Lecture Notes

Physics 2

Fall 2020

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Instructed by:
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Contents

Chapter 1

Electric Charge and Electric Field

DATE: 2020-08-17

ANNOUNCEMENTS:

Instructor - Dr. Emily Marshman

Office Hours - M 12:00pm - 1:00pm, T 10:00am - 1:00pm, W 12:00pm - 1:00am

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Book - University Physics with Modern Physics by Young and Freedman, 15th edition

Assignment (Sept 20 11:59): Chapter 21 Homework

Assignment (Aug 31): Lab 1

1.1 Introduction

1.1.1 Learning outcomes

- How objects become charged, and how we know it's conserved.
- How to use Coulombs law.
- Distinction between electric force and field.
- How to use idea of electric field lines.
- Calculate properties of electric charge distributions.

1.2 Electric Charge and Electric Fields

1.2.1 Electric charge

When we rub glass rods with silk, the rods become charged and repel each other.

A charged plastic rod **attracts** a charged glass rod, and both attract the cloth.

This shows there are two kinds of charge.

Electric charge and the structure of matter

The particles of the atoms are:

- the negative electrons
- the positive protons
- the uncharged neutrons

Atoms and Ions

A neutral atom has the same number of protons as electrons
A **positive ion** has one or more electrons removed.
A **negative ion** has an excess of electrons.

1.2.2 Conservation of Charge

- The proton and electron have the same magnitude of charge.
- This magnitude is **quantized** unit of charge.
- **principle of charge conservation** states the sum of all charges in a closed system is constant.

$$\boxed{\text{1 Coulomb } = \text{ charge on } 6.241 \times 10^{18} protons} \tag{1.1}$$

Coulomb

$$\boxed{\text{Charge on 1 proton, +e } = 1.6 \times 10^{-19} C} \tag{1.2}$$

Proton charge

$$\boxed{\text{Charge on 1 electron, -e } = -1.6 \times 10^{-19} C} \tag{1.3}$$

Electron charge

Example 1. *Common static electricity involves charges ranging from nanocoulombs to mircrocoulombs.*
(a) How many electrons are needed to form a charge of $-2.00nC$?
(b) How many electrons must be removed from a neutral object to leave a net charge of $0.500\mu C$

Solution 1 (a)**.**

$$\begin{aligned} \textit{Charge of } e &= -1.6 \times 10^{-19} C \\ -2.00\mu C &= -2.00 \times 10^{-9} C \implies \\ \frac{-2.00 \times 10^{-9} C}{-1.6 \times 10^{-19} C} &= 1.25 \times 10^{10} \textit{ electrons} \end{aligned}$$

Solution 2 (b)**.**

$$\begin{aligned} 0.500\mu C &= 0.500 \times 10^{-19} C \implies \\ \frac{0.500 \times 10^{-9} C}{-1.6 \times 10^{-19} C} &= 3.13 \times 10^{11} \textit{ electrons removed} \end{aligned}$$

Definition 1 (Conductor)**.** *A material that allows charge to flow through it easily (most metals).*

Definition 2 (Insulator)**.** *a material that does not allow charge to flow through it easily (e.g. plastic, paper, nylon, wood).*

1.3 Conductors, Insulators, and Induced Charges

1.3.1 Charge by contact

Electrons are transfered by rubbing the negatively charged rod on the metal sphere.

When the rod is removed, the electron distribute themselves over the surface.

1.3.2 Without contact (Induction)

1. An uncharged metal ball stands on an insulator
2. free electrons in the metal ball are repelled by the excess in the rod, and shift away from the rod.
3. While the rod is near, connect the ball to the ground with a conducting wire.
4. Free electrons in the metal ball are repelled by the excess in the rod, and shift away from the rod.
5. disconnect the wire and a net positive charge is left on the ball. The earth acquires an equal negative charge.

1.3.3 Electric Forces on Uncharged Objects

- negative plastic come causes shifting of charges within the neutral insulator, called **polarization**
- a charged object of **either** sign exerts an **attractive** force on an uncharged insulator.

1.4 Coulomb's Law

The magnitude of the electric force between two point charges is directly proportional to the product of their charges and inversely proportional to the square of the distance between them.

$$\boxed{F_e = k\frac{|q_1 q_2|}{r^2}} \tag{1.4}$$

Coulomb's Law

The direction of the force depends on the relative sign of the charge.

$$\boxed{k = \frac{1}{4\pi\epsilon_0} = 9.0 \times 10^9 \frac{Nm^2}{C^2}} \tag{1.5}$$

Proportionality Constant

$$\boxed{\epsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{Nm^2}} \tag{1.6}$$

Electric constant

Example 2 (Applying Coulomb's law).

1.5 Electric Fields

A charged object modifies the properties of the space around it. E.g. in the vicinity of a positive charge, other positives repell and negatives attract

Gravitational field:

$$
\begin{aligned}
F_g &= \frac{GMm}{r^2} \\
\frac{F_g}{m} &= \frac{GM}{r^2} \\
&\text{near earths surface} \\
\frac{\overline{F}_g}{m} &= \overline{g} = 9.8\frac{m}{s^2} \\
\overline{F}_g &= m\overline{g}
\end{aligned}
$$

Electric field:

$$
\begin{aligned}
F_e &= \frac{k\,|Qq_0|}{r^2} \\
\frac{F_e}{q_0} &= \frac{kQ}{r^2} = \overline{E}
\end{aligned}
$$

force / charge : electric field of point charge

$$
\boxed{\overline{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}} \tag{1.7}
$$

Electric field of a point charge

ϵ_0 Electric constant

q - Value of point charge

r - Distance from point charge to where field is measured

$\hat{r}$ **-** unit vector from point charge towards where the field is measured

Direction: electric field points **radially inward** towards negative charge and **radially outward** for positive charge.