phi}_{\omega_\phi},$$

where

the photon's wavelength is the ring circumference, $\lambda_\phi = 2\pi r_\phi$.

The photon radius is

$$\boxed{r_\phi = \frac{c}{\omega_\phi} = \frac{c}{2\pi\nu_\phi} = \frac{1}{2\pi}\lambda_\phi}$$

r_ϕ is of the order of the photon wavelength.

5.

Subphotons' Energies, and Mass

5.1 Subphotons' Charges

To have zero charge, the sub-photons must have opposite charges:

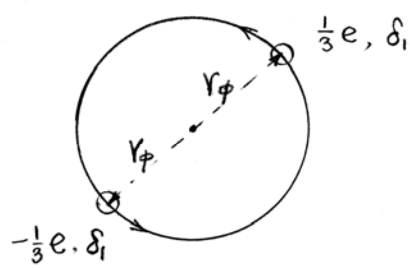
$\frac{1}{3}e$, and $-\frac{1}{3}e$, each with mass δ_1

or

$\frac{2}{3}e$, and $-\frac{2}{3}e$, each with mass δ_2

Perhaps, only one of these combinations occurs.

We'll first assume that the photon is a circular current vortex composed of the charges $\frac{1}{3}e$, and $-\frac{1}{3}e$, each with mass δ_1,



5.2 Coulomb Electric Attraction between the Subphotons

$$-\frac{1}{4\pi\varepsilon_0}\frac{(\frac{1}{3}e)^2}{(2r_\phi)^2}.$$

5.3 Lorentz Magnetic Attraction between the Subphotons

$$-\frac{2}{\pi}\frac{1}{4\pi\varepsilon_0}\frac{(\frac{1}{3}e)^2}{(2r_\phi)^2}.$$

__Proof__: The charge $\frac{1}{3}e$ generates the current $\frac{1}{3}e\nu$, which at distance $2r_\phi$, has the magnetic field

$$\mu_0\frac{1}{2\pi(2r_\phi)}(\tfrac{1}{3}e\nu_\phi) = \mu_0\frac{1}{4\pi r_\phi}\tfrac{1}{3}e\frac{c}{2\pi r_\phi}$$

$$= \frac{1}{2\pi}\frac{\mu_0}{\pi}\frac{\frac{1}{3}ec}{(2r_\phi)^2}.$$

That field applies on the $-\frac{1}{3}e$ charge, the Lorentz force,

$$(-\tfrac{1}{3}e)c(\frac{1}{2\pi}\frac{\mu_0}{\pi}\frac{\frac{1}{3}ec}{(2r_\phi)^2}) = -\frac{2}{\pi}\frac{\mu_0 c^2}{4\pi}\frac{(\frac{1}{3}e)^2}{(2r_\phi)^2}$$

$$= -\frac{2}{\pi}\frac{1}{4\pi\varepsilon_0}\frac{(\frac{1}{3}e)^2}{(2r_\phi)^2}.$$

5.4 The Centripetal Repulsion on the Subphotons

$$2\delta_1\frac{c^2}{r_\phi}.$$

5.5 Forces Balance $\quad 2\delta_1\frac{c^2}{r_\phi} = \frac{1}{4\pi\varepsilon_0}\frac{(\frac{1}{3}e)^2}{(2r_\phi)^2}(1+\frac{2}{\pi})$

5.6 Subphotons' Energies Balance

$$\underbrace{4\delta_1 \underbrace{c^2}_{\omega_\phi^2 r_\phi^2}}_{\text{rotation repulsion}} = \underbrace{\frac{1}{4\pi\varepsilon_0}\frac{(\frac{1}{3}e)^2}{2r_\phi}(1+\tfrac{2}{\pi})}_{\text{electro-magnetic binding}}$$

$$= \underbrace{\frac{c^2}{10^7}\frac{(\frac{1}{3}e)^2}{2r_\phi}(1+\tfrac{2}{\pi})}_{\text{electro-magnetic binding}}$$

5.7 The Subphoton Mass δ_1

$$\delta_1 = \frac{1}{10^7}\frac{(\frac{1}{3}e)^2}{\lambda_\phi}(\tfrac{\pi}{4}+\tfrac{1}{2})$$

Proof:

$$2\delta_1 \frac{c^2}{r_\phi} = \frac{1}{4\pi\varepsilon_0}\frac{(\frac{1}{3}e)^2}{(2r_\phi)^2}(1+\tfrac{2}{\pi})$$

$$\delta_1 = \frac{\mu_0}{4\pi}\frac{(\frac{1}{3}e)^2}{2r_\phi}(\tfrac{1}{4}+\tfrac{1}{2\pi})$$

$$= \frac{1}{10^7}\frac{(\frac{1}{3}e)^2}{\lambda_\phi}(\tfrac{\pi}{4}+\tfrac{1}{2})$$

5.8 Example from the visible spectrum

For $\lambda_\phi = 5\cdot 10^{-7}\,\mathrm{m}$,

$$\nu_\phi = \frac{3\cdot 10^8}{5\cdot 10^{-7}} = 6\cdot 10^{14}\,\mathrm{Hz}$$

$$\delta_1 = \frac{1}{10^7 9}\frac{e^2}{5\cdot 10^{-7}}(\tfrac{\pi}{4}+\tfrac{1}{2})$$

$$\approx (7.3)10^{-40}\text{Kg}$$

5.9 The Subphoton Mass δ_2

Assume that the photon is a current vortex composed of charges

$\frac{2}{3}e$, and $-\frac{2}{3}e$, each with mass δ_2.

By 5.2, the electric attraction is

$$-\frac{1}{4\pi\varepsilon_0}\frac{(\frac{2}{3}e)^2}{(2r_\phi)^2}$$

By 5.3, the magnetic attraction is

$$-\frac{4}{\pi}\frac{1}{4\pi\varepsilon_0}\frac{(\frac{2}{3}e)^2}{(2r_\phi)^2}.$$

By 5.4, the centripetal forces on the two subphotons are

$$2\delta_2\frac{c^2}{r_\phi}.$$

The forces balance is

$$2\delta_2\frac{c^2}{r_\phi} = \frac{4}{4\pi\varepsilon_0}\frac{(\frac{1}{3}e)^2}{(2r_\phi)^2}(1+\tfrac{4}{\pi})$$

$$\delta_2 = \frac{\mu_0}{4\pi}\frac{(\frac{1}{3}e)^2}{2r_\phi}(1+\tfrac{4}{\pi})$$

$$= \frac{1}{10^7} \frac{(\frac{1}{3} e)^2}{\lambda_\phi} (\pi + 4)$$

$$= 4\delta_1 .$$

For $\lambda_\phi = 5 \cdot 10^{-7} \mathrm{m}$,

$$\delta_1 \approx (7.3) 10^{-40} \mathrm{Kg},$$

$$\delta_2 \approx (2.9) 10^{-39} \mathrm{Kg}.$$

6.

Binding Electric Energy

We'll first assume that the photon is a circular current vortex composed of the charges

$$\tfrac{1}{3}e, \text{ and } -\tfrac{1}{3}e, \text{ each with mass } \delta_1.$$

6.1 The Photon's Binding Electric Energy

$$U_{electric} = -\frac{c^2}{18\cdot 10^7}\frac{e^2}{r_\phi} = -\frac{c\pi\nu_\phi e^2}{10^7\cdot 9}$$

Proof:

$$U_{electric} = \frac{1}{4\pi\varepsilon_0}\frac{(-\frac{1}{3}e)(\frac{1}{3}e)}{2r_\phi}$$

$$= -\frac{1}{72\pi\varepsilon_0}\frac{e^2}{r_\phi}$$

$$= -\frac{\mu_0 c^2}{72\pi}\frac{e^2}{r_\phi}$$

$$= -\frac{c^2}{18\cdot 10^7}\frac{e^2}{r_\phi}$$

$$= -\frac{c\pi\nu_\phi e^2}{10^7 9}.$$

6.2 The Photon's Binding Electric Energy is negligible compared with the photon's Radiation Energy

<u>*Proof*</u>:
$$= \frac{\dfrac{c\pi\nu_\phi e^2}{10^7 9}}{h\nu_\phi} = \frac{\pi c e^2}{10^7 9 h} \approx \pi \frac{3\cdot 10^8 (1.6)^2 10^{-38}}{10^7 9(6.63)10^{-34}} \approx 4\cdot 10^{-4}.$$

7.

Binding Magnetic Energy

7.1 The Photon's Binding Magnetic Energy

$$U_{magnetic} = -\frac{2}{\pi}\frac{c^2}{18\cdot 10^7}\frac{e^2}{r_\phi} = -\tfrac{2}{\pi}\frac{c\pi\nu_\phi e^2}{10^7\cdot 9}$$

Proof: The current due to the $-\tfrac{1}{3}e$ charge that turns ν_ϕ cycles/second is

$$I = -\tfrac{1}{3}e\nu_\phi.$$

The Magnetic Energy of this current is [Benson, p.486]

$$\tfrac{1}{2}LI^2.$$

By [Fischer, p.97]

$$L = \mu_0\frac{\pi(2r_\phi)^2}{2\pi(2r_\phi)} = \mu_0 r_\phi.$$

Thus, the magnetic energy due to the $-\tfrac{1}{3}e$ charge is

$$-\tfrac{1}{2}\mu_0 r_\phi(\tfrac{1}{3}e\nu_\phi)^2.$$

The same magnetic energy is generated by the $\tfrac{1}{3}e$ charge.

Therefore, the Magnetic Energy of the photon ring is

$$U_{magnetic} = -\mu_0 r_\phi(\tfrac{1}{3}e\nu_\phi)^2$$

$$= -\frac{4\pi}{10^7} r_\phi \tfrac{1}{9} e^2 \nu_\phi \frac{c}{2\pi r_\phi}$$

$$= -\frac{2}{10^7} \tfrac{1}{9} e^2 \nu_\phi c$$

$$= -\tfrac{2}{\pi} \frac{c\pi\nu_\phi e^2}{10^7 \cdot 9}.$$

7.2 The Binding Magnetic Energy is negligible compared with the photon's Radiation Energy

Proof: It is $\tfrac{2}{\pi}$ of the binding electric energy, which is negligible compared with the photon's radiation energy.

8.

Photon's Rotation Energy

8.1 The Rotation Energy of the Subphotons

$$2\delta_1\omega_\phi^2 r_\phi^2 = \frac{c^2}{18\cdot 10^7}\frac{e^2}{r_\phi}(\tfrac{1}{2}+\tfrac{1}{\pi}) = \frac{c\pi\nu_\phi e^2}{10^7\cdot 9}(\tfrac{1}{2}+\tfrac{1}{\pi})$$

Proof: The rotation energy of the subphotons is

$$2\delta_1\omega_\phi^2 r_\phi^2 = 2\delta_1 c^2$$

$$= \frac{1}{8\pi\varepsilon_0}\frac{(\frac{1}{3}e)^2}{2r_\phi}(1+\tfrac{2}{\pi}), \quad \text{by (4.6)}$$

$$= \frac{c^2}{18\cdot 10^7}\frac{e^2}{r_\phi}(\tfrac{1}{2}+\tfrac{1}{\pi}), \quad \text{by (6.1), and (7.1)}$$

$$= \frac{c\pi\nu_\phi e^2}{10^7\cdot 9}(\tfrac{1}{2}+\tfrac{1}{\pi}), \quad \text{by (6.1), and (7.1)}$$

8.2 The Subphotons' Rotation Energy is negligible compared with the photon's energy

Proof: The rotation energy is $(\frac{1}{2}+\frac{1}{\pi})$ of the binding electric energy, which is negligible compared with the photon's radiation energy.

9.

The Photon's Energy

9.1 The Photon's Energy

$$\boxed{h\nu_\phi = \underbrace{-\frac{\frac{1}{2}+\frac{1}{\pi}}{18\cdot 10^7}\frac{e^2}{r_\phi}c^2}_{\text{Rotation and Binding}} + \underbrace{m_\phi c^2}_{Translation} \approx m_\phi c^2},$$

$$m_\phi = \frac{h}{2\pi r_\phi c} + \frac{\frac{1}{2}+\frac{1}{\pi}}{18\cdot 10^7}\frac{e^2}{r_\phi} \approx \frac{h}{2\pi r_\phi c}.$$

Proof:
$$h\nu_\phi = \underbrace{\underbrace{2\delta_1\omega_\phi^2 r_\phi^2}_{Rotation} - \underbrace{\frac{1+\frac{2}{\pi}}{18\cdot 10^7}\frac{e^2c^2}{r_\phi}}_{Binding}}_{-\frac{1}{2}\frac{1+\frac{2}{\pi}}{18\cdot 10^7}\frac{e^2c^2}{r_\phi}} + \frac{h}{c}\frac{c^2}{2\pi r_\phi} + \frac{\frac{1}{2}+\frac{1}{\pi}}{18\cdot 10^7}\frac{e^2c^2}{r_\phi}$$

$$= \underbrace{2\delta_1\omega_\phi^2 r_\phi^2}_{Rotation} - \underbrace{\frac{1+\frac{2}{\pi}}{18\cdot 10^7}\frac{e^2c^2}{r_\phi}}_{Binding} + \underbrace{\left(\frac{h}{2\pi r_\phi c} + \frac{\frac{1}{2}+\frac{1}{\pi}}{18\cdot 10^7}\frac{e^2}{r_\phi}\right)}_{m_\phi}c^2.$$

Denoting

$$m_\phi = \frac{h}{2\pi r_\phi c} + \frac{\frac{1}{2}+\frac{1}{\pi}}{18\cdot 10^7}\frac{e^2}{r_\phi},$$

$$h\nu_{\phi} = \underbrace{-\frac{\frac{1}{2}+\frac{1}{\pi}}{18\cdot 10^{7}}\frac{e^{2}}{r_{\phi}}c^{2}}_{\text{Rotation and Binding}} + \underbrace{m_{\phi}c^{2}}_{Translation}$$

Since the rotation ,and the electromagnetic binding energies are negligible,

$$h\nu_{\phi} \approx m_{\phi}c^{2}.$$

10.

Photon's Radius-Energy Relation

10.1 *Photon's Frequency, mass, and Energy are proportional to* $\frac{1}{r_\phi}$,

$$\nu_\phi = \frac{c}{2\pi}\frac{1}{r_\phi},$$

$$m_\phi = \frac{h}{2\pi r_\phi c} + \frac{\frac{1}{2}+\frac{1}{\pi}}{18\cdot 10^7}\frac{e^2}{r_\phi}$$

$$\boxed{h\nu_\phi = \frac{hc}{2\pi}\frac{1}{r_\phi}}$$, *the photon Radius-Energy Relation*

10.2

$$\frac{r_{\phi_1}}{r_{\phi_2}} = \frac{\nu_{\phi_2}}{\nu_{\phi_1}} = \frac{m_{\phi_2}}{m_{\phi_1}} = \frac{h\nu_{\phi_2}}{h\nu_{\phi_1}}$$

10.3 *A blue photon radius is* $\frac{2}{3}$ *of a red photon radius,* $r_{blue} \approx \frac{2}{3} r_{red}$

A blue photon energy is $\frac{3}{2}$ *of a red photon energy,* $h\nu_{blue} \approx \frac{3}{2} h\nu_{red}$

Proof: $\lambda_{blue} \approx 4400A^\circ$, $\lambda_{red} \approx 6600A^\circ$,

$$\frac{\nu_{red}}{\nu_{blue}} = \frac{r_{blue}}{r_{red}} = \frac{\lambda_{blue}}{\lambda_{red}} \approx \frac{4400A^\circ}{6600A^\circ} = \frac{2}{3}.$$

11.

Photon's Mass

The quantity

$$m_\phi = \frac{h}{2\pi r_\phi c} + \frac{\frac{1}{2}+\frac{1}{\pi}}{18\cdot 10^7}\frac{e^2}{r_\phi}$$

$$\approx \frac{h}{c}\frac{1}{2\pi r_\phi} = \frac{h\nu_\phi}{c^2}$$

that satisfies the mass energy equation

$$h\nu_\phi \approx m_\phi c^2$$

may be viewed as the photon's mass.

The Subphoton mass is much smaller.

This is similar to the u, and d quarks which masses appear to be much smaller than the proton, and neutron masses.

11.1 Example from the visible spectrum

For $\lambda_\phi = 5\cdot 10^{-7}\,\mathrm{m}$,

$$\nu_\phi = \frac{3\cdot 10^8}{5\cdot 10^{-7}} = 6\cdot 10^{14}\,\mathrm{Hz},$$

$$m_\phi \approx \frac{h\nu_\phi}{c^2}$$

$$\approx \frac{1}{9 \cdot 10^{16}} (6.6) 10^{-34} \cdot 6 \cdot 10^{14}$$

$$= (4.4) 10^{-36} \text{Kg}$$

In (5.8), we found for the Subphoton,

$$\delta_1 \approx (7.3) 10^{-40} \text{Kg}$$

12.

Photon's Spin, and Color

12.1 The Subphotons' Orbital Angular Momentum

$$2\delta_1 c r_\phi = \frac{\alpha}{9c^2}(\tfrac{1}{4} + \tfrac{1}{2\pi})\hbar \approx 3.7 \times 10^{-21}\hbar,$$

where $\alpha \approx \frac{1}{137}$ *is the fine structure constant.*

<u>*Proof*</u>:

$$2\delta_1 c r_\phi = 2\delta_1 c \frac{c}{2\pi\nu_\phi}$$

Substituting $\delta_1 = \frac{1}{10^7}\frac{(\frac{1}{3}e)^2}{\lambda_\phi}(\frac{\pi}{4} + \frac{1}{2})$,

$$2\delta_1 c r_\phi = 2\frac{1}{10^7}\frac{(\frac{1}{3}e)^2}{\lambda_\phi}(\tfrac{\pi}{4} + \tfrac{1}{2})\frac{1}{2\pi\nu_\phi}$$

$$= \frac{1}{c10^7 \cdot 9}e^2(\tfrac{1}{4} + \tfrac{1}{2\pi})$$

Substituting $e^2 = \frac{2h\alpha}{\mu_0 c}$, where $\alpha \approx \frac{1}{137}$,

$$= \frac{1}{c10^7 \cdot 9}\frac{2h\alpha}{\mu_0 c}(\tfrac{1}{4} + \tfrac{1}{2\pi})$$

$$= \frac{\alpha}{9c^2}(\tfrac{1}{4} + \tfrac{1}{2\pi})\hbar$$

$$\approx \frac{\frac{1}{4} + \frac{1}{2\pi}}{9^2 10^{16} 137}\hbar$$

$$\approx 3.7 \times 10^{-21} \hbar$$

Therefore,

12.2 *The Photon's Spin is fixed for any photon of any color.*

13.

One-Photon Hypothesis

The photon ring model suggests that photon's colors are just different energy states of one photon.

In particular, subphotons appear to be former subelectrons, and there is only one electron,

13.1 The One-Photon Hypothesis

Each photon's radius r_ϕ determines a different color ν_ϕ,

and is considered a different photon.

But what appears as a different photon is only a different energy

state with energy $h\nu_\phi$, of one photon,

14.

Stopped Photon's Energy

Slow light is a well known phenomena, [Milonni], [Khurgin], and a photon may be brought to a halt.

14.1 The Stopped Photon Energy

$$-\frac{\frac{1}{2}+\frac{1}{\pi}}{18\cdot 10^{7}}\frac{e^{2}}{r_{\phi}}c^{2}$$

Proof: From (5.7), we have

$$h\nu_{\phi} = \underbrace{-\frac{\frac{1}{2}+\frac{1}{\pi}}{18\cdot 10^{7}}\frac{e^{2}}{r_{\phi}}c^{2}}_{\text{Rotation and Binding}} + \underbrace{m_{\phi}c^{2}}_{Translation}$$

A stopped photon would have zero translation energy

$$m_{\phi}c^{2}.$$

But will exist with its rotation and binding energy,

$$-\frac{\frac{1}{2}+\frac{1}{\pi}}{18\cdot 10^{7}}\frac{e^{2}}{r_{\phi}}c^{2},$$

which is its Rest Energy.

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