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From classical to quantum mechanics: A change in approach to deal with microscopic particles

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ABSTRACT:

Newtonian mechanics is the basis of Classical Physics. Newton's mechanics, Thermodynamics, Wave theory of Optics and also Maxwell's electromagnetic theory belong to the mechanism of Classical Physics and can be used to describe a wide range of phenomena in the Universe. But these theories fail to explain the phenomena in the atomic and nuclear system. For example, proton-atom scattering as well as the flow of electrons in a semiconductor.

Quantum mechanics is the most successful scientific theory that has completely changed our view of the world. The failure of Classical Physics was spotlighted by the theory of black body radiation and photoelectric effect. **Max Planck** and **Albert Einstein** provided the explanations of both phenomena based on quantum hypothesis. Also, *Uncertainty Principle* is the keystone of Quantum Physics.

Modern quantum mechanics was born in the mid-1920s. It was formulated first as *matrix mechanics* by **German physicist Werner Heisenberg, Max Born** and **Pascual Jordan** and as *wave mechanics* by **Louis de Broglie** and **Erwin Schrödinger**; and thereafter, as *quantum statistics of subatomic particles* by **Fermi-Dirac** and **Bose-Einstein**. In 1930s, Dirac formulated his relativistic quantum mechanics by combining relativistic mechanics with quantum mechanics.

INTRODUCTION:

Since the beginning of historical times, the principles of natural phenomena have been studied by Philosophers and Scientists both. In the early 20th century, the world view was based on Classical Physics which led to determinism, a principle that had its origins in the philosophical thinking of **Rene Descartes** of France. Descartes considered the universe as a wide clockwork machine that moves continuously onward, towards eternity. According to its interpretation, the future of the world is preordained and fully predictable. All of natural phenomena is described specifically by physical laws and principle, can be predicted from past to future in the frame work of Classical Physics with precision. In the first decades of the 20th century, Physicists and Philosophers had a great surprise that their world view was destroyed, uprooted, and tumbled by a physical theory known as quantum mechanics. Classical Physics can succeed to explain a wide range of macroscopic phenomena, such that the motion of billiard balls and space rockets, but amazingly they failed, when it was applied to microscopic phenomena, such that proton-atom scattering or the flow of electrons in a semiconductor. The world as it looks like to our senses is not what it really is. Behind the manifest of everyday objects, there lies an external shadow world related to potentiality and uncertainty. The world, as viewed to our eyes, go against the description of this, since its base is so different from our everyday experience. The transformation from the microworld to the macroworld, i.e., how the macro world comes out from the microworld, is a mystery to both Physicists and Philosophers. The theory that describes how the microworld works is known as quantum mechanics. It is the most successful scientific theory that has ever been generated and also it has completely changed our view of the world. Even now, for all of its success, there are aspects of quantum theory which remain utterly perplex, even to physicists like **Albert Einstein**. Once **Richard Feynman** said, "I think I can safely say that nobody understands quantum mechanics." According to **Steven Weinberg**, "There is now in my opinion no entirely satisfactory interpretation of quantum mechanics."

ANALYSIS:

➢ ROLE OF CLASSICAL PHYSICS AND DETERMINISM:

In classical physics, all feature of a particle or a system could be known to infinite precision. A classical physicist uses trajectories for measurement of position and momentum of a particle: [r(t), p(t); t >t0], gives trajectory at time t, where the linear momentum is, by definition:

$$p(t) = md/dtr(t)= mv(t)$$

[m is mass of the particle]

Trajectories are 'state descriptors' in Newtonian physics. Evolution of the state of a particle is explained by its trajectory. To know the trajectory for t>to, we need to know V (r, t), the potential energy of the particle and its initial conditions at to.

From Newton's Second Law of motion:

$$md^2 /dt^2 \, r(t) = – V (r, t)$$

From primary conditions, we can predict position and momentum of all particles – in fact of the entire universe. Hence classical physics assigns to the universe about an objective reality and independent of human observers. The world of classical universe is that it is to be expected and led to the conception of determinism, which supported by *Newtonian mechanics* and French philosophers (*Descartes* et al.). If the universe is specified, then for every incident there must be a cause. Principle of causality was the backbone on which the composition of classical physics was grown during 19th century. It predicts reliability of experimental results. Universe acts as a boundless, mindless machine and the Free Will has nothing to play. In this universe, our loves, hopes, and dreams are trivial misapprehension and human desires are senseless. It is comparable to *Karma theory of Hinduism* which says that every event is pre-set and pre-destined. The acceptance is a dehumanizing philosophy. It conducts to stand up of *Marxism* in Europe.

➢ FAILURE OF CLASSICAL PHYSICS:

(a) Black Body Radiation: -

Classical Mechanics failed to explain the Black Body spectrum of radiation over all frequency ranges, which came to be known as UV catastrophe. There was an incongruity between theory and experiment. Classically, the radiant energy density dρ was explained by the following equation:

$$d\rho\ (\nu, T) = 8\pi\kappa_B T\nu^{2}\ d\nu/c^3$$

The above formula proves that as the frequency of light ν increases the radiant energy density reaches infinity as shown in Figure 1. However, the experimental results deny the theory. Also, it was established by experiments that the radiant energy density tends to decrease as the frequency increased in the UV spectrum.

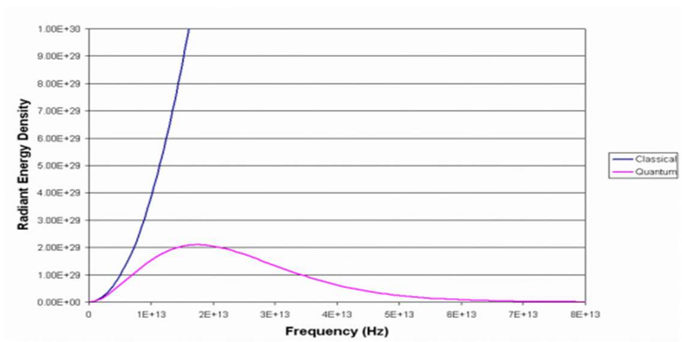

Fig 1: Blackbody Radiation

Max Planck (1900) succeed to explain blackbody radiation and derived the following equation to correctly describe the experimental results (refer to Figure 1):

$$d\rho\ (\nu, T) = 8\pi h/c^3\ (\nu^3\ d\nu/e^{\,h\nu/\kappa}\ B^{T} - 1)$$

Planck was able to obtain this formula by assuming that the energies of the oscillators were quantized (i.e., E=nhν, where h is Planck's constant = $6.626\text{x}10^{-34}\text{J}^{-s}$. Planck's quantization of energy was a complete assumption that marked the beginning of a new field of Quantum Physics.

(b) Photoelectric Effect:

Quantum Physics approach was used to describe the experimental results of the photoelectric effect, which is simply emission of electrons from a metal surface when light beam falls on it The classical explanation was that the metal's electrons could oscillate with the light and in the end break away from the surface with a kinetic energy which would depend on the intensity of the incident radiation.

However, the experimental observations appear that the kinetic energy of the emitted electrons is independent of the intensity of the radiation. In fact, no electrons were emitted, no matter how intense the incident radiation was, if frequency of light beam is smaller than a given threshold frequency for that metal. Planck's concept of quantized energy was used by Einstein in a modified form to explain the experimental results of Photoelectric effect. Einstein suggested that light could travel in small quantized packets of energy (photons) instead of exactly behaving as a classical wave. Einstein showed that the kinetic energy of the ejected electrons was equal to (the energy of the incident photon - the energy barrier (known as work function ϕ)). This explanation is described by the following equation:

$$KE=1/2\ mv^{2}=h\nu-\phi$$

Thus, Einstein model was succeeding to explain the experimental results including the lack of dependence of the energy of the emitted photons on the intensity of the incident radiation. The failure of some frequencies of light to emit any photons from the metal surface is based on that the incident photons have energy less than the work function of the metal. Einstein used photoelectric effect to experimentally direct the value of Planck constant, which showed to be the same as determined by Planck.

THE QUANTUM POINT OF VIEW: -

In quantum world-view, we must leave the classical concept of a particle and its trajectory. At microscopic level, an electron acts as a particle and as a wave (dual nature of matter). Hence, its route is unpredictable and concept of destinism is no longer valid in quantum world. Quantum behaviour can be conveyed in the language of probabilities, not certainties. It is fundamentally statistical in nature and involves random chance. Heisenberg's principle is the rock stone of quantum world:

$\Delta x\ (t_0)\ \Delta p_x\ (t_0) \geq 1/2\ h/2\pi \geq 1/2\ ħ$, where h (Planck's constant) = 6.626x10-34J-s. Position and momentum are basically incompatible observables, in the sense that precise value of one precludes knowing anything about the other. Classical physics gives precise details about the properties and behaviour of particles and systems but quantum physics does not say because of constraints such as Heisenberg's Uncertainty Principle, which says a fundamental limit on knowledge.

➢ THE RISE OF QUANTUM PHYSICS: -

There are three phases in the development of Quantum Physics:

1. Planck's introduction of Quantum hypothesis known as quantization of energy ($E=h\nu$).
2. Bohr's old Quantum Theory, that served as a bridge between Planck's Quantum hypothesis and modern Quantum mechanics.
3. Quantum theory of Heisenberg and Schrodinger.

Though their versions seem different (*Matrix Mechanics* and *Wave Mechanics*) but there is coincidence between the two approaches. **Neils Bohr** get a hint from Planck's quantization hypothesis and explained the idea of quantization of angular momentum of electrons in their orbits around the nucleus. It failed to describe even spectra of hydrogen atom successfully. Bohr's atomic model was improved by **Sommerfeld**. The ***Bohr-Sommerfeld*** *quantization theory* was succeed to explain many things about atomic spectra, related to the fine structure of the hydrogen atom.

➢ INTER-RELATIONSHIP BETWEEN CLASSICAL AND QUANTUM PHENOMENA: -

The predictions of quantum mechanics have been proved experimentally to a huge range of accuracy. According to the coincidence principle between classical and quantum mechanics, all objects obey the laws of quantum mechanics, and classical mechanics is just an approximation for broad systems of objects. Quantum Mechanics (QM) approaches Classical Mechanics (CM) when:

- ❖ $\nu \to 0$, this is noted in the phenomenon of blackbody radiation (Fig. 1).
- ❖ $h \to 0$, this is seen when taking the limit as $h \to 0$ for the average quantum mechanical energy ($h\nu/e^{h\nu/\kappa_B T} - 1$). Note that this limit is equal to the average classical energy
  ($k_B T$).
- ❖ $n \to \infty$, this is well known as the Bohr Correspondence Principle (QM→CM, n→ infinity)

CONCLUSION:

We reside in a macroscopic world and our general sense experiences and intuition related to it. Quantum physics is against to that intuition. Quantum physics work at a level which is one step removed from reality. In classical physics, we can visualize the phenomenon-particle trajectory, but in quantum physics, we walk through a cloud of uncertainty, probability and indeterminacy. The microcosm can be recognized but it cannot be seen. Also, mathematics is the language of quantum physics. In classical physics, we use mathematics but we can talk about those ideas without recourse to mathematics. This is not possible with quantum mechanics. But quantum mechanics is obviously important to know about individual atoms as well as molecules, a important part of science as well as the world.

REFERENCES:

- https://en.wikipedia.org/wiki/Quantum_mechanics
- Classical physics vs quantum physics: An overview DOI:10.13140/2.1.4187.4562

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