Determination of Photon Mass with its Main Physical Parameters
Energy, Wavelength and Velocity

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Abstract

The photon mass as a particle can be determined by its main physical parameters (energy, wavelength, velocity). The determined photon mass is $2.2 \times 10^{-34}$ kg and it is the same value of all electromagnetic radiation from gamma rays to radio waves.
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Abstract

The photon mass as a particle can be determined by its main physical parameters (energy, wavelength, velocity). The determined photon mass is $2.2 \times 10^{-34}$ kg and it is the same value of all electromagnetic radiation from gamma rays to radio waves.

Keywords: photon, energy, wavelength, velocity

1. Introduction

A photon is an elementary particle, a quantum of electromagnetic radiation and the force carrier of electromagnetic force. Photon is moving at the speed of light. Photons exhibit wave–particle duality nature and belongs to the type of boson particles. Planck (1901) proposed that the energy stored within a material object should be regarded as composed of an integer number of discrete, equal-sized parts. Einstein (1905) introduced the idea that light itself is made of discrete units of energy.

2. Physical foundations

The particle or corpuscular nature of photon means that it must has mass. All photons of electromagnetic radiation from gamma rays to radio waves are a result of excitation, transition, vibration or rotation of particles (nucleus, atom or molecule). Inside the limits of nucleus, atom or molecule which have distances of $10^{-16}$ m, $10^{-10}$ m, $10^{-9}$ m it can't be measure any of its characteristics (energy, frequency, wavelength, …), so all physical parameters of the photon
can be determined only outside their limits which can be taken as an average distance of \(10^{-8}\) m. The main physical parameter of the photon (Energy & wavelength, velocity) can be used to determine its mass.

3. Mathematical foundation

The photon mass, energy wavelength, velocity and average distance outside (nucleus, atom, molecule) can be connected in the following equation

\[
m_{\text{photon}} = \frac{E \times \lambda}{v^2 \times d} \quad (1)
\]

where
- \(E\) is the energy of photon in J
- \(\lambda\) is the wavelength of photon in m
- \(v\) is the velocity of photon in m/s \((3 \times 10^8\) m/s)
- \(d\) is a distance in m \((10^{-8}\) m)

4. Calculating mass of the photon

4.1 Photon mass in \(\gamma\) – Ray band with frequency \(10^{20}\) Hz

\[
E = 6.6 \times 10^{-14} \text{ kg m}^2\text{s}^{-2}, \quad \lambda = 3 \times 10^{-12} \text{ m}, \quad v^2 \times d = 9 \times 10^{16} \times 10^{-8} = 9 \times 10^8 \text{ m}^3\text{s}^{-2}
\]

then according to equation (1) the photon mass is

\[
m_{\text{photon}} = 2.2 \times 10^{-34} \text{ kg}
\]
4.2 Photon mass in X–Ray band with frequency $10^{18}$ Hz

$E = 6.6 \times 10^{-16} \text{ kg m}^2 \text{s}^{-2}$, $\lambda = 3 \times 10^{-10} \text{ m}$, $v^2 \times d = 9 \times 10^{16} \times 10^{-8} = 9 \times 10^8 \text{ m}^3 \text{s}^{-2}$

then according to equation (1) the photon mass is

$m_{\text{photon}} = 2.2 \times 10^{-34} \text{ kg}$

4.3 Photon mass in ultraviolet band with frequency $10^{16}$ Hz

$E = 6.6 \times 10^{-18} \text{ kg m}^2 \text{s}^{-2}$, $\lambda = 3 \times 10^{-8} \text{ m}$, $v^2 \times d = 9 \times 10^{16} \times 10^{-8} = 9 \times 10^8 \text{ m}^3 \text{s}^{-2}$

then according to equation (1) the photon mass is

$m_{\text{photon}} = 2.2 \times 10^{-34} \text{ kg}$

4.4 Photon mass in visible band with frequency $5 \times 10^{14}$ Hz

$E = 3.3 \times 10^{-19} \text{ kg m}^2 \text{s}^{-2}$, $\lambda = 3 \times 10^{-7} \text{ m}$, $v^2 \times d = 9 \times 10^{16} \times 10^{-8} = 9 \times 10^8 \text{ m}^3 \text{s}^{-2}$

then according to equation (1) the photon mass is

$m_{\text{photon}} = 2.2 \times 10^{-34} \text{ kg}$

4.5 Photon mass in Infra – red band with frequency $10^{14}$ Hz

$E = 6.6 \times 10^{-20} \text{ kg m}^2 \text{s}^{-2}$, $\lambda = 3 \times 10^{-6} \text{ m}$, $v^2 \times d = 9 \times 10^{16} \times 10^{-8} = 9 \times 10^8 \text{ m}^3 \text{s}^{-2}$
then according to equation (1) the photon mass is

\[ m_{\text{photon}} = 2.2 \times 10^{-34} \text{ kg} \]

4.6 Photon mass in microwave band with frequency \(10^{13} \text{ Hz}\)

\[ E = 6.6 \times 10^{-21} \text{ kg m}^2 \text{ s}^{-2}, \lambda = 3 \times 10^{-5} \text{ m}, \nu^2 \times d = 9 \times 10^{16} \times 10^{-8} = 9 \times 10^8 \text{ m}^3 \text{ s}^{-2} \]

then according to equation (1) the photon mass is

\[ m_{\text{photon}} = 2.2 \times 10^{-34} \text{ kg} \]

4.5 Photon mass in radio wave band with frequency \(10^{11} \text{ Hz}\)

\[ E = 6.6 \times 10^{-23} \text{ kg m}^2 \text{ s}^{-2}, \lambda = 3 \times 10^{-3} \text{ m}, \nu^2 \times d = 9 \times 10^{16} \times 10^{-8} = 9 \times 10^8 \text{ m}^3 \text{ s}^{-2} \]

then according to equation (1) the photon mass is

\[ m_{\text{photon}} = 2.2 \times 10^{-34} \text{ kg} \]

5. Conclusion

The particle nature of photon means that it must has mass. The photon mass can be determined from its main physical parameters (energy, wavelength, velocity).

References
