REVISION: ELECTRICITY & MAGNETISM 18 JUNE 2013

Lesson Description

In this lesson we revise:

- the phenomenon of magnetism and define a magnetic field
- the phenomenon of electrostatics and conservation of charge
- electric circuits and circuit calculations

Key Concepts

Magnetism

Magnetism is an interaction that allows certain kinds of objects, which are called ‘magnetic’ objects, to exert **forces** on each other **without physically touching**.

This is due to a magnetic field which surrounds the objects. The field and subsequently the force experienced gets weaker as one moves further away from the object.

A **magnetic field** is a region in space where a magnet or object made of magnetic material will experience a **non-contact**, **magnetic force**.

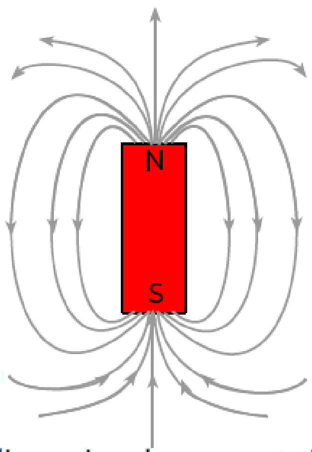
Like (identical) poles of magnets repel one another whilst unlike (opposite) poles attract.

Representing magnetic fields

Magnetic fields can be represented using **magnetic field lines.** These lines are drawn from North to south. Remember that a magnet has a field in 3 dimensions (all around it), however, for simplicity we only draw a 2 D cross section.

Note:

- Field lines **never cross**.
- **Arrows** drawn on the field lines indicate the direction of the field.
- A magnetic field points from the **north to the south pole** of a magnet.
- Strong magnetic field = field lines close together
- Weak magnetic field = field lines far apart



2-dimensional representation

The number of field lines drawn crossing a given two dimensional surface is referred to as the magnetic **flux**. The magnetic flux is used as a measure of the strength of the magnetic field through that surface.

Electrostatics

Positive charge	Negative charge
Protons in the nucleus.	Electrons spinning around nucleus in atom

Overall objects can be:

Neutral **Positively charged** **Negatively charged**

How? Through contact or friction: electrons transferred

Electrons lost - positively charged object is formed
Electrons gained - negatively charged object is formed

Attraction and Repulsion

- Unlike (opposite) charges are attracted to each other
- Like (same) charges are repelled from each other.
- The closer together the objects are the stronger the forces experienced

Conservation of Charge

Charge is neither created nor destroyed, it can only be transferred
Charge is measured in coulombs (C).
Each electron has a charge of $q = 1.6x10^{-19}C$
So the overall charge on an object will be

$$Q = nq_e$$

- Conductors allow charge to move through them easily
  - Excess charge will spread evenly over the surface of a spherical objects
- Insulators do not allow charge to move through them easily.

Identical, conducting spheres in contact share their charge according to:

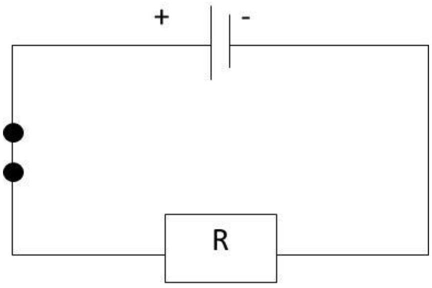
$$Q = \frac{Q_1 + Q_2}{2}$$

Circuit Components

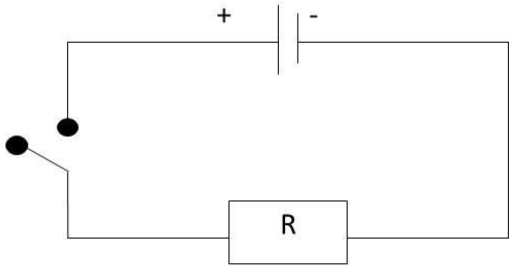
Any electrical circuit is made up of several components, such as a power source and conducting wire. However, for an electric current to flow the following conditions need to be met:

- an energy source, i.e. a battery
- conductors
- circuit must be closed

A closed circuit is a circuit which allows electric current to flow as there are no gaps or spaces in the circuit.

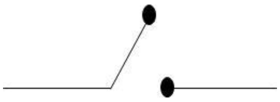
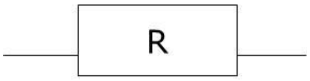
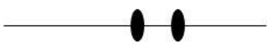
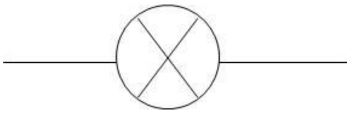
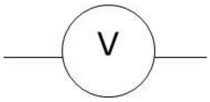
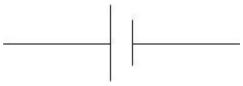
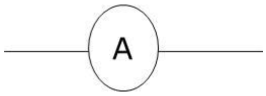
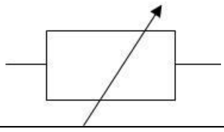


Closed Circuit



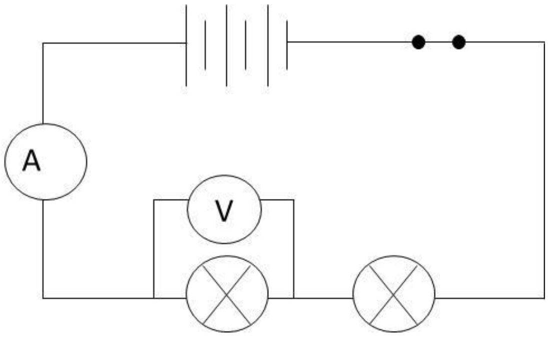
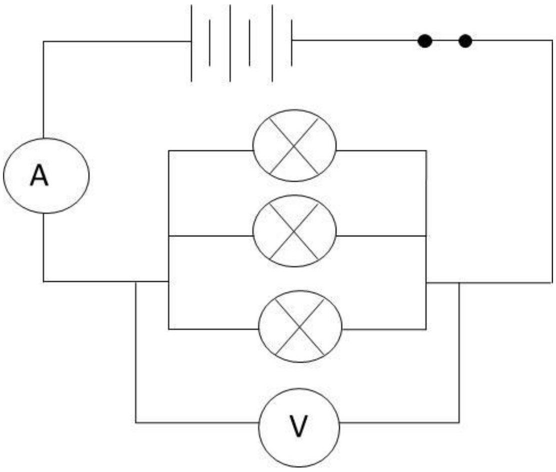
Open Circuit

It is important to know the correct symbols for the components of an electric circuit.

Component	**Symbol**	**Component**	**Symbol**
Conductor		Open switch	
Resistor		Closed switch	
Light bulb		Voltmeter	
A cell		Ammeter	
Rheostat			

Series and Parallel Circuits

The components in a circuit can be connected either in series or parallel.

Series Circuit	Parallel Circuit
	
There is only one path for the current to flow through.	There is more than one path for the current to flow through.

Potential Difference

If a charge, such as an electron, is in an electric field it will possess electrical potential energy. Charges will move from a high potential energy to a low potential energy. This causes a difference in potential energy between two points. This difference in potential energy is used to do work in the circuit. This work can be experienced in the form of light or heat, for example. As the resistance of the component increases, the potential difference across that component will also increase.

Potential difference is defined as the difference in the electric potential energy per unit charge between any two points in a circuit (also called voltage)

The electric potential difference across the poles of a battery is known as the emf, but only when there is no current flowing.

When current is flowing the potential difference across the poles of a battery is known as potential difference (pd)

Potential difference across a resistor or battery is measured using a voltmeter. A voltmeter is always connected in parallel over the component. A voltmeter has a very high resistance, so if it is connected in series it will prevent any current from flowing through the circuit.

Potential difference and emf is measured in volts (V).

Potential difference can be calculated using the following equation:

$$V = \frac{W}{Q}$$

Where:
- V = potential difference measured in volts (V)
- W = work / energy measured in joules (J)
- Q = charge measured in coulomb (C)

Current Strength

Electric current is the flow of charge, either positive or negative. In order for electric current to flow, a source of electric energy is necessary, i.e. a battery.

The direction of current in circuit can either be described as conventional current or electron flow. Conventional current is defined as the direction of the current moving from the positive pole of a cell through the circuit to the negative pole of the cell.

Electron flow is defined as the direction of the current moving from the negative pole of a cell through the circuit to the positive pole of the cell.

Electric current strength is defined as the rate at which electric charge flows in a circuit.

Electric current strength is measured using an ammeter. An ammeter is connected in series in a circuit. An ammeter has an extremely low resistance therefore if it is connected in parallel no current will flow through the component as it will all go through the ammeter inside.

Current strength can be calculated using the following equation:

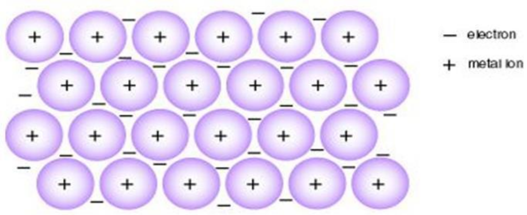
$$I = \frac{Q}{\Delta t}$$

Where:

- I = current strength measured in amperes (A)
- Q = charge measured in coulomb (C)
- Δt = time measured in seconds (s)

Resistance

In a circuit the path for the current is made using conductors. Conductors are made from metals such as copper. Metals consist of metallic bonds. Metallic bonds are characterised by densely packed positive ion kernels with a sea of delocalised electrons. The delocalised electrons allows current to flow, as they are free to move through the metal.



Source: http://www.talktalk.co.uk/reference/encyclopaedia/hutchinson/m0030538.html

Thus, electric current in a metal is the flow of electrons. When the electrons are moving they bump into each other the positive ion kernels of the metal. This allows kinetic energy to be transferred, which in turn causes the conductor to become hot and the flow of current decreases.

A good conductor has very little resistance to the flow of current.

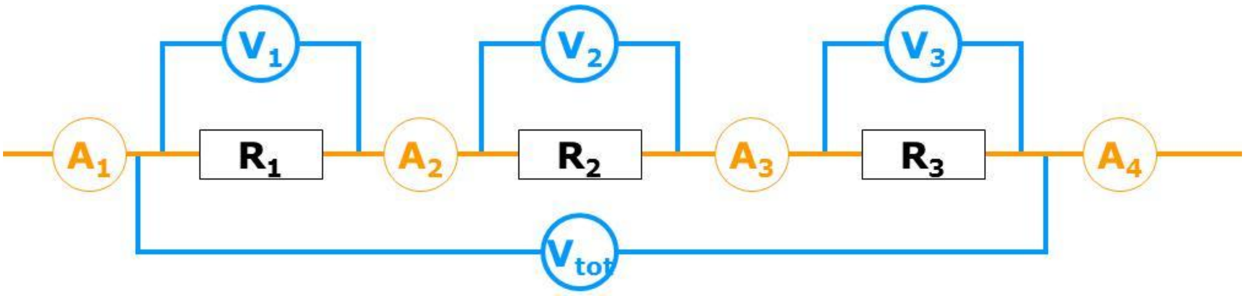
Resistors

A resistor is a component in a circuit which resists the flow of charge through the circuit. It is a bad conductor and is said to have a resistance (symbol R).

Electrical energy is converted into other types of energy, such as heat, light or kinetic.

Resistors can be connected in series or in parallel in a circuit.

Series Circuit

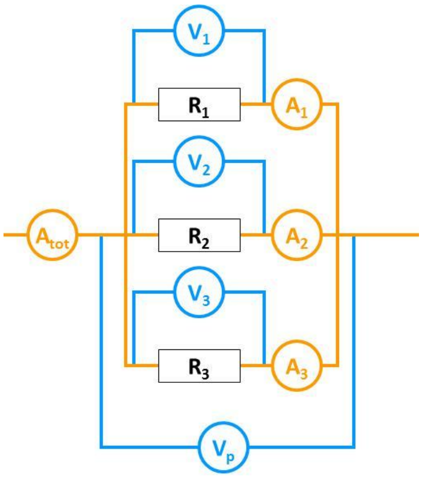


When resistors are connected in the series, the total resistance of the circuit increases as more resistors are added. The greater the number of resistors the smaller the current in the circuit will be.

The total resistance in the circuit is calculated as follows:

$$\boldsymbol{R_{TOT} = R_1 + R_2 + R_2}$$

Parallel Circuit



When resistors are connected in parallel, the total resistance in the circuit becomes smaller. The smaller the total resistance the greater the current in the circuit will be.

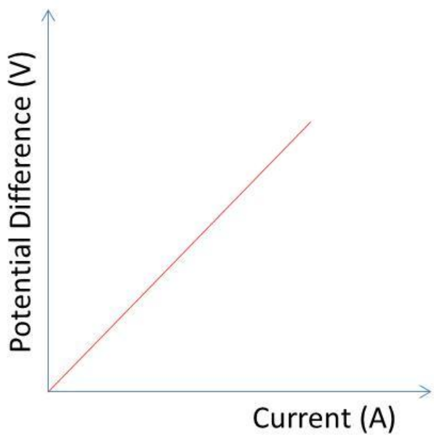
The total resistance in the circuit is calculated as follows

$$\frac{1}{R_{TOT}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Resistance is measured in ohms (Ω) and is given the symbol R.

Ohm's Law

From the simulation it can be seen that the resistance of a resistor is constant. Also, as the current through the resistor increases so the potential difference across the resistor also increases. If a graph of potential difference versus current is drawn a straight line will be found, as shown in the sketch graph. The straight line, through the origin proves that potential difference and current are directly proportional.



Thus ohm's law is stated as: *The potential difference over a resistor is directly proportional to the current through the resistor, provided the temperature of the resistor remains constant.*

Ohm's law can be represented as an equation:

$$R = \frac{V}{I}$$

R = resistance measured in ohm (Ω)
V = potential difference measured in volts (V)
I = current measured in ampere (A)

Questions

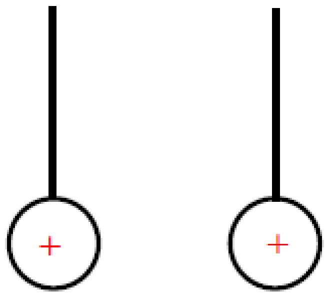
Question 1

Unlike poles:

Draw the magnetic field when unlike poles are brought together. Predict what force will be experienced by the magnets.

Question 2

I have 2 charged spheres each hanging from string as shown in the picture below.



The spheres will:

a.) swing towards each other due to the attractive electrostatic force between them.
b.) swing away from each other due to the attractive electrostatic force between them.
c.) swing towards each other due to the repulsive electrostatic force between them.
d.) swing away from each other due to the repulsive electrostatic force between them.

Question 3

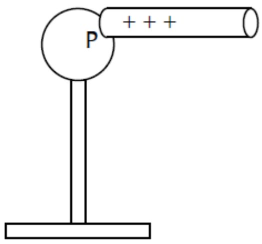
I have two positively charged metal balls placed 2 m apart.

a.) Is the electrostatic force between the balls attractive or repulsive?
b.) If I now move the balls so that they are 1 m apart, what happens to the strength of the electrostatic force between them?

Question 4

(Adapted from IEB 2005/11 HG)

An uncharged hollow metal sphere is placed on an insulating stand. A positively charged rod is brought up to touch the hollow metal sphere at P as shown in the diagram below. It is then moved away from the sphere.



Where is the excess charge distributed on the sphere after the rod has been removed?

a.) It is still located at point P where the rod touched the sphere.
b.) It is evenly distributed over the outer surface of the hollow sphere.
c.) It is evenly distributed over the outer and inner surfaces of the hollow sphere.
d.) No charge remains on the hollow sphere.

Question 5

If 100 J of work is done when 15 C of charge moves through a light bulb, calculate the potential difference across the light bulb.

Question 6

Calculate the current in a circuit, if 72 C of charge moves past a point in the circuit in 5 seconds.

Question 7

Three resistors of 2Ω, 3Ω and 4Ω are connected in a circuit. Calculate the total resistance when

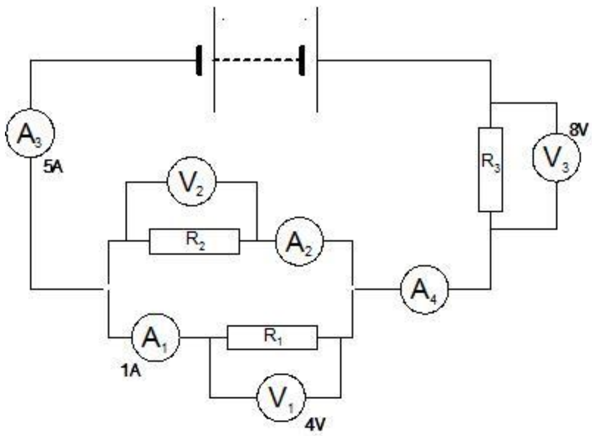
a. the resistors are connected in series
b. the resistors are connected in parallel.

Question 8

A resistor has a resistance of 15 Ω. Calculate the current through the resistor when the potential difference across the resistor is 20 V.

Question 9

In the circuit, the ammeter readings are A_1 = 1A and A_3 = 5A. The voltmeter readings are V_1 = 4V and V_3 = 8V.



a.) What is the reading on A_2?
b.) What is the reading on V_2?
c.) What is the reading on A_4?
d.) Calculate the resistance of R_1; R_2; R_3.

Links

- PHet simulations: Magnets
  http://phet.colorado.edu/en/simulation/magnet-and-compass
  http://phet.colorado.edu/en/simulation/magnets-and-electromagnets
- Inside a resistor: http://phet.colorado.edu/en/simulations/category/physics
- Virtual circuit lab: http://phet.colorado.edu/en/simulation/circuit-construction-kit-ac-virtual-lab
- Ohm's Law notes: http://www.physicsclassroom.com/Class/circuits/u9l3c.cfm
- Ohm's Law calculations: http://www.youtube.com/user/EducatorVids3?v=1y11UJjhQtI
- Ohm's Law Explained: http://www.youtube.com/watch?v=axyT2TFvH_U