METHODOLOGY FOR TEACHING THE SUBJECT: “HISTORY OF THE DEVELOPMENT OF PARTICLE PHYSICS”

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Abstract: The study of the discovery of elementary particles and their developmental history expands our understanding of the origin of the universe and its future.

Annotatsiya: Elementar zarralarning ochilishi va uning rivojlanish tarixini o’rganish olamning vujudga kelishi va uning kelajagi haqida tasavvularni kengaytiradi.

Аннотация: Изучение открытия элементарных частиц и истории их развития расширяет представления о возникновении Вселенной и её будущем.

It is well-known that scientific research, discoveries, and inventions in various fields of physics form the foundation for modern technologies. Consequently, great achievements are being made in social progress and the improvement of human life. Furthermore, through the advancement of science, our concepts regarding the birth and future of the universe have significantly broadened. Global threats to humanity have been identified, and the necessary measures to mitigate them are being established. The topic "History of the Development of Particle Physics" plays a crucial role in studying the structure of the universe.

This topic is extremely fascinating because it reveals the particles that constitute matter. The concept of the 'elementary particle' emerged in relation to the microscopic structure of matter. In the early 20th century, the atom was considered the smallest unit representing the properties of matter, and it was believed that all substances were composed of atoms. The discovery of the atom's complex structure—showing it consists of three types of particles (electrons, and protons and neutrons within the nucleus)—reduced the number of discrete elements thought to define matter's characteristics. This shifted the focus toward elementary particles: the non-discrete components that form the parts of matter. However, the term 'elementary' is not entirely accurate. This is because, for a long time, protons and neutrons were regarded as elementary particles, but it was later discovered that they possess a complex structure. The structural layers of matter may indeed be infinite. Currently, there is a hypothesis regarding the existence of **'geometric quanta,'** which suggests that at a distance of 10^{-33}cm, interactions are so intense that specific micro-objects are formed within space itself, and no distance smaller than this can exist. These are referred to as geometric quanta or **strings**.

Today, the term 'elementary particles' is understood to include a group of subatomic particles; it does not refer to atoms (with the exception of the proton, which is the nucleus of a hydrogen atom). A particle is defined as 'elementary' if, at the given moment of scientific understanding, it has no known internal structure. In the previous century, atoms themselves were viewed as elementary particles (Appendix 1.1: All matter is composed of neutral particles—atoms—with dimensions of approximately 10^{-10}m. This fact was fully confirmed as early as the 19th century).

2. However, the atom is not an indivisible, structureless entity as ancient philosophers hypothesized; instead, it is a complex **quantum-mechanical object**.

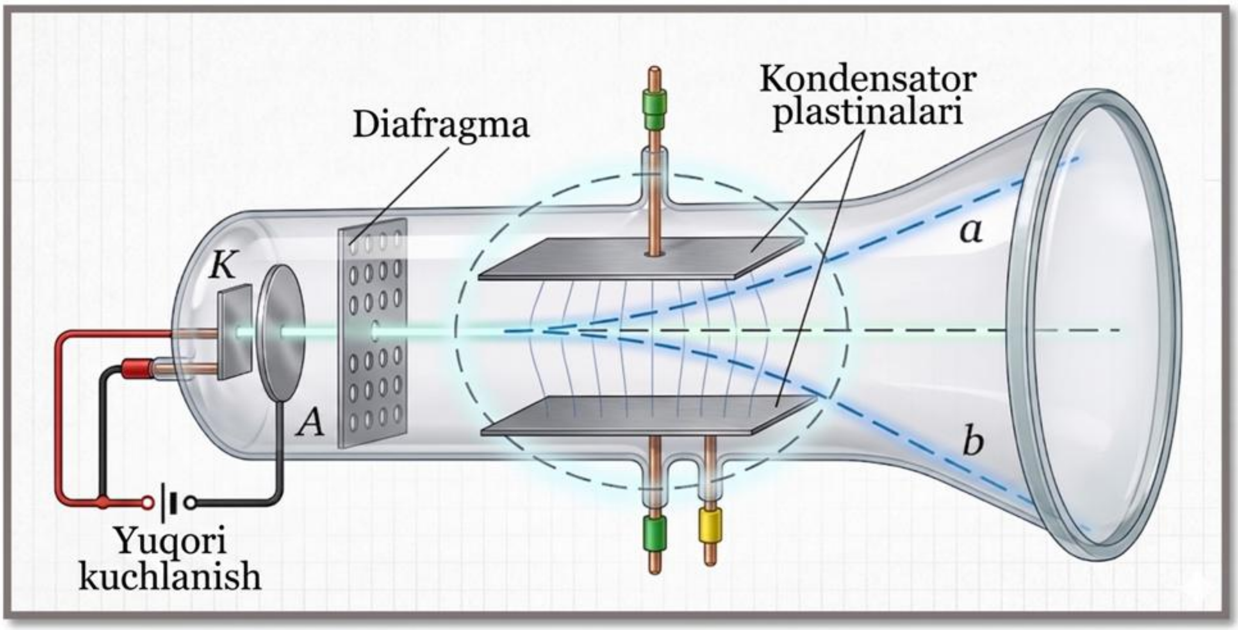
3. A constituent part of the atom is its **electron shell**, which has a total charge equal to Z_e (N. Bohr, 1913; A. Sommerfeld, 1915–1916). At the same time, this shell determines all the **chemical and physical properties** of the atom.

4. At the center of the atom, there exists a nucleus with dimensions of approximately $10^{(-15)}$m, carrying a charge of $+Z_e$ (E. Rutherford, 1911–1914).

5. The atomic nucleus consists of Z protons and $A-Z$-neutrons; that is, it is composed of a total of $Zp+(A-Z)n=A$ particles (nucleons).

In the early 20th century, through E. Rutherford's experiments, it was determined that the atom's internal structure consists of a nucleus and electrons. While the size of an atom is approximately 10^{-8} cm, the nucleus is 10,000 times smaller. According to modern theory and experimental data, the size of an electron is smaller than 10^{-16} cm; therefore, the electron is currently classified as an elementary particle.

The internal structure of the nucleus was identified following its discovery, revealing that it is composed of nucleons—specifically protons and neutrons. The nucleus is sufficiently dense, and the average distance between nucleons is several times larger than their own individual dimensions. It took nearly half a century to understand what nucleons themselves are composed of. During this period, various other fundamental questions of nature were also resolved.



Pic-1

2. History of the Discovery of Elementary Particles

The history of the discovery of elementary particles begins with the **electron**, discovered by **J.J. Thomson in 1897**. He demonstrated that cathode rays are produced by a stream of tiny particles.

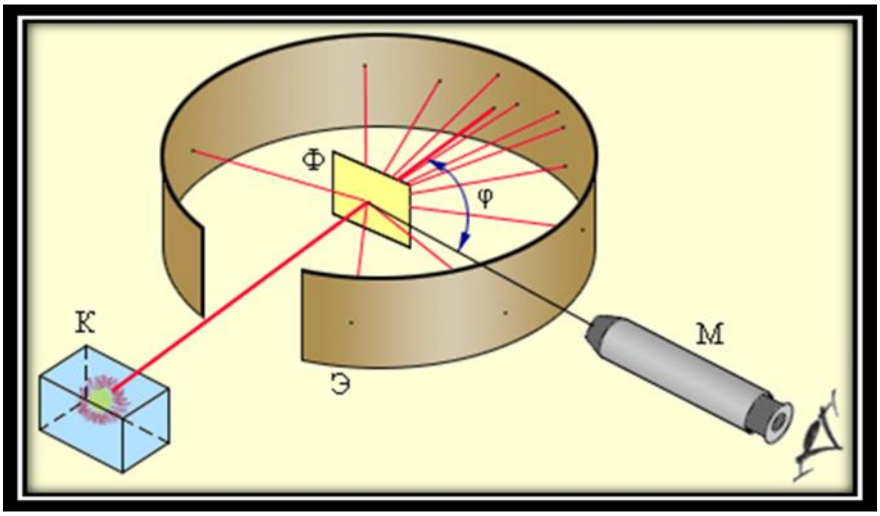
In **1911**, **Ernest Rutherford** studied the passage of alpha radiation from natural radioactive sources through thin foils of various materials, proving that the positive charge of an atom is concentrated in a compact **nucleus**. In **1919**, he discovered the **proton**—a particle ejected from the atomic nucleus with a mass 1,836.2 times greater than that of an electron.

In **1932**, **James Chadwick** discovered the third particle within the atom: the **neutron**. By observing the interaction of alpha particles with beryllium, he identified this new particle, which has a mass close to that of a proton but carries no electric charge.

Image Description (J.J. Thomson's Experiment)

The provided illustration depicts a cathode ray tube used to determine the properties of electrons:

- **K (Cathode) & A (Anode):** Connected to a high-voltage source (**Yuqori kuchlanish**) to accelerate the particles.
- **Diafragma (Diaphragm):** Collimates the beam into a straight line.
- **Kondensator plastinalari (Capacitor plates):** Create an electric field to deflect the beam.
- **Deflection paths (a and b):** Show how the beam bends in response to electric and magnetic fields, allowing for the calculation of the electron's specific charge.



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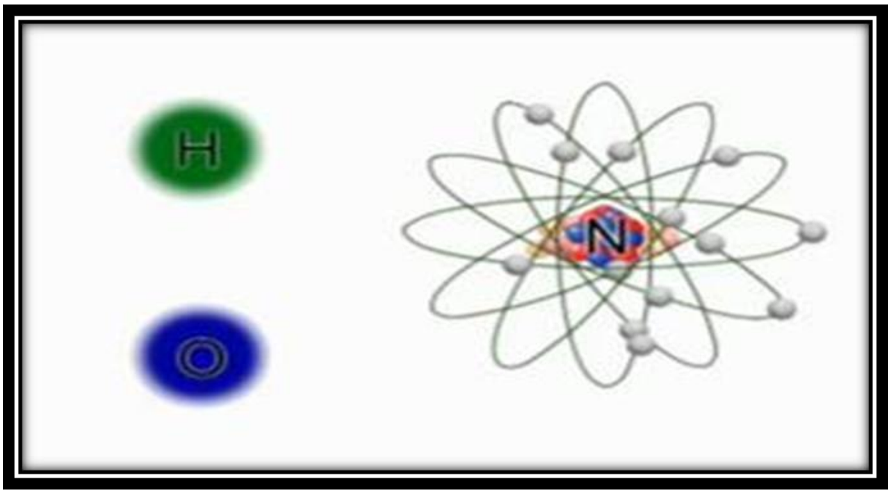
The development of the theory of elementary particles can be divided into three stages.

Stage 1: From the Electron to the Positron (1897–1932) During this period, elementary particles were viewed in a sense similar to 'Democritus's atoms,' but in a deeper and broader context. The Greek philosopher Democritus called the simplest indivisible particle an 'atom.' He believed that all various objects, plants, and animals were composed of unknown indivisible particles, and that the changes observed in the universe resulted from the simple rearrangement of these atoms. In his view, everything in the world changes except for the atom itself.

However, at the end of the 19th century, through experiments studying cathode rays, J.J. Thomson discovered that the electron is a constituent part of the atom. The objective of Thomson's experiment was to determine the specific charge of the particles which, according to the prevailing view of British physicists, produced the cathode rays.



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In Thomson’s experiment, trajectory **a** is formed in an electric field, and trajectory **b** is formed in a magnetic field. When both fields act simultaneously, the beam of rays remains undeflected. From this equilibrium, the specific charge of the particles forming the cathode rays is determined using the following formula:

$$\frac{e}{m} = 1{,}76 \times 10^{-11} \mathrm{C/kg}$$

This particle was identified as the **electron**. Consequently, 1897 was declared the year of the electron's discovery.

Stage 2: From the Positron to Quarks (1932–1970)

During this stage, it was established that all elementary particles can transform into one another.

Stage 3: From the Quark Hypothesis to the Present Day (Starting from 1964)

This stage is characterized by the understanding that many elementary particles have a complex internal structure. Based on experiments, a group of 'strange' particles was discovered: K-mesons and hyperons, whose masses are greater than those of nucleons. In the 1970s, a group of 'charmed' particles with even greater masses was discovered.

Pic-4

During the process of teaching this topic, students will develop the knowledge and skills necessary to understand the advancement of science, the internal structure of the universe, and the processes of its origin.

References:

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