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Chapter 1 : Origins of Quantum Physics

1- Historical Stations

The history of quantum mechanics dates back to the early 1900s, when scientists first began to observe **phenomena** that **could not be explained** by **classical** physics. The development of quantum mechanics can be broadly divided into three main periods:

- ***The early period (1900-1925):*** This period saw the development of the first theories of quantum mechanics, including Max Planck's theory of quantized energy and Niels Bohr's model of the atom.
- ***The intermediate period (1925-1935):*** During this period, ***Werner Heisenberg***, ***Erwin Schrödinger*** and ***Paul Dirac*** developed the ***matrix mechanics***, ***wave mechanics***, and ***the principles of quantum mechanics***.
- ***The modern period (1935-present):*** This period saw the development of the modern formalism of quantum mechanics, including the discovery of quantum field theory and the development of new techniques for solving quantum mechanical problems.

1.1. Important figures in the history of quantum mechanics

- One of the most important figures in the history of quantum mechanics is ***Albert Einstein***, who made significant contributions to the development of the theory. He is known for his famous equation $\boldsymbol{E = mc^2}$ and for his contributions to the development of quantum mechanics, including his explanation of ***the photoelectric effect*** and his criticism of the probabilistic nature of quantum mechanics.

- Other notable figures in the history of quantum mechanics include ***Max Planck***, ***Niels Bohr***, ***Werner Heisenberg***, ***Erwin Schrödinger***, ***Paul Dirac***, and ***Max Born***, to name a few.

2.The failure of classical physics

The failure of classical physics to explain several microscopic phenomena such as:

- **Blackbody radiation**,
- **Photoelectric effect**,
- **Compton Effect**,
- **De Broglie wavelength of material particles,**

had cleared the way for seeking new ideas outside its purview.

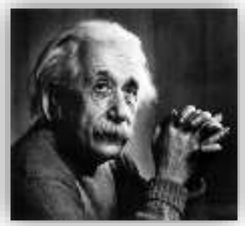
2.1) Max Planck (1858 – 1947)

- The first real breakthrough came in 1900 when Max Planck introduced the concept of the *quantum* of energy. In his efforts to explain the phenomenon of blackbody radiation, he succeeded in reproducing the experimental results only after postulating that the energy exchange between *radiation* and its surroundings takes place in *discrete*, or *quantized*, amounts.

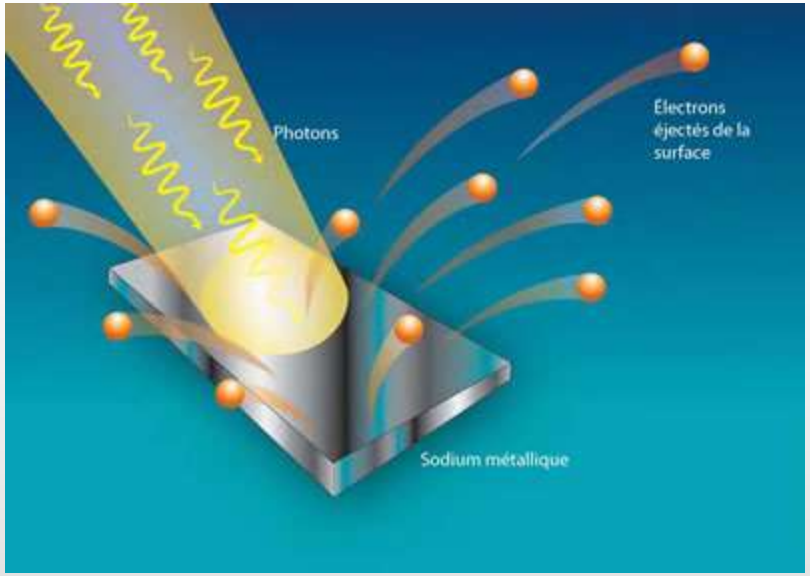
- He argued that the energy exchange between an *electromagnetic wave* of frequency ν and matter occurs *only in integer multiples* of $h\nu$, which he called the energy of a *quantum*, where h is a fundamental constant called *Planck's constant*. The quantization of electromagnetic radiation turned out to be an idea with far-reaching consequences.

- Planck's idea, which gave an accurate explanation of blackbody radiation, prompted new thinking and triggered an avalanche of new discoveries that yielded solutions to the most outstanding problems of the time.

2.2) Einstein, 1905



- In 1905 Einstein provided a powerful consolidation to Planck's quantum concept. In trying to understand the photoelectric effect, Einstein recognized that Planck's idea of the quantization of the *electromagnetic* waves must be valid for *light* as well.

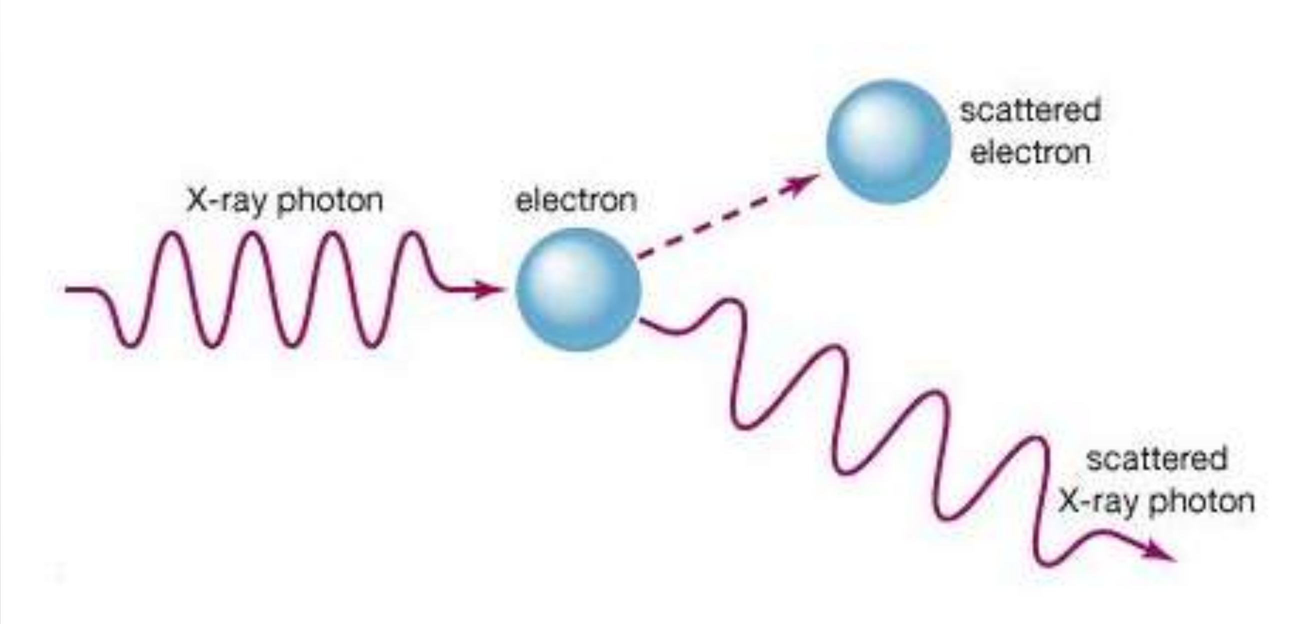


- So, following Planck's approach, he posited that *light itself is made of discrete bits of energy (or tiny particles)*, called *photons*, each of energy $\boldsymbol{h\nu}$, $\boldsymbol{\nu}$ being the frequency of the light.

- The introduction of the photon concept enabled Einstein to give an elegantly accurate explanation to the photoelectric problem, which had been waiting for a solution ever since its first experimental observation by Hertz in 1887.

2.3) Compton, 1923

- Then in 1923 Compton made an important discovery that gave the most conclusive confirmation for the corpuscular aspect of light. By scattering X-rays with electrons, he confirmed that the X-ray photons behave like particles with momenta ***($h\nu/c$)*** ; ***ν*** is the frequency of the X-rays.



This series of breakthroughs—due to Planck, Einstein and Compton—gave both the theoretical foundations as well as the conclusive experimental confirmation for the particle aspect of waves; that is, the concept that waves exhibit particle behavior at the microscopic scale. At this scale, classical physics fails not only quantitatively but even qualitatively and conceptually.

2.4) Louis de Broglie, 1923

- As if things were not bad enough for classical physics, de Broglie introduced in 1923 another powerful new concept that classical physics could not reconcile:

- he postulated that not only does radiation exhibit particle-like behavior but, conversely, ***material particles*** themselves display *wave-like* behavior.

- This concept was confirmed experimentally in 1927 by Davisson and Germer ; they showed that interference patterns, a property of waves, can be obtained with material particles such as electrons.