2005-2006 Physics Olympiad Preparation Program

– University of Toronto –

Canadian Association of Physicists (CAP) High School Exam
takes place on Friday, April 7, 2006. To be selected for the National Finals, the successful participation in CAP Exam is essential.

POPTOR Weekend and Final Exam
to select Ontario students for the National Finals will be held from May 19 to May 21, 2006

National Olympiad Finals
at the University of Toronto will be held on May 28 - June 4, 2006 .

This problem set gives you the last chance to participate in the 2005-2006 competition for the best problem created by our POPTOR contestants. Name your self-made problem as "My Problem", and mail this problem and its solution on a separate sheet of paper along with the solutions of the POPTOR problems. You may send us any number of problems, but only self-made and unique will be considered. Authors of the best problems will be awarded during the POPTOR Weekend.

Problem Set 6: AC Circuits, Electronics and General

Due April 3, 2006

Problem 1.
A linear conductor of length l and mass m is attached to identical vertically suspended springs with the spring constant k (fig.1). A uniform magnetic field $\boldsymbol{B}$ is perpendicular to the plane of the circuit. A capacitor with the capacitance C is initially charged, and the voltage across the capacitor is V_0. After the switch S is closed, the conductor starts oscillating harmonically with period that is significantly greater than the time of the discharging of the capacitor.
Find the amplitude of the oscillation.

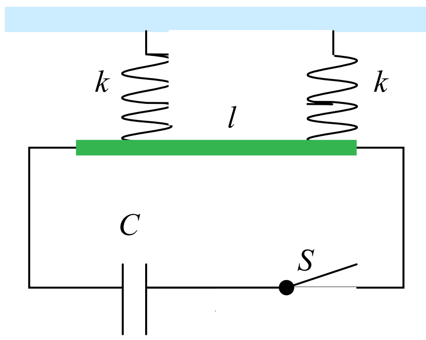

Fig.1.

Problem 2.
Brief theory.
Energy emitted per second by one square meter of a hot object with the surface temperature T is given by Stefan-Boltzmann law:

$$S = \frac{E}{\Delta t \cdot A} = \frac{P}{A} = \sigma T^4 e \quad (2.1)$$

where S is called the intensity of radiation; P is the power of radiation; A is the area of the surface; T is the surface temperature in kelvins; $\sigma = 5.67 \cdot 10^{-8}$ W/(m^2·K^4), is a universal constant; and e is the emissivity. Its value varies from zero to unity. When an object is in thermal equilibrium with its surroundings, it radiates and absorbs energy at the same rate, and its temperature remains constant. An ideal absorber is called a **black body** and is defined as an object that absorbs all the energy incident on it, and for such an object, $e = 1$. For the purposes of estimation of some thermal parameters, many objects can be considered the black bodies with $e = 1$ in eq.(2.1).

All objects in our problem must be treated as black bodies.
A cloud of cosmic dust contains iron particles. The melting point for iron is $T = 1808$ K. Find the distance from the iron particle to the center of the Sun, at which the iron particle starts melting, using the following data: when the center of the Earth is at the distance of $1.50 \cdot 10^{11}$m from the center of the Sun, the intensity of solar radiation at the Earth's orbit is 1.37 kW/m^2.

Problem 3.

A star of mass M and radius R emits from its "surface" a photon with frequency f_0. Find the gravitational shift for the frequency of the photon, $\Delta f / f_0$, very far from the star.

Problem 4.

In the process of radioactive decay, a nucleus of ^{210}Po that is at rest emits an alpha particle (^4_2He) in the ground state (the quantum state with the lowest possible energy). Initially the alpha particle has a kinetic energy of 5.77 MeV.
Find:

(a) the other product of the decay;
(b) the initial speed of the nucleus of this product;
(c) what fraction of the total reaction energy (disintegration energy) does the kinetic energy of the product form;
(d) the heat emitted as a result of decay of 1.00 mg of ^{210}Po during the half-life time.

Problem 5 (A black box experiment).

A first-year university student did not like to use a heavy and large notebook for his records during the laboratories. He preferred to write experimental results without details on a little piece of paper, and relied on his memory. Once, he was not accurate with his data and did not make clear notes during the measurements of current and voltage in an experiment with electric circuit. The single source of information was a traditional little piece of paper with some sketches of experiments and measured values shown on fig.5.1. Actually, the student produced a problem with a so-called "black box", the contents of which he now has to recall. The unknown electric circuit exists inside a "black box" with three terminals. Two terminals are grounded, i.e. connected to the earth, which potential is zero. The student remembers that he measured the current through the third, not grounded, terminal. All current scales are in amperes, and the voltage scales are in volts. Using the student's notes, help him to find the contents of the black box.

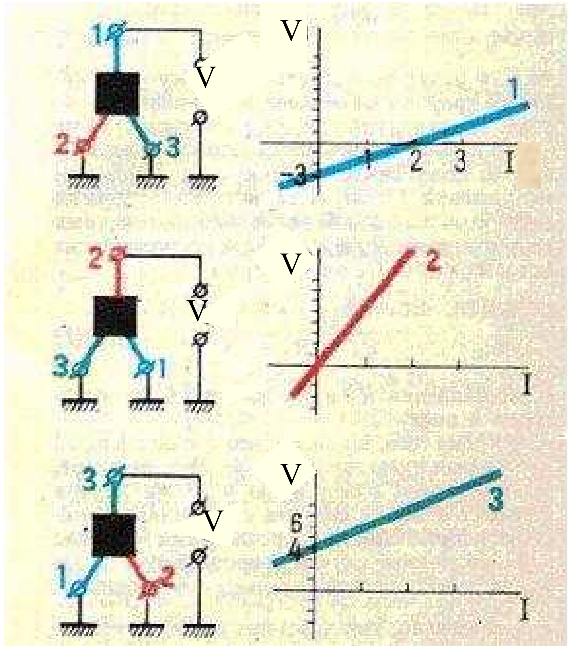

Fig.5.1