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The Physical Meaning of Planck's Constant

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Abstract

Max Planck was able to explain the spectrum of black body radiation by introducing h as the fundamental constant of nature. But for several years, including up to now, the scientists have failed to explain the significance of the energy of black body radiation and electromagnetic wave being quantized. In this paper I give physical explanation of both h and $E_n = nh\nu$. Additionally, I state that the particles in electromagnetic waves are negatively charged massless particles whose charge is of the order of 10^{-36} Coulomb, and the current flow in electromagnetic wave is of the order of 10^{-19} Ampere.

Keywords: Black body radiation, electromagnetic wave, light, energy quanta, energy density

1. Introduction

To explain the spectrum of blackbody radiation, Max Planck has to assume that material oscillators of the material forming the enclosure have energies as discrete packets, an integral multiple of $h\nu$ [1].

$$E_n = nh\nu \quad \textbf{(1)}$$

$n = 0,1,2,3 \ldots \ldots \ldots$

There is no energy value intermediate of $(n-1)h\nu$ and $nh\nu$. No one has been able to explain till today that why the black body emits radiation having discrete energy levels. For many years (even) Max Planck (himself) was troubled with the fact that the assumption of discrete energy quanta of radiation was the one that forced the theoretical result to match with the Wein's displacement law, without the theory of discrete energy quanta having in itself any physical significance [2,3].

Starting with equation (1) above Max Planck found the energy density of blackbody radiation at a particular temperature as [4]

$$U(\lambda, T) = \frac{8\pi hc}{\lambda^5} \frac{1}{e^{hc/\lambda kT - 1}} \quad \textbf{(2)}$$

where λ is the wavelength of blackbody radiation and c is the speed of radiation transmission. Max Planck proposed that h is a fundamental constant of nature and its value does not change from one electromagnetic wave to the other. In honour of Max Planck, h is called Planck's constant. By fitting the value $U(\lambda, T)$ to Wein's displacement curve, Max Planck found the value of h to be $6.55\,X10^{-34}$ Jsec. The value of h known today from a large number of other experiments is $6.625\,X\,10^{-34}$ Jsec [5,6,7,8].

It was Albert Einstein who laid the foundation of quantum physics by stating that not only the material oscillators of the material forming the enclosure of black body oscillate with energy $h\nu$ but also the electromagnetic wave trapped inside the blackbody enclosure. With this hypothesis Albert Einstein successfully explained photoelectric effect. However, even Albert Einstein could not physically explain the significance of $E_n = nh\nu$. In the paragraphs that follow I explain the physical significance of both h and $E_n = nh\nu$.

2. Explaining h

Unit of h is Jsec, hence we can write h as

$$h = Et \quad \textbf{(3)}$$

where E is energy and t is time

or $h = Fxt$ **(4)**

where F is force between two consecutive photons that make up the electromagnetic wave and x is the distance travelled by the photon. Since a photon/radiation can keep travelling up to infinite distance, in equation (4) above we standardise x as the distance travelled by photon in 1 sec. Hence

$$h = F(ct)t$$

Take $t = 1$sec

$$h = Fc \quad \textbf{(5)}$$

For an electromagnetic wave, all three F, c and h are fundamental constants

$$F = {}^{h}/_{c} = \frac{6.625X10^{-34}}{3X10^8}$$

or $F = 2.208X10^{-42}$ N **(6)**

Why is there existence of force in wave? The experiment of Compton effect clearly shows that electromagnetic wave behaves like particle also. So, one particle can exert force on another particle along a wave. The value of h is a fundamental constant for just 1 wave. So, how many waves have travelled a point in space in 1 second? That quantity is the frequency ν. Thus the energy quanta of an electromagnetic wave is $h\nu$. The integer n in $nh\nu$ stands for n different orientations in which the n coherent waves are travelling. Because there cannot be any fractional orientation between the $(n-1)$th orientation and the nth orientation, the electromagnetic waves are quantized.

Electromagnetic wave is particle also. Let one wave be formed by just 1 particle, adjacent wave by just 1 another adjacent particle. What types of particles are these? These are massless charged bodies with charge q. The two such adjacent charges exert electrostatic force upon each other given by

$$F = \frac{1}{4\pi\epsilon_0}\frac{q^2}{\lambda^2} \quad \textbf{(7)}$$

or $q^2 = F(4\pi\epsilon_0)\lambda^2$

$$\text{or } q = \sqrt{(4\pi\epsilon_0)F}\,\lambda \quad \textbf{(8)}$$

Electromagnetic waves are because of the vibration of massless charged bodies in transverse mode. The value of charge is

$$q = \sqrt{4\pi X 8.85 X 10^{-12} X 2.208 X 10^{-42}}\,\lambda$$

$$\text{or } q = 15.67 X 10^{-27}\,\lambda \quad \textbf{(9)}$$

Conclusions

Wavelengths of electromagnetic waves are of the order of nano-meters. Therefore charge for the wavelength of 1 nm is

$$q = 15.67 X 10^{-27} X 1 X 10^{-9}$$

$$\text{or } q = 15.67 X 10^{-36} \text{ Coulomb} \quad \textbf{(10)}$$

Thus the charge of electromagnetic wave-particle is far less than that of electron. Also the higher the wavelength of electromagnetic wave, the greater is the charge of the particle that makes up the wave. Planck's constant is simply the multiplication of the force exerted between the two adjacent particles in a wave with the velocity of the particle. Hence, for matter wave

$$h = Fv \quad \textbf{(11)}$$

Then F will depend inversely on the velocity v of the matter and will no longer be a fundamental constant. One last question remains to be answered- what sign the charged particles of electromagnetic wave possess? To answer this one needs to go a little bit into the biology of eye. When light falls onto our retina, we see the objects around us. Behind the retina is optic nerve that is saturated with Na^+ ions. This indicates that to close the electrical circuit with optic nerves and make the current flow, negative charges are needed. Hence the particles that make up the electromagnetic wave are negatively charged which get attracted to Na^+ ions in optic nerve and make the vision possible. Let me now evaluate the amount of current flow in electromagnetic wave.

In electromagnetic wave, a charge q travels λ in time

$$t = \frac{\lambda}{c} = \frac{1}{\nu} \quad \textbf{(12)}$$

Therefore, current is given by

$$i = \frac{q}{t} = q\nu \quad \textbf{(13)}$$

Therefore, for electromagnetic wave with wavelength= 1nm

$$i = \frac{15.67X10^{-36}X3X10^{8}}{10^{-9}}$$

or $i = 47X10^{-19}$Ampere

Therefore, the current in electromagnetic wave is of the order of 10^{-19} Ampere.

I searched the internet extensively for other research works seeking the physical meaning of Planck's constant and I found the work [3] as latest as 2021. This work claims that the electron undergoing vortex motion in the sea of particles making up the vacuum has its angular momentum related to the Planck's constant. The particles that make up the vacuum are the particles in negative energy state [9]. Thus this research [3] investigates the role of h in the hydrodynamic superfluid vortex motion of electron possessing angular momentum because of its own spin.

At the end the work [3] relates h to some hydrodynamic variables and provides a new method for measuring h instead of finding any physical meaning. My work has found out the physical meaning of h in the context of electromagnetic waves and matter waves, where as the work [3] combines the special theory of relativity and the general theory of relativity to the hydrodynamic vortex variables. Work [3] does not talk of electron-wave but of electron spin. Hence the two works (mine and [3]) are entirely different.

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