Quantum Mechanics-Section2

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1 Wave *vs.* Particle

If someone has to differentiate between a wave and a particle - Well, they are totally different. A particle is small and finite object with a mass. One can find a definite position for a particle, i.e. one can point to a particle and say 'Here it is.' Particles are localized. On the other hand, a wave is massless, wiggling extended entity. They are not localized. One has to define a region in space and say, 'The wave exist within this region.'

Particles move along straight path unless there is externally acting force on them. When they bounces off each other, they change direction of motion. This does not occur in case of waves. Instead of being bounced off, they interfere with each other. Superposition of waves generates constructive or destructive interference.

Moving particles and waves, both carry momentum and energy with them. A bullet carries away kinetic energy from gun to target. Water waves carry energy on water surface. Classical physics has established particle and wave model theories to explain various phenomena. The pressure of gases are explained in terms of particle model, calculating the change of momentum of atoms or molecules while they collide with container wall. On the other hand, wave model describes the motion of acoustic waves.

Classical physics, therefore, can not explain phenomena where particles demonstrates wavelike characteristics and waves show granular properties. In fact there are many examples (experimental evidences) where subatomic particles, like electrons show wave nature. There are other examples where light, a well-known electromagnetic wave by Maxwell's theory, demonstrates such properties that can only be explained by its particle-like behavior.

We are going to discuss such phenomena, in two parts:
(1) Particle nature of waves.
(2) Wave nature of particles.
After finishing these two sections, we shall conclude with the idea of wave particle duality, where particle and wave natures of quantum mechanical entities will be correlated through probabilistic approach.

2 Particle nature of waves

From the Maxwell's equations, it is well established that light is electromagnetic wave, where electric $\overrightarrow{E}$ and magnetic field $\overrightarrow{B}$ field vectors oscillate sinusoidally on perpendicular planes that contain the propagation vector $\overrightarrow{k}$. In this wave model of light, the wavelength λ, frequency ν and velocity c is correctly defined, whereas the intensity of light I is proportional to the average of the square of the electric field vector $\overline{E^2}$. Wave model also explains the propagation of light through matter, transfer of light from one medium to another through interface and a few related phenomena like refection, refraction and dispersion *etc.* Starting from the phenomenon of superposition of light waves, appearance of fringe pattern due to constructive and destructive interference, this classical picture of electromagnetic wave explains many optical phenomena of physics, *e.g.* diffraction, polarization *etc.* Obviously, wave optics is preferred as a more useful tool over ray optics, since it is successful to solve most of the complex optical phenomena. However, there are situations where light interacts directly with atoms and subatomic particles. There are cases, where light is absorbed by an atom or scatters a subatomic particle. It was noted that the wave model of light fails to explain few phenomena where a direct interaction of light with matter is involved. In this section, we shall discuss few such cases for which the classical theory of light has no proper explanation and we need help of quantum mechanics, namely the photoelectric effect and the Compton effect.

References

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[1]Figures are collected from online resources.