



Basic Electrical and DC Theory

Course Number: EE-02-301

PDH: 10

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Module 1: Atom and Its Forces

Learning Objectives

By the end of this section, you will be able to:

- **Analyze** the interaction between charged particles using Coulomb's Law and the First Law of Electrostatics.
- **Define** key electrical parameters including electrostatic force, field intensity, potential difference, and electromotive force (EMF).
- **Evaluate** the properties of materials based on atomic structure and electron valence to determine conductive potential.

Executive Summary: Electricity is fundamentally the flow of electrons driven by electrostatic forces. For the professional engineer, understanding the physics of the atom—specifically the behavior of valence electrons and the laws of electrostatics—is critical for analyzing circuit behavior, insulation breakdown, and conductor sizing. This section establishes the physical laws governing charge interaction (Coulomb's Law) and the creation of potential difference (Voltage), which are the prerequisites for current flow in any electrical system.

Atomic Structure and Charge

Elements serve as the basic building blocks of matter. The atom acts as the smallest particle retaining the element's properties. While the nucleus contains positively charged protons and neutral neutrons, the engineering focus lies on the orbiting negatively charged electrons.

- **Proton:** Fundamental positive charge (+) located in the nucleus. The number of protons defines the Atomic Number.
- **Electron:** Fundamental negative charge (-) orbiting the nucleus in concentric shells.
- **Net Charge:** In a natural state, atoms contain equal numbers of protons and electrons, resulting in an electrically neutral balance.

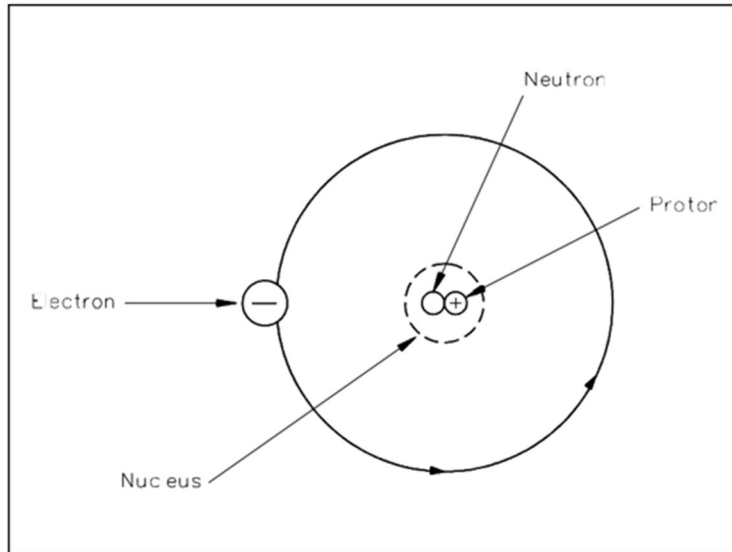


Figure 1: The Atom

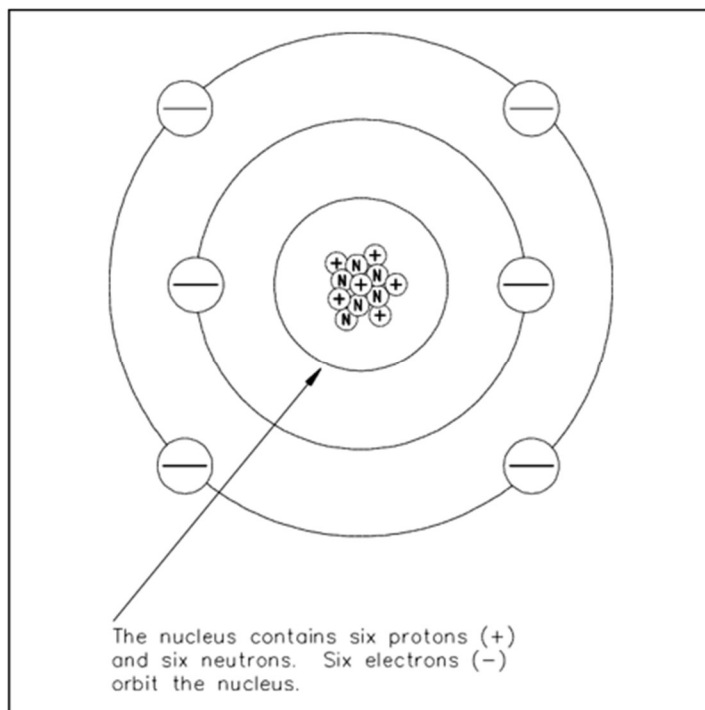


Figure 2: The Carbon Atom

Electrostatic Force and Field Theory

The electron is held in orbit by **electrostatic force**, a mutual attraction between the positive nucleus and the negative electron. This force counteracts the electron's motion, maintaining its orbital stability.

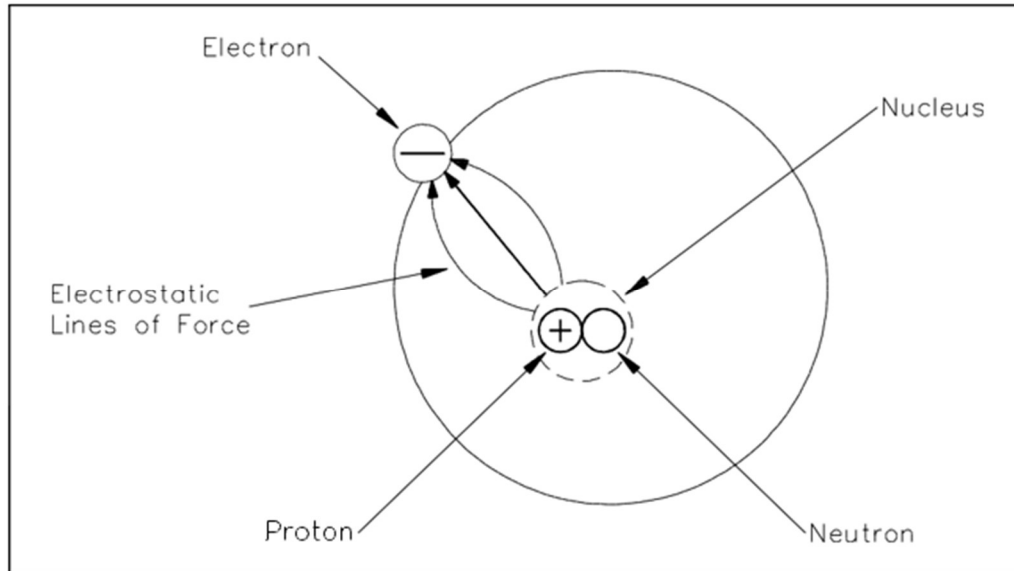


Figure 3: Electrostatic Force

The First Law of Electrostatics

The fundamental interaction between charged bodies dictates circuit behavior:

- **Unlike charges attract:** Electrons and protons pull toward each other.
- **Like charges repel:** Two electrons or two protons push away from each other.

When an object gains or loses electrons, it develops a net charge. A surplus of electrons results in a negative charge, while a deficiency results in a positive charge. The "Electric Charge" is the measurable quantity of these electrons.

Electrostatic Fields

An **electrostatic field** exists around every charged particle. This field represents the force vector that would act upon a charged particle placed within it.

- **Field Concentration:** When opposite charges approach, the field concentrates between them (Attraction).
- **Field Distortion:** When like charges approach, lines of force repel each other (Repulsion).

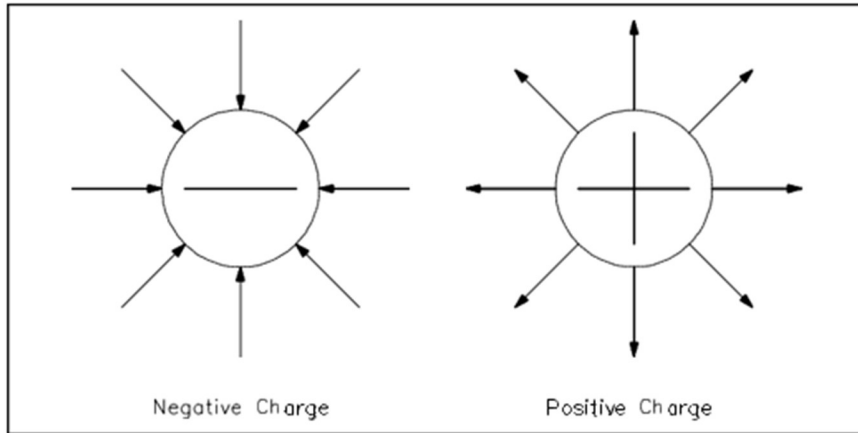


Figure 4: Electrostatic Field

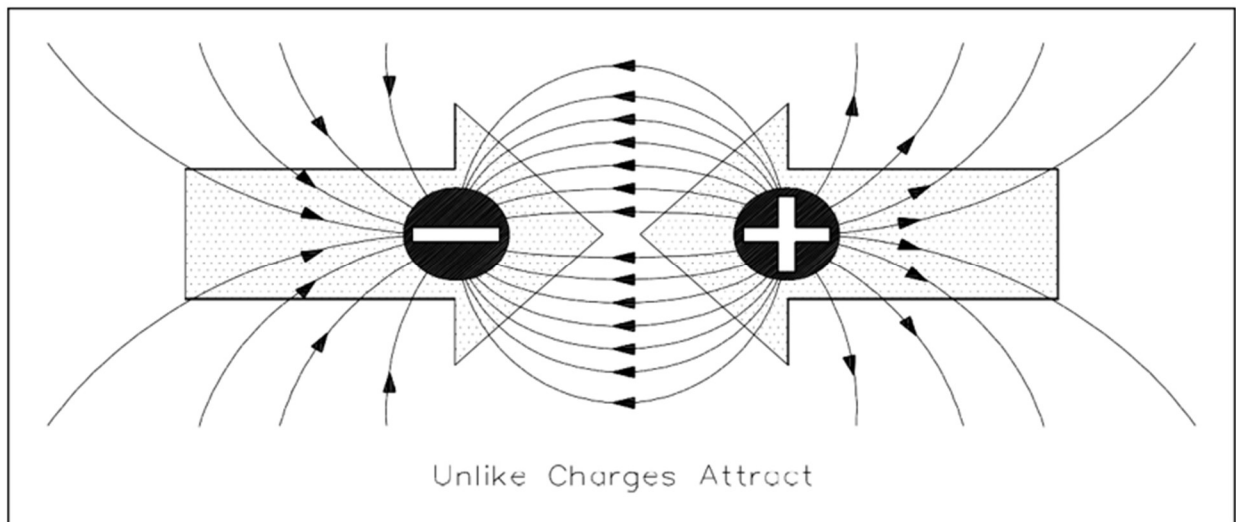


Figure 5: Electrostatic Field Between Two Charges of Opposite Polarity

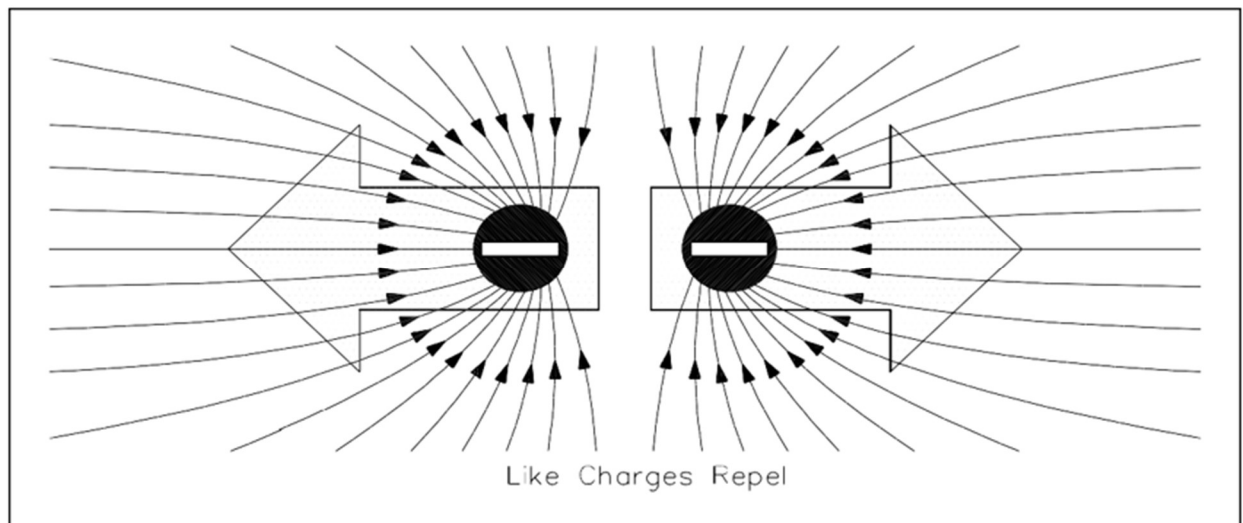


Figure 6: Electrostatic Field Between Two Charges of Like Polarity

Coulomb's Law


The magnitude of electrostatic force (attraction or repulsion) is governed by Coulomb's Law.

Equation 1-1:

$$F = K \frac{q_1 \cdot q_2}{d^2}$$

Where:

- **F** = Force of electrostatic attraction or repulsion (Newtons)
- **K** = Constant of proportionality (Coulomb² / N-m²)
- **q₁** = Charge of first particle (Coulombs)
- **q₂** = Charge of second particle (Coulombs)
- **d** = Distance between two particles (Meters)

 **Calculation Note:** Notice that force is **inversely proportional to the square of the distance**. A small decrease in insulation thickness or spacing between conductors can exponentially increase the electrostatic force and potential for dielectric breakdown.

Potential Difference and Electromotive Force (EMF)

Potential difference quantifies the strength of the electrostatic force between two charged objects. It represents the ability to do work—specifically, the work required to move a charged particle against the field.

- **Voltage (V):** The unit of measure for potential difference. One Volt represents the potential required to force electrons to move.
- **Electromotive Force (EMF):** The sum of all potential differences of all charged particles in an electrostatic field.

In practical application, if a conductor connects two objects with a potential difference, electrons will flow from the negative body to the positive body to equalize the charge.



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