
LUT University
LAND OF THE CURIOUS
LES10A020 Engineering Physics

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Engineering Physics
Lecture 3

by
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Electric Charge

Electric Charge

- Electric charge is composed of basic units of electrical charge
- The most fundamental unit is the charge of one electron (-) or proton (+):

$$|Q_e| = |Q_p| = e = 1,602176634 \cdot 10^{-19}\ \mathrm{C} \qquad Q = \pm n \cdot e$$

- Any charge in an object can be either positive or negative, but always multitudes of the basic charge.
- Two positive or negative charges repel each other, while positive and negative charge have an attraction

The Force Between Two Charged Particles

- The charged particles manifest the attraction or repulsion via a force.
- If two objects are charged, the force they act towards each other is

$$F_C = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q_1 Q_2}{r^2} = k \cdot \frac{Q_1 Q_2}{r^2}$$

$\varepsilon_0 \approx 8{,}854188 \cdot 10^{-12}\ \mathrm{C^2/Nm^2}$

- Here ε_0 is the permittivity of vacuum.
- For different substances, their permittivity may differ.

Non-Vacuum Permittivity

- When the charges are not in vacuum, the permittivity of substance ε_r influences the formula as below:

$$F_C = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q_1 Q_2}{\varepsilon_r r^2} = k \cdot \frac{Q_1 Q_2}{\varepsilon_r r^2}$$

Voltage and Energy

- The separation of positive and negative charges requires work and therefore, as these charges form a potential, it has some energy content
- The potential difference between different objects is called voltage.
- Voltage can be expressed with charge and energy:

$$U = \frac{\Delta E}{\Delta Q}$$

- The unit of voltage is volt: (V = J/C)

Current

- If two objects with charge are connected with each other via a wire (conductor), their charge balances out.
- The flow of charged particles between the objects is called current, or more accurately direct current, that can be expressed with changes in charge and time:

$$I = \frac{\Delta Q}{\Delta t}$$

- The charged particles flow freely via the conductor, if there is nothing stopping it.

Current and Power

- As the charge flows thought a conductor, it releases energy.
- The power the energy is released can be expressed via current and voltage:

$$P = \frac{\Delta E}{\Delta t} = \frac{\Delta E}{\Delta Q} \cdot \frac{\Delta Q}{\Delta t} = U \cdot I$$

Battery as a Voltage Source

- Batteries can be used to store electricity via storing it into the energy of chemical reactions.
- Battery is charged by charging it with a sufficient voltage and discharged by letting the electricity flow out via a conductor that connects into an electric circuit.
- The charging capacity of a battery is often expressed in ampere hours.

Example: Charging a battery

- Let us assume we have a battery with 4510 ampere hour capacity that is charged full in 11 hours. How strong current was used in charging it?
- Solution: We solve the current with the equation

$$I = \frac{\Delta Q}{\Delta t} = \frac{4510\ \text{mAh}}{11\ \text{h}} \approx 410\ \text{mA}$$

Ohm's Law

- We familiarize ourselves with Ohm's Law by using the online physics book "College Physics" by Urone and Hinrichs.
- This book is a valuable free resource for learning basic physics!
- Please use it as support material in your studies!
- The book is available here.

“College Physics” by Urone and Hinrichs.

- Chapters 20.2-4 and beginning of Chapter 20.5 were discussed at the end of the lecture.

Thank you for your attention!