

Module 11: Electric Forces and Electric Fields (PHY 1200)

Introduction

Electricity is a fundamental aspect of the natural world. Electric forces influence the behavior of atoms, molecules, and many technological systems.

Everyday technologies such as:

- electrical circuits
- computers
- communication systems

rely on the motion and interaction of electric charges.

In physics, the study of electric forces begins with understanding electric charge and the forces that charges exert on one another.

Electric Charge

Electric charge is a fundamental property of matter.

There are two types of electric charge:

- positive charge
- negative charge

These two types of charge interact in predictable ways.

Opposite charges attract each other.

Like charges repel each other.

Examples of Electric Charge

In atoms:

- protons carry positive charge
- electrons carry negative charge

The interaction between these charges helps determine the structure of matter.

Conservation of Charge

Electric charge is conserved.

This means that charge cannot be created or destroyed.

Instead, charge can only be transferred from one object to another.

For example, when an object becomes electrically charged by friction, electrons are transferred between surfaces.

Electric Force

Electric charges exert forces on one another.

The magnitude of this force depends on:

- the amount of charge
- the distance between charges

This relationship is described by Coulomb's Law.

Coulomb's Law

Coulomb's Law describes the electric force between two charges.

The equation is:

$$F = k (q_1 q_2 / r^2)$$

where:

F = electric force

q_1 = first charge

q_2 = second charge

r = distance between charges

k = Coulomb constant

The Coulomb constant is approximately:

$$k = 9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$$

Understanding Coulomb's Law

Coulomb's Law shows that:

- the force increases as charges increase
- the force decreases as distance increases

The force depends on the inverse square of the distance.

If the distance doubles, the force becomes four times smaller.

Example Calculation

Two charges are separated by a distance of 0.5 meters.

$$q_1 = 2 \times 10^{-6} \text{ C}$$

$$q_2 = 3 \times 10^{-6} \text{ C}$$

Find the electric force.

Step 1

Write Coulomb's Law.

$$F = k (q_1 q_2 / r^2)$$

Step 2

Substitute values.

$$F = (9 \times 10^9)(2 \times 10^{-6} \times 3 \times 10^{-6}) / (0.5^2)$$

Step 3

Calculate.

$$2 \times 3 = 6$$

$$6 \times 10^{-12}$$

Multiply by constant:

$$9 \times 10^9 \times 6 \times 10^{-12} = 54 \times 10^{-3}$$

Divide by r^2 :

$$0.5^2 = 0.25$$

$$F \approx 0.216 \text{ N}$$

The electric force is approximately 0.216 newtons.

Electric Fields

Instead of describing electric forces directly between charges, physicists often use the concept of an electric field.

An electric field describes the region around a charge where other charges experience a force.

The electric field represents how a charge influences the space around it.

Electric Field Strength

The electric field produced by a point charge is given by:

$$E = k (q / r^2)$$

where:

E = electric field strength

q = charge producing the field

r = distance from the charge

Example

A charge of $4 \times 10^{-6} \text{ C}$ produces an electric field at a distance of 2 meters.

Find the electric field strength.

$$E = k (q / r^2)$$

Substitute values:

$$E = (9 \times 10^9)(4 \times 10^{-6}) / (2^2)$$

Calculate:

$$2^2 = 4$$

$$4 \times 10^{-6} \times 9 \times 10^9 = 36 \times 10^3$$

$$36 \times 10^3 \div 4 = 9 \times 10^3$$

$$E = 9000 \text{ N/C}$$

Electric Field Lines

Electric fields are often represented using field lines.

Field lines illustrate the direction and strength of the electric field.

Properties of field lines include:

- they point away from positive charges
- they point toward negative charges
- closer lines indicate stronger fields

Field line diagrams help visualize electric interactions.

Superposition of Electric Fields

When multiple charges are present, the total electric field is the vector sum of the individual fields produced by each charge.

This principle is known as superposition.

The electric field contributions from each charge must be added together to determine the net field.

Applications of Electric Fields

Electric fields play an important role in many technologies.

Examples include:

- particle accelerators
- electronic devices
- capacitors
- medical imaging equipment

Understanding electric fields helps explain how charged particles move in electrical systems.

Practice Problems

1. What are the two types of electric charge?
2. What happens when two positive charges interact?
3. Write Coulomb's Law.
4. If the distance between charges doubles, how does the force change?
5. What does an electric field represent?

Calculation Practice

1. Two charges:

$$q_1 = 1 \times 10^{-6} \text{ C}$$

$$q_2 = 2 \times 10^{-6} \text{ C}$$

Distance = 1 meter

Find the electric force.

2. A charge of $3 \times 10^{-6} \text{ C}$ produces an electric field at 3 meters.

Find the electric field strength.

Challenge Problems

1. Two charges are separated by 0.25 meters.
If the distance doubles, how does the electric force change?
2. Explain why electric field lines never cross.
3. Describe the direction of electric field lines around a positive charge.