Module M2-1(V4KK) Electrical Engineering

LECTURE 1 INTRODUCTION
AUGUST 2013

Topics

- Introduction to the contents of this course
  - electrostatics
  - magneticstatics
  - electrical circuits
- Natural phenomena related to these contents
- Engineering applications of these contents

Electricity is about stationary charges; and moving charges (or current)

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- Electrical charges could be electrons, positive ions, or negative ions
- In most cases, we deal with electrons
- Electrical charges appear in nature, for example,
  - in the electrons or
  - in materials that lose or gain electrons

An electron is part of an atom

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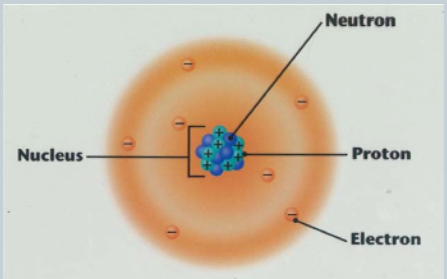

Neutron- has no charge (i.e. is neutral) and is also located in the nucleus. Neutrons fill in the spaces between protons.

Proton- has a positive charge and is located in the nucleus.

(Isotopes are atoms of the same element, having the same numbers of protons but different neutrons)

Electron- has a negative charge and is located outside of the nucleus in an electron cloud around the atom

(Quantum mechanics tells us that electron orbits are not fixed, probability of finding electrons are distributed in space-slides).

An electron has charge and mass

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- VDO [13]: Atom structure, orbiting electrons http://www.youtube.com/watch?v=3nYAgLaYreI
- Electrons and protons have the same magnitude of charge (elementary charge, e)
  - Electron ($-e$): -1.60×10^{-19} C
  - Proton ($+e$): $+1.60 \times 10^{-19}$ C
- This is why electrons are forced to orbit around the nucleus.
- Electrostatic forces hold atoms together

(Attraction between electron and protons (nucleus) are balanced by a centrifugal force due to curving trajectories of electrons).

The science of electricity is a study of charges and the resulting phenomena appearing in nature

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- Natural phenomena include, for example, lightning , thunder, hairs standing on ends.
- [VDO: 1] Lightning, charges in nature http://www.youtube.com/watch?v=Sp9bKDHRfsM

In a conductor, electrons that receive sufficient energy will escape from atoms

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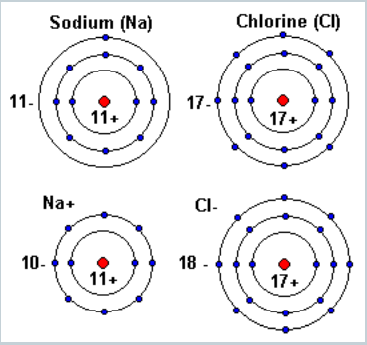
An atom with a deficiency of electrons is positively charged.



An atom with an excess of electrons is negatively charged.

- The escaping electrons can move freely in a conductor or on its surface (For electrons to escape from atoms/molecules, input energy is required, e.g. heat, UV, X-ray)
- **ATOMS DO NOT GAIN OR LOSE PROTONS!!!!**

Any charged object (positive or negative) attracts a neutral object

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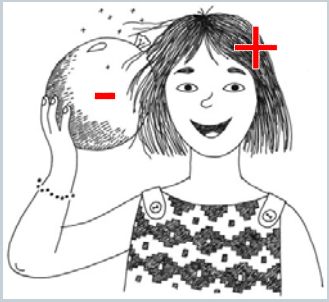
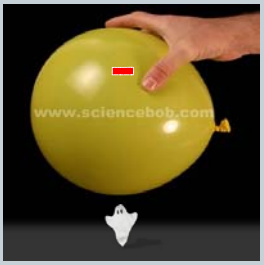
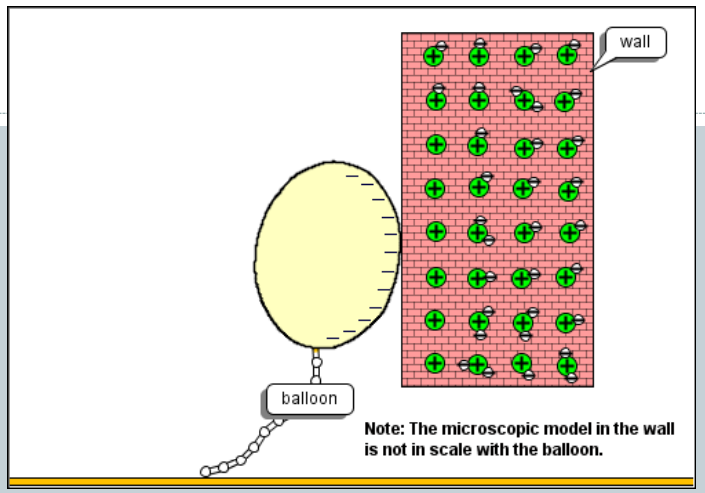


A balloon when rubbed on your head becomes charged by picking up extra electrons from your hair.



That same balloon, because it is charged, will attract a neutral object like pieces of paper.



When the balloon is placed against the wall,
the excess electrons will repel the electrons in the wall and
be attracted to the positive charges.

Each electrical charge creates an electrical field around itself

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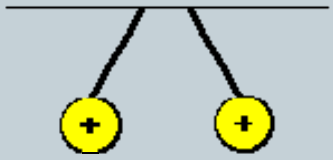
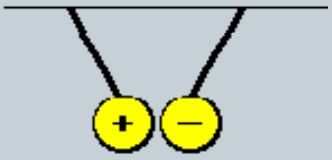


Charges with the same polarity repel



Charges with the opposite polarities attract

- An electric field produces forces that act on charges
- An evidence of this force is a movement of charges
- Phenomena that arises from stationary charges or charges that move slowly are the scopes of electrostatic field

Below are examples of electric field lines of force

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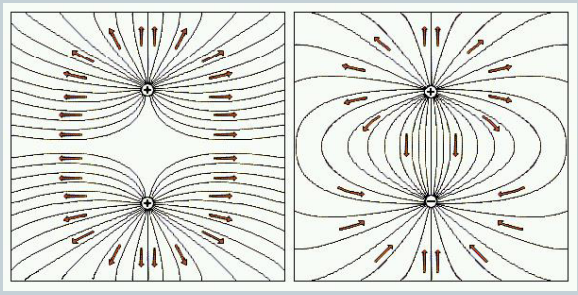

- Electric field (**E**) acts or produces forces on both positive and negative charges.
- We define the strength of an electric field by the magnitude of electric field (a vector). The strength is a magnitude of force acting on a positive test charge (of 1 Coulomb)

Electrical current

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- Electric current is defined to be the amount of electrical charges that flow through a surface per a unit time (i=dq/dt)
- Electrical current is analogous to a flow rate of water

  (electrical charge analogous to amount of water)
- [VDO 7] Current, voltage, safety considerations http://www.youtube.com/watch?v=EJeAuQ7pkpc

Current can produce a magnetic field

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- When the flow rate of charges is steady (or does not change over time), the resulting current will also be steady.
- In turn, a steady current will produce a steady magnetic field.
- A study of magnetic fields that are steady or change slowly over time is a scope of a subject called "Magnetostatics"

A change in magnetic field produces electrical current

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- [VDO 2] magnetic field ➔ current
  http://www.youtube.com/watch?v=hajIIGHPeuU

In turn, a change in electric current produces a magnetic field

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- [VDO 3] current ➔ magnetic field, Faraday's law of electromagnetic induction http://www.youtube.com/watch?v=txmKr69jGBk
- The relationship between electric fields and magnetic fields is a scope of the subject called "Electromagnetics"

Phenomena that result from electrostatics can be applied to create electrical devices

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- Such as a laser printer
  - [VDO 8] Applications of electrostatics, like charges repel, opposite charges attract (long) http://www.youtube.com/watch?v=yMmupCmo-70
  - [VDO 14] highlight of printing process (short) http://www.youtube.com/watch?v=KtXes1sgUb4

Phenomena that result from magnetostatic can be applied to create electrical generators, maglev trains

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- Power generators
  - are energy sources for home applicants and electrical circuits
  - change an energy in anther form into an energy in the electrical form
  - [VDO 9] power generatorhttp://www.youtube.com/watch?v=m-ehwxV4nf0
- Magnetically levitated (maglev) trains
  - attain a speed as fast as 500 km/hr
  - [VDO 15] maglev trains, applications of magnetostatics http://www.youtube.com/watch?v=aIwbrZ4knpg
- In order to control the flow of electricity, we need to understand and analyze the electrical circuits

Three major laws govern the electrical circuits

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- Kirchhoff's Current Law (KCL)
  - [VDO 18] KCL (technical); Trimmed to 2.28http://www.youtube.com/watch?v=QbTr25UTR7s
- Kirchhoff's Voltage Law (KVL)
  - [VDO 4] KVL (technical)http://www.youtube.com/watch?v=KjNwqX-DB2w
- Voltage-current (V-I) relationships
  - [VDO 6] voltage, current, resistance, V-I relationship http://www.youtube.com/watch?v=cdOOg1aX0zc

Applications of electrostatics

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- Knowledge in electrostatics can be applied to, for example,
  - create positive charges and negative charges---a process called doping--- in semiconductors
  - join materials between P and N junctions, resulting in semiconductor diodes, which allow the current to flow only in one direction
- [VDO]: PN junction
  - http://www.youtube.com/watch?v=W6QUEq0nUH8
- By joining the P-type and N-type materials that have different amount of changes, engineers create transistors, thyristors, field-effect transistors, and other electrical components
- Understanding the functions, properties, and applications of electrical components is a scope of a scope of a subject called "applied electrostatics"

Applications of magnetostatics

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- Knowledge in magetostatics helps us to design the devices that transform the kinetic energy into electrical energy, and vice versa
- These devices include power generators, motors, transformers
  - which are main components of power system; detecting device of indicating instruments; transducer; and sensors in controlled systems
- [VDO] applications of electromagnetic, motors
  - [VDO 20] DC motor: http://www.youtube.com/watch?v=9Wby4aHyXJQ
  - [VDO 17] 3-phase motor http://www.youtube.com/watch?v=LtJoJBUSe28

We can categorize electrical circuits according to their functions

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- Examples of categories: rectifier, invertor, convertor, amplifier, operation amplifier, and logic gate
- The resulting categories will help engineers
  - systematically and efficiently apply these circuits
  - design and solve problems (duty, specific data, and performance)

Control System

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- Principles for controlling interconnected devices, for the purpose of producing stability and regularity, as well as specifying the needed rules, is a scope of a subject called “control system”

Maxwell's equations

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- Electromagnetic field can be created by electric and magnetic fields that change overtime
- Maxwell's equation describe how electric and magnetic fields are generated and altered by each other
- Maxwell's equations are fundamentals to the design and analysis of communication systems, transmission lines, radio and television broadcasting, sound and light propagations
- [VDO 12]: Maxwell's equations http://www.youtube.com/watch?v=VdoL8IOwJw0

Summary

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- Introduction to the contents of this course
- Major topics of this course are
  - electrostatics
  - magnetostatics
  - electrical circuits
- Natural phenomena that illustrate these topics
- Applications of these topics