Homework 17

Electric current and Ohm's law

If we connect two points corresponding to different electrical potential energies with a metal wire, the charged particles in the metal, the electrons, will move from the point of higher potential energy to the point of lower potential energy. ***The transfer of electrical charge is called "electrical current"***. Any material with charged particles which are able to move can conduct electrical current. This class of material is called "conductors". Metals, for example, are conductors. In most of the metals electrical current is conducted by negatively charged electrons. In salt solution the current is conducted by both positively and negatively charged ions. Materials which do not conduct electrical current are called insulators.

Magnitude of electrical current in a conductor is equal to the charge which passes through the cross section of the conductor per unit time. Current is measured in Amperes (A). This name is after Andre-Marie Ampere (1775-1836), a French physicist and mathematician.

Andre-Marie Ampere (1775-1836)

1A means that a charge of 1C passes through the cross section of a conductor per 1 second. Historically, it is the unit of charge (1 Coulomb) which was defined through the unit of electrical current. We remember that to introduce a unit for measuring of "something" we have to provide a recipe or describe the experiment which will allow any scientist or engineer to calibrate the measuring device. There is a relatively simple experiment which makes possible calibration of electrical current magnitude. This experiment is based on the property of two parallel wires with same direction of electrical current to attract each other. If the current directions in the wires are opposite the fires repel each other. The origin of this force is magnetic field surrounding the wires. Later we will discuss magnetic field in details. What is important for us now is the fact that the force of attraction (repulsion) of the wires depends on the distance between the wires, the wire lengths, the type of media surrounding the wires, and, the most important fact, on the *magnitude of electrical current* in the wires. So, if two parallel wires with the same current magnitude, 1m long, separated by a distance of 1m in vacuum interact with the force of $2x10^{-7}$N, the current in the wires is 1A. Then we can measure the charge, transferred through the cross section of the wire. This amount of charge is called 1 Coulomb.

Ohm's law.

Simply speaking, Ohm's law establishes the connection between the voltage drop across a piece of material and current in this piece. Just to remind: voltage (or, more correct, *potential difference*) between two points is the work which we have to do to move a unit positive charge from

point 2 to point 1 or the work which a unit positive charge will do moving from point 1 to point 2. ***This work does not depend on the path we have chosen to move the charge.*** The voltage is measured in joules per coulomb, or *volts.* The potential difference of 5V (5 volts) between point 1 and point 2 means that a 1C charge will perform work of 5J if moved from point 1 to point 2. If potential is higher in the point 2 then the potential difference is positive, otherwise it is negative. If we maintain a positive potential difference between two points and connect these two points with a piece of metal wire or other material which is able to conduct electrical current the charged particles in the wire will move from point 1 to point 2 if they are positive, and from point 2 to point 1 if they are negative, so there will be electrical current in the wire. The current *I* between two points is proportional to the voltage *U* between these points.

$$U = R \cdot I$$

The coefficient R is called electrical resistance. The resistance of a piece of wire depends on the length of the wire, on its thickness and on the wire material. The resistance is measured in Ohms. This unit is named after Georg Simon Ohm, German physicist and high school teacher.

Georg Simon Ohm (1789_1854)

The resistance of 1 Ohm means that if we apply a potential difference of 1 Volt we will obtain current of 1A.

Using my favorite analogue between the current flow in a conducting wire and water flow in a tube, I can represent the resistance as the magnitude, proportional to the inverse diameter of the tube. A wider tube allows more water to flow through it, so it's "resistance" is low.

1. Molecules of hydrogen consist of charged particles – electrons and protons. Is it correct to say that flow of hydrogen is electric current?
2. A charge of 300C passes through the filament of a bulb in 10 min. Find the current in the filament.
3. N droplets of mercury are charged, and each has a potential ***v***. (Electric potential of a spherical droplet can be calculated using the expression for the potential of a charged sphere which you have obtained in the previous homework.) After merging the N droplets form a single big droplet. What is the potential of this droplet?
4. What voltage (potential difference) is needed to put a current of 5A through a wire with a resistance of 10Ohm?
5. For the problem 1, find the work which is done when a charge of 3C is moved from the positive terminal of the voltage source (battery) to the negative one? Describe the energy transformation: where it is taken from and where does it go.

6. How much time does it take to move the charge of 3C from the positive terminal to the negative one if the current is 5A