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

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Abstract

The excitation, transition, vibration and rotation of nuclei, atoms and molecules leading to the emission of all photons from gamma rays to radio waves as a result of the physical mechanisms responsible for excited states. The photon energy with its corresponding frequency, wavelength and distance can be determined by the main physical parameters (mass, distance, time) of the mentioned particles (Sanad, 2024). The photon mass as a particle can be determined by its main physical parameters (energy, wavelength, velocity). The determined photon mass is $2.2X10^{-34}$ *kg and it is the same value of all electromagnetic radiation from gamma rays to radio waves.*

Keywords: photon, energy, wavelength, velocity.

Introduction

In 1901 Max Planck published a proposal to describe the spectral distribution of the electromagnetic energy radiated by hot bodies and proposed a concept of quantum of energy (Planck, 1901), which in turn allowed Einstein in 1905 to introduce the concept of photon (Einstein, 1905). Both concepts are an important part of the theoretical foundations of quantum mechanics and its empirical mathematical expression

$$E = h\nu$$

Which is called Planck – Einstein relation. The proportionality constant h is known as Planck's constant and is equal to $6.626x10^{-34}$ $J.Hz^{-1}$.

The 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 belong to the type of boson particles. The photoemission spectroscopy technique has experienced a great advancement in the last few decades (Huefner, 1995; Damascelli et al., 2003; Liu et al., 2008; Zhou et al., (n.d.). In modern photoemission spectroscopy, the energy of the photoelectrons can be precisely measured, and the emission angle of photoelectrons can also be measured that provides information of electron momentum in the measured material.

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 is impossible to measure any of its characteristics or physical parameters (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.

Mathematical Foundation

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

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

where

E is the energy of photon in J
λ is the wavelength of photon in m
v is the velocity of photon in m/s ($3x10^8$ m/s)
d is a distance in m (10^{-8} m)

Calculating Mass of the Photon

Photon mass in γ – Ray band with frequency 10^{20} Hz

$E = 6.6 x10^{-14}$ kg $m^2 s^{-2}$,
$\lambda = 3 x10^{-12}$ m,
$v^2 x d = 9x10^{16}x10^{-8} = 9x10^8$ $m^2 s^{-2}$

then according to equation (1) the photon mass is

$m_{photon} = 2.2X10^{-34}$ kg

Photon mass in *X* – Ray band with frequency 10^18 Hz

$E = 6.6 \times 10^{-16}$ kg m^2 s^{-2},

$\lambda = 3 \times 10^{-10}$ m,

$v^2 \times d = 9x10^{16}x10^{-8} = 9x10^8$ m^3 s^{-2}

then according to equation (1) the photon mass is

$m_{photon} = 2.2X10^{-34}$ kg

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

$E = 6.6 \times 10^{-18}$ kg m^2 s^{-2},

$\lambda = 3 \times 10^{-8}$ m,

$v^2 \times d = 9x10^{16}x10^{-8} = 9x10^8$ m^3 s^{-2}

then according to equation (1) the photon mass is

$m_{photon} = 2.2X10^{-34}$ kg

Photon mass in visible band with frequency $5x10^{14}$ Hz

$E = 6.6 \times 10^{-19}$ kg m^2 s^{-2},

$\lambda = 3 \times 10^{-7}$ m,

$v^2 \times d = 9x10^{16}x10^{-8} = 9x10^8$ m^3 s^{-2}

then according to equation (1) the photon mass is

$m_{photon} = 2.2X10^{-34}$ kg

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

$E = 6.6 \times 10^{-20}$ kg m^2 s^{-2},

$\lambda = 3 \times 10^{-6}$ m,

$v^2 \times d = 9x10^{16}x10^{-8} = 9x10^8$ m^3 s^{-2}

then according to equation (1) the photon mass is

$m_{photon} = 2.2X10^{-34}$ kg

Photon mass in microwave band with frequency 10^{13} Hz

$E = 6.6 \times 10^{-21}$ kg m^2 s^{-2},

$\lambda = 3 \times 10^{-5}$ m,

$v^2 \times d = 9x10^{16}x10^{-8} = 9x10^8$ m^3 s^{-2}

then according to equation (1) the photon mass is

$m_{photon} = 2.2X10^{-34}$ kg

Photon mass in radio wave band with frequency 10^{11} Hz

$E = 6.6 \times 10^{-23}$ kg m^2 s^{-2},

$\lambda = 3 \times 10^{-3}$ m,

$v^2 \times d = 9x10^{16}x10^{-8} = 9x10^8$ m^3 s^{-2}

then according to equation (1) the photon mass is

$m_{photon} = 2.2X10^{-34}$ kg

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). The determined photon mass is less than the electron mass nearly four thousand times and it is the same value of all electromagnetic radiation from gamma rays to radio waves.

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