

2003-2004 Physics Olympiad Preparation Program

– University of Toronto –

Problem Set 5: Electricity and Magnetism

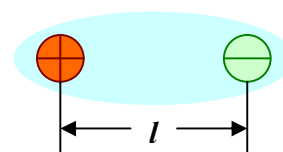
Due March 8, 2004

1. Always-fidgety molecules.

We can imagine a polar molecule, as a system with two point masses carrying unlike charges with invariable distance between them (Fig.1).

This molecule is put in the uniform electric field with the strength $E=300 \text{ V/cm}$. The molecular average length is $l = 10^{-8} \text{ cm}$, the masses of charges are $m = 10^{-24} \text{ g}$, the magnitude of charges is equal to $e = 1.6 \times 10^{-19} \text{ C}$.

Find the period of oscillations of the molecule in the field.



2. Lightning production.

In the high voltage electrostatic generator electric charges are carried by the belt, made of a special insulating material, and charge a large metallic sphere with radius $R=1.5 \text{ m}$, as it is shown in Fig.2.

Width of the belt is $l=1\text{m}$, its speed is 20 m/s . A discharge in the air takes place when the strength of electric field exceeds $E=30 \text{ kV/cm}$.

Estimate the maximal values of voltage and current that can be obtained with such generator.

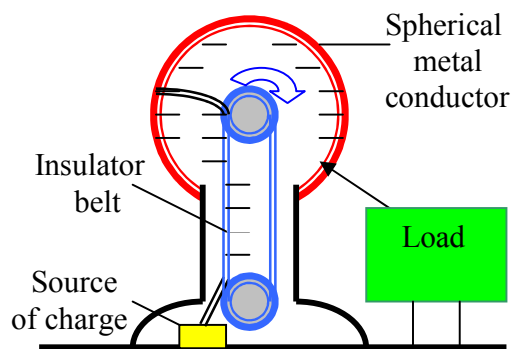


Fig.2

3. Electronics.

The diode is connected in the circuit with given electro-motive force ε , as it is shown in Fig.3a. Current versus voltage function for diode is represented in Fig.3b. The capacitor with capacitance C is not charged initially. Then switch K is turned on.

What is the amount of heat that is produced in the resistor with resistance R while the capacitor is being charged?

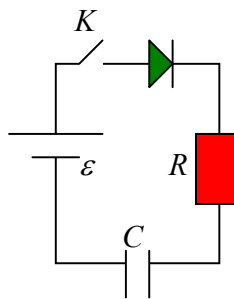


Fig.3a

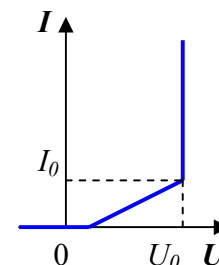


Fig.3b

4. Either in Guelph, or in CERN.

In the circular accelerator with radius R a very thin beam of protons with non-relativistic speed is injected. The mass m and the charge e of proton are well known. The initial current in the accelerator is I , the total number of particulates is n . The magnetic flux through the beam circuit changes with the rate of $\dot{\varphi}$, while the radius of the beam track remains unaltered.

What is the value of current after one turn of the particles?

What is the name of such kind accelerator?

5. Imagine your experiment.

Take a battery with known value of EMF ε (electromotive force) and a number N of equivalent capacitors with capacitance C and wires for connecting circuit.

What is the maximal value of the potential difference that you can obtain with this kit?

What will be the sequence of your actions to achieve this result?