



COURSE CODE: PHY 102

COURSE TITLE: General Physics II

COURSE UNITS: 2 Units

MODULE 1

Lesson 1: Forces in Nature and Electrostatics

Introduction: This lesson introduces the fundamental forces of nature and the basic principles of electrostatics. Understanding these concepts is crucial for comprehending the behavior of matter and energy at both microscopic and macroscopic levels.

Learning Outcomes: By the end of this lesson, students will be able to:

- Identify and describe the four fundamental forces of nature.
- Explain the properties and applications of the gravitational force.
- Explain the properties and applications of the electromagnetic force.
- Explain the properties and applications of the strong nuclear force.
- Explain the properties and applications of the weak nuclear force.
- Define electrostatics and its importance.
- Describe the properties of electric charge and Coulomb's Law.
- Define and calculate electric fields and electric potential.
- Identify and explain the applications of electrostatics.

Fundamental Forces of Nature

In physics, forces are interactions that can change the motion of an object. All forces in nature arise from a few fundamental interactions. These fundamental forces govern the behavior of matter and energy in the universe. There are four recognized fundamental forces: **gravitational force, electromagnetic force, strong nuclear force, and weak nuclear force**. Each of these forces has unique properties and plays a crucial role in the universe.

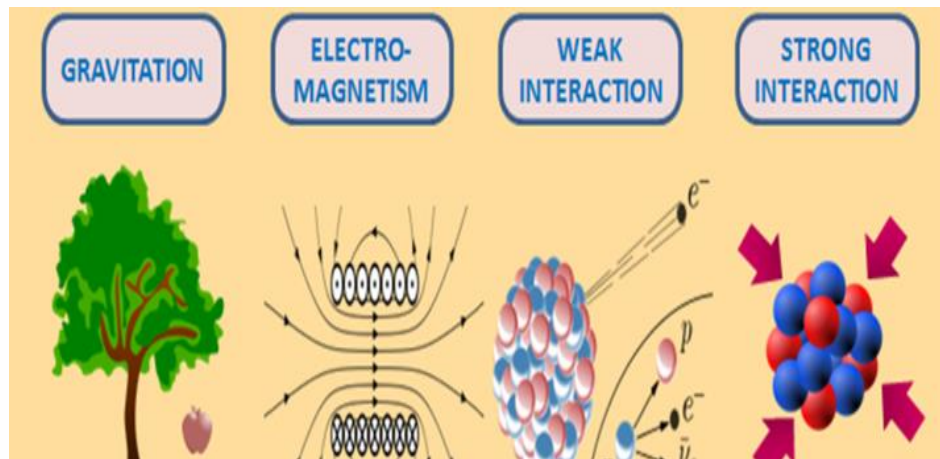


Figure 1: Fundamental Forces of Nature (<https://physicscommunication.ie/the-four-fundamental-forces-of-nature/>)

1. Gravitational Force

The **gravitational force** is the weakest but most pervasive of the four fundamental forces. It is always **attractive** and acts between any two objects with mass. Newton's Law of Universal Gravitation mathematically describes this force as:

$$F = G \frac{m_1 m_2}{r^2}$$

Where:

F = gravitational force (N)

G = gravitational constant

m_1, m_2 = masses of the objects (kg)

r = distance between the centers of the objects (m)

Gravitational force is responsible for the motion of planets, moons, and galaxies, and it governs phenomena such as tides and free fall.

2. Electromagnetic Force



The **electromagnetic force** is much stronger than gravity and acts between electrically charged particles. Unlike gravity, it can be both **attractive and repulsive**. It is governed by **Coulomb's Law**, which states that the force between two charges is:

$$F = k \frac{|q_1 q_2|}{r^2}$$

Where:

F = electromagnetic force (N)

k = Coulomb's constant

q_1, q_2 = magnitudes of the charges (C)

r = distance between the charges (m)

This force is responsible for electricity, magnetism, and chemical bonding, making it crucial in everyday life.

3. Weak Nuclear Force

The **weak nuclear force** is responsible for nuclear decay processes such as **beta decay** in radioactive atoms. This force is weaker than both the strong nuclear and electromagnetic forces but stronger than gravity. The weak interaction is mediated by particles called **W and Z bosons** and plays a crucial role in nuclear reactions and the fusion process in stars.

4. Strong Nuclear Force

The **strong nuclear force** is the strongest of all fundamental forces. It acts at very short ranges (about m) and holds protons and neutrons together in the nucleus of an atom. Without this force, atomic nuclei would disintegrate due to the repulsion between positively charged protons. The strong force is mediated by particles called **gluons**, which bind quarks together within protons and neutrons.



Introduction to Electrostatics

Electrostatics is the branch of physics that deals with the study of electric charges at rest, the forces between them, and the behavior of charged objects in an electric field. The study of electrostatics is crucial in understanding fundamental concepts such as Coulomb's law, electric fields, and potential energy. Electrostatic principles have applications in various fields, including electronics, material sciences, and atmospheric physics.

Electric Charge

Electric charge is a fundamental property of matter, and it comes in two types: **positive charge** and **negative charge**. Like charges repel each other, while unlike charges attract. The unit of charge is the **Coulomb (C)**, named after Charles-Augustin de Coulomb. The smallest unit of charge is carried by electrons (-e) and protons (+e), where C.

Properties of Electric Charge:

1. **Charge Quantization:** Charge exists in discrete packets and is always an integral multiple of the elementary charge (e).
2. **Charge Conservation:** The total charge in an isolated system remains constant.
3. **Charge Transfer:** Charge can be transferred by conduction, induction, or friction.

Coulomb's Law

Coulomb's law describes the electrostatic force between two point charges. It states that the force between two charges is directly proportional to the product of their magnitudes and inversely proportional to the square of the distance between them.

$$F = \frac{k_e \cdot |q_1 \cdot q_2|}{r^2}$$

Where:

F is the electrostatic force (N)

q_1 and q_2 are the magnitudes of the charges (C)

r is the distance between the charges (m)



k_e is Coulomb's constant,

Coulomb's law is similar to Newton's law of gravitation but applies to electric charges instead of masses.

Electric Field

An electric field is a region around a charged object where another charge experiences a force.

The strength of the electric field at a point is given by:

$$E = \frac{F}{q}$$

Where:

E is the electric field strength (N/C)

F is the force on a test charge (N)

q is the magnitude of the test charge (C)

For a point charge, the electric field is given by:

$$E = \frac{k_e \cdot |Q|}{r^2}$$

Where Q is the source charge.

Electric Potential Energy and Potential

Electric potential energy is the work done in moving a charge within an electric field.

The electric potential energy per unit charge:

$$U = \frac{k_e \cdot q_1 \cdot q_2}{r}$$

The electric potential (V) at a point is:

$$V = \frac{U}{q}$$

For a point charge, the electric potential is:



$$V = \frac{k_e \cdot Q}{r}$$

Where:

- U is the electric potential energy (J),
- V is the electric potential (V),
- Q is the source charge (C),
- r is the distance from the charge (m).

Applications of Electrostatics

Electrostatic principles are widely applied in:

1. **Capacitors:** Devices that store charge and energy in electric fields.
2. **Photocopiers and Printers:** Use electrostatic attraction to transfer ink.
3. **Lightning:** Caused by charge accumulation in clouds.
4. **Electrostatic Precipitators:** Remove pollutants from industrial emissions.

Summary

Fundamental forces govern all interactions in the universe and include **gravitational force, electromagnetic force, strong nuclear force, and weak nuclear force**. These forces dictate the behavior of matter and energy. Understanding these forces is essential in physics, as they explain both microscopic and macroscopic phenomena, shaping the fundamental structure of the universe.

Electrostatics is the study of electric charges at rest, their interactions, and the electric fields they generate. It is grounded in the fundamental principles of charge, force, and potential. Charges come in two types, positive and negative, and they follow properties like charge quantization, conservation, and transfer. Coulomb's law describes the force between two point charges, which is proportional to the product of their magnitudes and inversely proportional to the square of the distance between them. Electric fields describe the region around a charge where other charges experience a force, and the potential energy and potential quantify the work done in moving charges within these fields. Electrostatics finds applications in diverse areas such as capacitors, printers, lightning, and pollution control devices. Understanding



electrostatic concepts is essential for advancing knowledge in physics, engineering, and technology.

Evaluation Questions:

1. Describe the four fundamental forces of nature and give an example of a phenomenon governed by each force.
2. State Coulomb's Law and explain how it is similar to and different from Newton's Law of Universal Gravitation.
3. Explain the properties of electric charge and give examples of how charge can be transferred.
4. Define electric field and electric potential, and explain how they are related.
5. List and describe three applications of electrostatics in everyday life or technology.

Suggested Answers:

1. Gravitational: Planetary motion. Electromagnetic: Lightning. Strong: Nuclear stability. Weak: Radioactive decay.
2. Coulomb's Law: $F = k(q_1q_2)/r^2$. Newton's Law: $F = G(m_1m_2)/r^2$. Both are inverse square laws, but Coulomb's Law deals with charges and can be attractive or repulsive, while Newton's Law deals with masses and is always attractive.
3. Charge properties: Quantization, conservation, transfer. Transfer examples: Friction, conduction, induction.
4. Electric field: Force per unit charge. Electric potential: Potential energy per unit charge. They are related by $V = U/q$ and $E = -dV/dr$.
5. Capacitors: Store charge. Photocopiers: Transfer ink. Electrostatic precipitators: Remove pollutants.