



# Physics of atom

## Lecture One / Theoretical

### Part One

## Atomic and Nuclear Physics

First stage

Dr. Ahmed Najm Obaid

2025-2026



## **Objectives:**

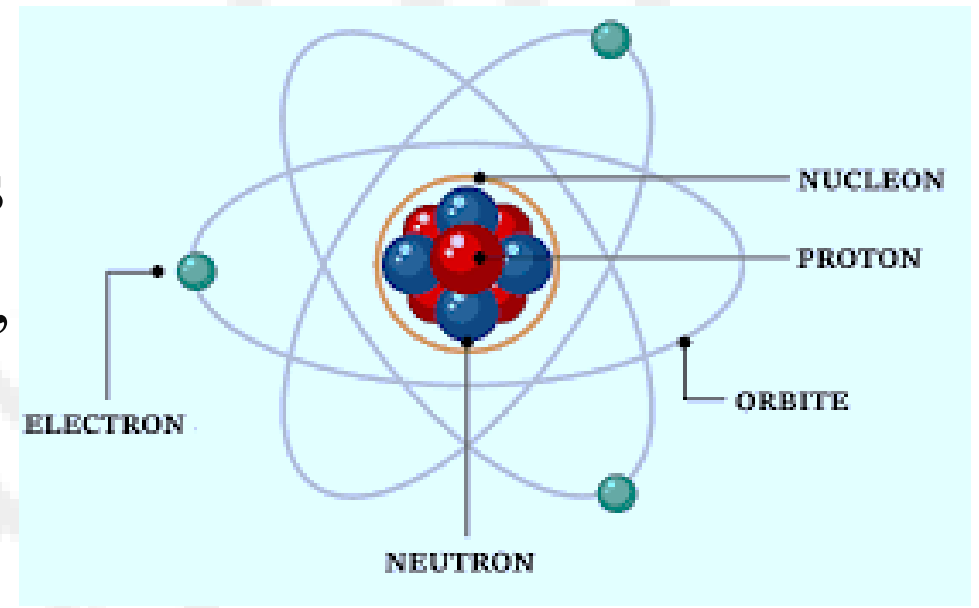
1. Define the atomic and Nuclear Structure.
2. Learn the types of the ionization radiation.
3. Know the mechanism of radiation interaction with matter.
4. Define the interaction scatter radiation with matter.
5. Discuss the types of attenuation coefficient.
8. Define nanotechnology science, types of nanomaterials synthesis, and their applications.
9. To inform students as to the importance of renewable energy in the energy mix required for generation within nations.
10. The students will acquire sharp knowledge of nanotechnology-based alternate sources of energy.
11. The students may work on advanced materials for renewable and green energy.
12. The students will get a clear understanding of Solar technology.
14. They will also understand the importance of energy storage techniques.
15. They will be clear about the role of nanotechnology in improving the efficiency in energy usage

# Atomic and Nuclear Physics

- Fundamental particles
- Nuclear Binding energy
- Nuclear Stability

# Introduction

- **Atomic and nuclear physics** describes particles (i.e., electrons, protons, neutrons), their structure, properties, and behaviour.
- **Atomic** and **nuclear** physics are **not** the same.
- **The nuclear physics** deals with the **nucleus** as a system consisting of **nucleons** (protons and neutrons).
- **The atomic physics** deals with the **atom** as a system consisting of a **nucleus** and **electrons**.
- **The main difference** is **in the scale**. While the term **atomic** deals with  $1\text{\AA} = 10^{-10}\text{m}$ , where  $\text{\AA}$  is an ångström (according to Anders Jonas Ångström), the term **nuclear** deals with  $1\text{ femtometre} = 1\text{ fermi} = 10^{-15}\text{ m}$ .



**Electrons.** The electrons are negatively charged, almost massless particles that account for most of the size of the atom. Electrons were discovered by Sir John Joseph Thomson in 1897. Electrons are located in an electron cloud, which is the area surrounding the nucleus of the atom. The electron is only one member of a class of elementary particles which forms an atom

**Protons** are positively charged, massive particles located inside the atomic nucleus. Ernest Rutherford discovered protons in 1919, when he performed his gold foil experiment.

**Neutron.** Neutrons (neutral charge) are located in the nucleus with the protons. Along with protons, they make up almost all of the atom's mass. Neutrons were discovered by James Chadwick in 1932 when he demonstrated that penetrating radiation incorporated beams of neutral particles

# The Standard Model: the Elementary Particles

The physical world is composed of combinations of various **subatomic** or **fundamental particles**. **These are the smallest building blocks of matter.**

The **Standard Model** is the prevailing theory describing the **fundamental particles** and **forces** in the universe. It **organizes elementary particles** into categories based on their properties and interactions.

- All matter except **dark matter** is made of molecules made of atoms. Atoms consist of two parts: an **atomic nucleus** and an **electron cloud**.
- Electrons spin around the atomic nucleus, which is generally made of protons and neutrons, even composite objects. **Inside the protons and neutrons, we find the quarks.** It was proposed by Murray Gell-Mann and George Zweig in 1964 to explain patterns in particle physics.
- **In particle physics,** an **elementary or fundamental particle** is a particle whose **substructure is unknown.**

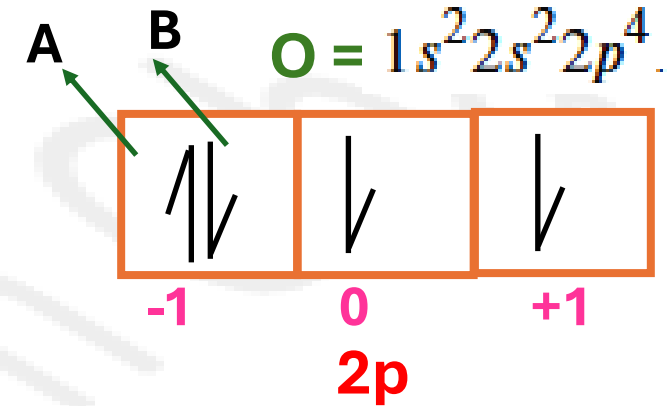
# The Standard Model: the Elementary Particles

## Classification

The Standard Model classifies elementary particles into two main groups: fermions and bosons. Fermions are the building blocks of matter, while The bosons are generally “force particles” that mediate interactions among fermions. This classification is based on the intrinsic angular momentum, or spin, of the particles.

## Fermions and Bosons

Fermions, such as quarks and leptons, obey the Pauli exclusion principle, which dictates that no identical fermions can simultaneously occupy the same quantum state. Conversely, Bosons do not obey this principle and can occupy the same quantum state, allowing them to mediate forces.



i.e: (l), s = 0, p=1, d=2. f= 3

Electron (B)	Electron (A)	quantum numbers
2	2	n
1	1	l
-1	-1	ml
-1/2	+1/2	ms

# Quarks: The Essence of Matter

**Quarks**, the fundamental building blocks of matter, come in **six** distinct types. There are six types of quarks, grouped into three generations based on **increasing mass**:

## 1. First Generation (Lightest and most common):

**Up (u)**: Charge =  $+2/3$  → Found in protons and neutrons.

**Down (d)**: Charge =  $-1/3$  → Also in protons and neutrons.

**Example**: A **Neutron** = 1 up quark + 2 down quarks (total charge 0).

A **Proton** = 2 up quarks + 1 down quark (total charge +1).

## 2. Second Generation (Heavier, rare in everyday matter):

**Charm (c)**: Charge =  $+2/3$  → Found in high-energy collisions.

**Strange (s)**: Charge =  $-1/3$  → Seen in particles like kaons.

## 3. Third Generation (Heaviest, only in extreme conditions):

**Top (t)**: Charge =  $+2/3$  → Discovered in 1995

**Bottom (b)**: Charge =  $-1/3$  → Used in studies of particle decay.

# Quarks: The Essence of Matter

## Hadrons

Quarks are never found in **isolation**; they combine to form composite particles called **hadrons**. For every quark, there is a corresponding type of antiparticle. The antiquarks have the **same mass, mean lifetime, and spin** as their respective quarks, but the **electric charge and other charges have the opposite sign**).

## Properties

**Charge:** Quarks have fractional electric charges (either  $+2/3$  or  $-1/3$  of the electron's charge).

**Mass:** Ranges widely, from very light (e.g., up/down quarks) to extremely heavy (e.g., top quarks).

**Confinement:** Quarks are never found alone; they are permanently bound together by the **strong nuclear force** (via gluons).

# Leptons: The Lightweight Champions

**Leptons** are a family of **elementary particles** in the Standard Model of particle physics.

The **Six Leptons (Three Generations)**

Leptons come in three pairs, or "generations," with **increasing mass**:

## 1. **First Generation (Common in everyday matter):**

1. Electron ( $e^-$ ): Found in atoms, governs chemistry.
2. Electron Neutrino ( $\nu_e$ ): Produced in nuclear reactions.

## 2. **Second Generation (Produced in high-energy events):**

1. Muon ( $\mu^-$ ): Discovered in cosmic rays; decays into electrons.
2. Muon Neutrino ( $\nu_\mu$ ): Observed in particle accelerators.

## 3. **Third Generation (Rarest, heaviest):**

1. Tau ( $\tau^-$ ): Discovered in 1975; decays in  $10^{-13}$  seconds.
2. Tau Neutrino ( $\nu_\tau$ ): Detected experimentally in 2000 A.M.

# Leptons: The Lightweight Champions

**Charged leptons:** Electron ( $e^-$ ), muon ( $\mu^-$ ), and tau ( $\tau^-$ ) each have (a charge of -1).

**Neutrinos** ( $\nu_e, \nu_\mu, \nu_\tau$ ): (Neutral, charge = 0). (A **neutrino** is an elementary particle, one of the particles which make up the universe. Neutrinos are electrically neutral, weakly interacting and able to pass through great distances in matter without being affected.

## Mass:

- 1. Electron:** Lightest ( $0.511 \text{ MeV}/c^2$ ), stable.
- 2. Muon:** ( $105.7 \text{ MeV}/c^2$ ) and **Tau** ( $1,777 \text{ MeV}/c^2$ ): Heavier and short-lived.
- 3. Neutrinos:** Extremely light (exact masses unknown, but  $<1 \text{ eV}/c^2$ ).

**Anti-Leptons.** For every lepton, there is a corresponding type of antiparticle. The best-known of all antileptons are the **positrons (+1)** and the antineutrinos (**charge = ?**)

## Leptons vs. Quarks

Feature	Leptons	Quarks
<b>Strong Interaction</b>	No	Yes (via gluons)
<b>Charge</b>	$-1$ or $0$ (integer)	$+2/3$ or $-1/3$ (fractional)
<b>Composite?</b>	No (elementary)	No (elementary)
<b>Generations</b>	3 (electron, muon, tau + neutrinos)	3 (up/down, charm/strange, top/bottom)