

DUAL NATURE OF RADIATION

PARTICLE NATURE OF LIGHT: THE PHOTON

INTRODUCTION OF PHOTON

The photon, alternatively known as a light quantum, represents a minuscule unit of energy within the realm of electromagnetic radiation. The concept of the photon first emerged in 1905 as a result of Albert Einstein's elucidation of the photoelectric effect. In his explanation, he postulated the existence of discrete energy packets during the propagation of light. Einstein further inferred that the light quantum possessed momentum, which was expressed as $(h\nu/c)$, where 'h' represents Planck's constant, 'ν' denotes the frequency of light, and 'c' signifies the speed of light. This considerable energy value and the associated momentum strongly suggested that the light quantum could be regarded as a particle. Subsequently, this particle was designated as the "photon." Thus, a photon is defined as a distinct bundle, or quantum, of electromagnetic or light energy. As photons lack mass, they propagate at the speed of light, approximately $3 \times 10^8 \text{ m/s}$.

BASIC PROPERTIES OF PHOTON

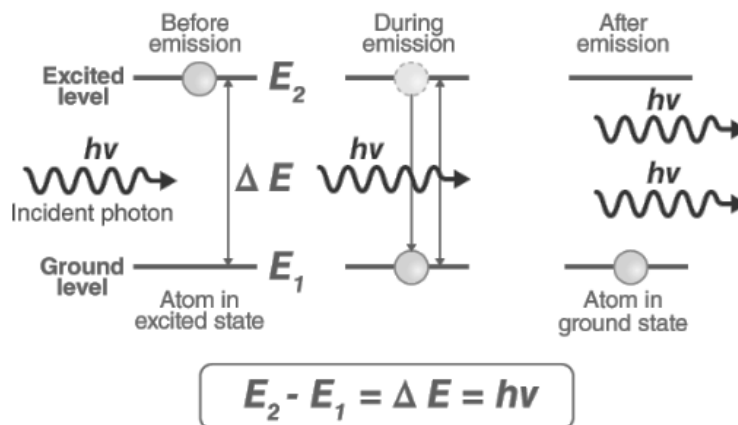
As per the photon theory of light, we can succinctly outline the characteristics of photons as follows:

- Each photon possesses momentum denoted as 'p' (equal to $h\nu/c$), energy denoted as 'E' (equal to $h\nu$), and it travels at the speed 'c,' which is the speed of light.
- Photons are electrically neutral, rendering them immune to deflection by electric and magnetic fields.
- The existence of photons can be either terminated or generated when radiation is absorbed or emitted, respectively.
- In photon-particle collisions, the total momentum and total energy are conserved, ensuring that these fundamental properties remain constant.
- All photons of light sharing a specific frequency and wavelength exhibit identical energy levels.
- Importantly, photons have zero rest mass, meaning they possess no mass when they are not in motion.

PHOTON PRODUCED

Various methods can be employed to generate photons, all of which rely on a common underlying mechanism operating within an atom. This mechanism pertains to the stimulation of electrons that orbit the nucleus of each atom. Ordinarily, an electron occupies a specific, predetermined orbital path around the nucleus. However, when we introduce energy to an atom, we have the capacity to elevate its electrons to higher energy levels or orbitals.

The emission of a photon occurs when an electron, residing in an orbital with higher energy than usual, transitions back to its original, lower-energy orbital. This electron, during its descent from a high-energy to a lower-energy state, emits a photon characterized by particular attributes. The emitted photon carries a frequency that precisely corresponds to the magnitude of the electron's energy descent.



PHOTON HAVE MOMENTUM

We are cognizant of the principle that mass can be regarded as another manifestation of energy, as elucidated by Einstein's theory of special relativity. Even though a photon lacks mass, it possesses momentum that is directly proportional to its energy. This photon momentum is a consequence of both its energy and its frequency, in accordance with the Planck-Einstein relation, $E = hf$. However, because a photon invariably travels at the constant speed of light, it cannot possess mass, in line with Einstein's established equations. Nevertheless, it is evident that a photon must possess energy, as it is responsible for instigating the photoelectric effect. Consequently, the logical inference is that the entire energy of a photon is manifested in the form of motion. Consequently, it follows that if a photon is in motion and possesses energy, it must inherently possess momentum as well.

DIFFERENCE BETWEEN PHOTON AND ELECTRON

PHOTON	ELECTRON
A photon is a type of elementary particle that primarily acts as a carrier of energy	An electron is a subatomic particle that is present in all atoms.
A photon has no charge.	It possesses a negative charge of magnitude 1.62×10^{-19} coulomb.
It has no rest mass	An electron has a mass of 9.19×10^{-31} kilograms
A photon travels at the speed of light	Electrons cannot obtain the speed of light

APPLICATIONS OF PHOTONS

Photons find numerous practical applications in technology, and several of these applications are outlined below:

- 1. Laser Technology:** One of the significant uses of photons is in laser technology. In a laser beam, photons align themselves in the same direction and possess the same wavelength. This effect is achieved by directing energized electrons through an optical "gain medium," such as glass or a gas.
- 2. Planck's Energy Formula:** Engineers frequently employ Planck's energy formula, $E (=h\nu)$, to calculate the change in energy associated with photon absorption. This formula also aids in determining the frequency of the light emitted when a photon is released.
- 3. Hardware Random Number Generators:** Various hardware devices used for generating random numbers make use of the detection of single photons to produce truly random sequences of numbers.

NUMERICAL ON PHOTONS

Example.

A laser generates light that is monochromatic, with a frequency of 8×10^{14} hertz (Hz), and the emitted power is 2.0×10^{-3} watts (W). The question pertains to determining the energy carried by a single photon within the light beam.

Solution.

Each photon has an energy which is given by the formula:

$$E = h\nu$$

Substituting the values in the above equation, we get

$$E = (6.63 \times 10^{-34} \text{ J s}) (6.0 \times 10^{14} \text{ Hz}) = 5.304 \times 10^{-19} \text{ J}$$