PARTICLE VS WAVE NATURE AND PHOTON

Particle vs Wave Nature:

Particles are typically conceptualized as aggregated matter entities that move collectively, maintaining unity in motion. Conversely, waves are perceived as disturbances propagating longitudinally, wherein atoms oscillate about their equilibrium positions, creating perturbations within the medium. Particles, characterized by their aggregated nature, lack the capacity to demonstrate interference effects as they represent conglomerates of matter with mass. This inherent mass prevents particles from undergoing the breakage and rejoining necessary for exhibiting interference phenomena. They either move as a unified entity or remain stationary. In contrast, waves showcase interference and diffraction effects due to their ability to split and recombine, resulting in constructive (crest aligning with crest, trough aligning with trough) or destructive (crest aligning with trough) interference patterns. The energy associated with particles is determined by their mass and velocity, reflecting the kinetic energy resulting from their motion. Conversely, the energy of waves is computed based on their wavelength and velocity, indicating the energy carried by the wave due to its propagation through the medium.

Properties of photons:

According to the photon theory of light, we can succinctly summarize the characteristics of photons as follows:

➤ Each photon possesses momentum, symbolized as 'p,' which is equal to Planck's constant (h) multiplied by the frequency (ν) and divided by the speed of light (c). Additionally, they carry energy, represented as 'E,' equivalent to Planck's constant (h) multiplied by the frequency (ν). Photons travel at the speed of light (c).

➤ Photons are electrically neutral, making them impervious to deflection by electric and magnetic fields.

➤ The presence or absence of photons can be determined by the absorption or emission of radiation, respectively.

➤ In collisions between photons and particles, both the total momentum and total energy remain conserved, ensuring the preservation of these fundamental properties.

➤ All photons of light sharing the same frequency and wavelength exhibit identical energy levels.

➤ Notably, photons possess zero rest mass, indicating that they have no mass when they are not in motion.

Applications of Photons

Photon applications span a diverse range of technological fields, offering practical solutions across various domains. Here are several notable applications where photons play a pivotal role:

1) **Laser Technology:**
Photons are integral to laser technology, where they align in a singular direction with uniform wavelengths. This alignment is achieved by channeling energized electrons through an optical "gain medium" such as gas or glass, resulting in coherent light emission.

2) **Planck's Energy Formula:**
Engineers frequently leverage Planck's energy formula, E ($=h\nu$), to precisely calculate energy changes associated with photon absorption. Moreover, this formula aids in determining the frequency of light emitted upon photon release, offering crucial insights into light-matter interactions.

3) **Hardware Random Number Generators:**
Photon detection forms the foundation of various hardware random number generators, facilitating the creation of genuinely random number sequences. By detecting single photons, these devices generate unpredictable outcomes essential for cryptographic applications and simulations.

Ex. In this scenario, a laser produces light characterized by monochromaticity, with a specific frequency of 8×10^{14} hertz (Hz), and an emitted power of $2.0\times10^{(-3)}$ watts (W). The inquiry focuses on calculating the energy content of an individual photon within the emitted light beam.

Sol. The energy possessed by each photon can be determined using the formula:
$$E = h\nu.$$
Upon substituting the respective values into the equation, we arrive at:
$$E = (6.63 \times 10^{-34} \text{ J s}) (6.0 \times 10^{14} \text{ Hz}) = 5.304 \times 10^{-19} \text{ J}.$$