Homework 8

Ohm's law.

Last class we discussed voltage, current and resistance. 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 1 to point 2 or the work which the electric force does when a unit positive charge is moved from point 2 to point 1. ***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 (potential in point 2 minus potential in point 1 !) means that the electric force will perform work of 5J on 1C which is moved from point 2 to point 1. 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 2 to point 1 if they are positive, and from point 1 to point 2 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.

$$U = R \cdot I \qquad (1)$$

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. The magnitude, which is reciprocal to the resistance is called conductance. The unit of conductance is 1/Ohm, or Siemens (S).

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.

Resistance R of a wire can be calculated using the following expression:

$$\boldsymbol{R = \rho \frac{l}{A},} \qquad (2)$$

where $\boldsymbol{l}$ is the length of the wire, $\boldsymbol{A}$ is the cross-section area of the wire and $\boldsymbol{\rho}$ is the coefficient which is called *resistivity*. Resistivity is measured in Ohm/m and does not depend on the wire geometry and is a property of the wire material. Parameter $\boldsymbol{\sigma}$, reciprocal to resistivity is called "*conductivity*":

$$\boldsymbol{\varrho = \frac{1}{\sigma}} \qquad (3)$$

All materials follow into three major groups depending on their conductivity (or resistivity), (Table 1). Materials with a very low conductivity are called "*insulators*". They are marked by dots in the left side of Table 1. Examples of insulators are glass, diamond and fused quartz. Highly conductive materials are shown in the left side of the table. These are called "*conductors*" and are mostly metals such as silver, copper and platinum. The conductivity of the third group, *semiconductors*, can be varied in a wide range. That is why it is shown by lines rather than dots in Table 1. All electronics devices such as cell phones, computers, TVs are based on semiconductors (silicon is the most common).

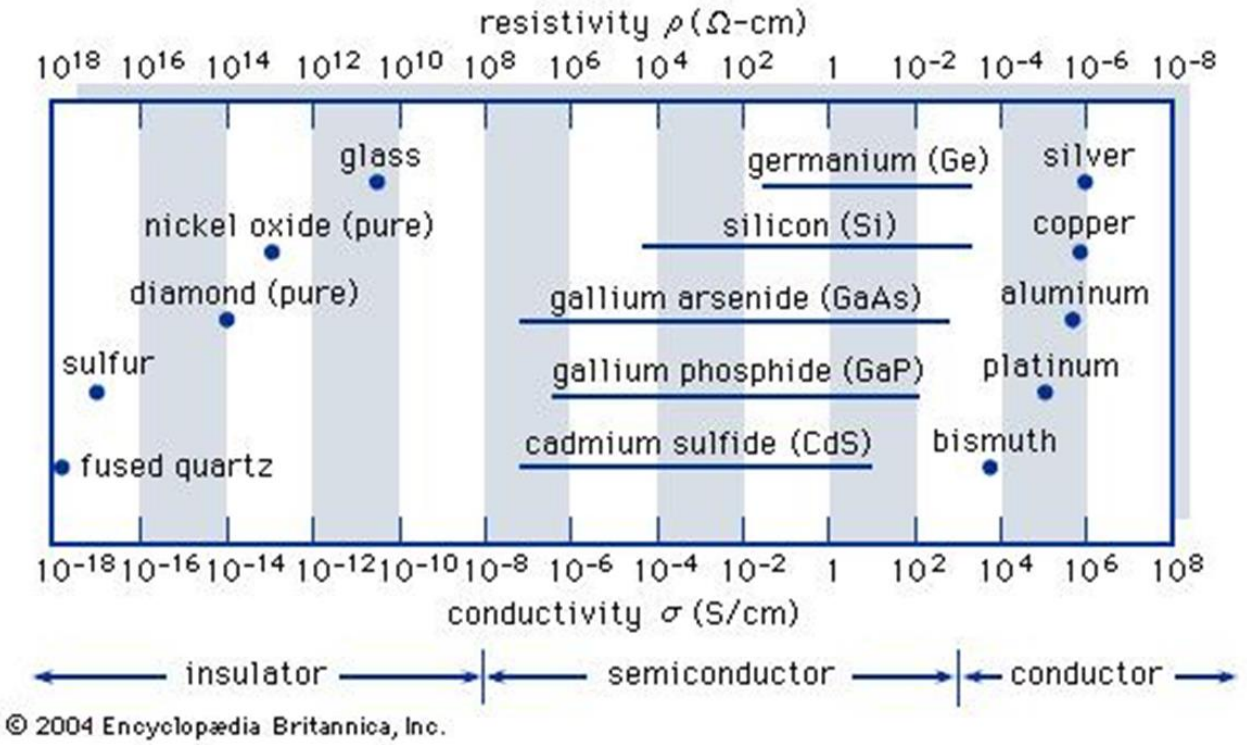

Table 1. Conductivity and resistivity of various materials.

Problems:

1. What voltage (potential difference) is needed to put a current of 5A through a wire with a resistance of 10Ohm?

2. 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.

3. 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?

4. A 5km copper wire has a resistance of 12Ohm. Calculate the mass of the wire. (the resistivity of copper is 1.7×10^{-8}Ohm m and the density of copper is 8.96 g/cm^3).