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D.P II (Physics). Lecture (7)

Photon:

The wave-like character of radiation, failed to explain the observed energy distribution in the continuous spectrum of radiation emitted by hot bodies. To meet this serious problem. Planck, in 1901, presented his quantum theory of radiation. According to this theory, ~~radiation~~ radiation is emitted (or absorbed) discontinuously in indivisible packets of energy. These packets were named as photons or quanta. Each photon of radiation of a given frequency ν has the same energy which is $h\nu$, where h is known as Planck's Constant.

$$\therefore E = h\nu.$$

Einstein extended Planck's quantum hypothesis by assuming that radiation not only is emitted (or absorbed) as indivisible photons, but also continues to propagate through space as photons.

Properties of photons:

(1) The energy of photons:

The energy of a photon is always determined by, $E = h\nu$.

The energy of the photon is independent of its intensity and depends only on its frequency ν. It is not the same for all kinds of radiation.

The energy of a photon is usually expressed in terms of a unit electron volt (eV) which is defined as the energy acquired by an electron when it moves through a potential difference of 1 volt. Since charge of an electron

$e = 1.6 \times 10^{-19}$ coulomb.

& $V = 1$ volt.

$1\,eV = 1.6 \times 10^{-19}$ coulomb $\times 1$ volt.

$= 1.6 \times 10^{-19}$ Joule.

The energy of the photons of the visible region varies from 2 eV to 3 eV.

2. Mass and momentum of Photons:

Since the photons are propagated with the speed of light, the theory of relativity can be applied to them. According to this theory the mass m, and energy E are equivalent and connected by the relation,

$$E = mc^2$$

c be the velocity of light.

Therefore, the photon must possess mass of its own (known as dynamic or kinetic mass) given by the relation;

$$m = \frac{E}{c^2}$$
$$= \frac{h\nu}{c^2}$$

It ~~should~~ should be noted that restmass of photon = zero.

Since, momentum = mass × velocity

$$p = mc$$
$$= \frac{h\nu}{c^2} \cdot c = \frac{h\nu}{c}$$
$$= \frac{h}{\lambda}. \quad [\because c = \nu\lambda]$$

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∴ Momentum of photon

$$p = \frac{h}{\lambda}$$

3. <u>Non Electric Nature of Photons:</u>

Photons are chargeless particles, i.e. electrically neutral and are, therefore, not deflected by electric or magnetic fields.

4. - The size $h\nu$ (energy content) of a photon is proportional to the frequency of radiation so that photons of different radiations are of different sizes. For example, blue photons are larger than red photons. X-rays photons are considerably larger than visible light photons.

5. - The intensity of radiation I is equal to the number of photons N, crossing an area per second multiplied by the size ($h\nu$) of the photon.

$$I = N h\nu.$$

Thus, we see that for a given frequency, the intensity depends simply upon the number of photons.