Canadian Association of Physicists (CAP) High School Exam is appointed to Thursday, April 5, 2007. To be selected for the National Finals, the successful participation in the CAP Exam is essential.

2006-2007 Physics Olympiad Preparation Program

– University of Toronto –

We are finishing the competition for the best problems 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 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 2, 2007

Problem 1.

In an experiment carried out by S. C. Collins between 1955 and 1958, a current was maintained in a superconducting lead ring for 2.50 yr with no observed loss. If the inductance of the ring was 3.14×10^{-8} H, and the sensitivity of the experiment was 1 part in 10^9, what was the maximum resistance of the ring? (*Suggestion:* Treat this as a decaying current in an *RL* circuit.)

Problem 2.

A diode is a device that allows current to be carried in only one direction (the direction indicated by the arrowhead in its circuit symbol). Find in terms of ΔV and R the average power delivered to the diode circuit of Figure 2.1.

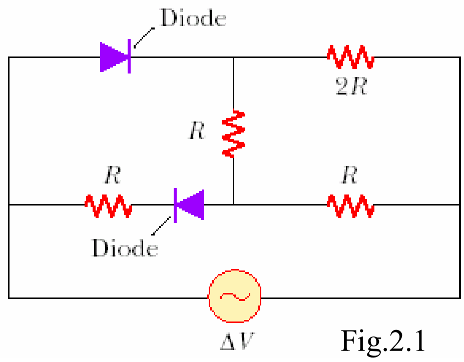

Fig.2.1

Problem 3.

A plane electromagnetic wave has an intensity of 750 W/m^2. A flat, rectangular surface of dimensions 50 cm × 100 cm is placed perpendicular to the direction of the wave. The surface absorbs half of the energy and reflects half. Calculate

(a) the total energy absorbed by the surface in 1.00 min and

(b) the momentum absorbed in this time.

Problem 4.

Two circuits like the one shown in Figure 4.1 are identical except for the value of L. In the circuit A the inductance of the inductor is L_A, and in the circuit B it is L_B. The change of current in any RL-circuit is characterized by the time constant $\tau = L/R$. The time constant equals the time interval for the decreasing current to drop by the factor of e (the base of the natural logarithm) and equals the time interval for the increasing current to reach $(1 - e^{-1}) \approx 0.632$ of its maximum value. A switch S is designed so that it is never open, which would cause the current to stop. The switch is thrown to

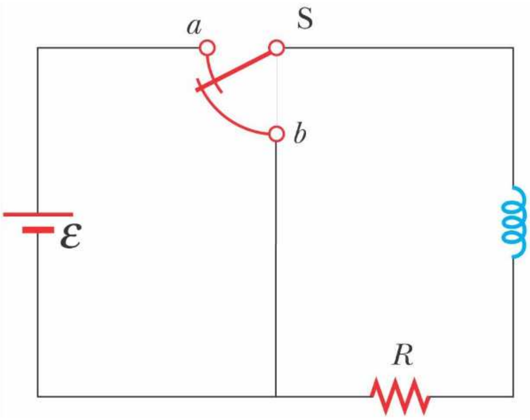

Fig.4.1

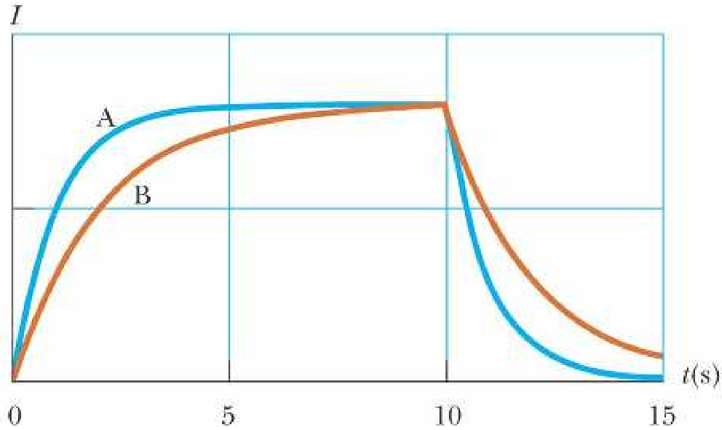

Fig.4.2

position a at $t = 0$. At $t = 10$ s, the switch is thrown to position b. The resulting currents for the two circuits are as graphed in the Figure 4.2.
Assuming that the time constant τ of each circuit is much less than 10 s, estimate roughly the relationship between L_A and L_B?

Problem 5.
A first-year university student performs an experiment with photoelectric effect. He uses an experiment device, sketched in Figure 5.1. The cathode C is illuminated by the beam of light (the beam of photons) and emits electrons with the maximum kinetic energy at the surface of the cathode K_{max}. The relationship among the frequency of photons f, the value of K_{max} and the work function ϕ of the metal of the cathode (the work done on the electron to bring it out of the surface with zero kinetic energy) is give by the Einstein's equation for the photoelectric effect:

$$hf = K_{max} + \phi,$$

where h is Planck's constant.

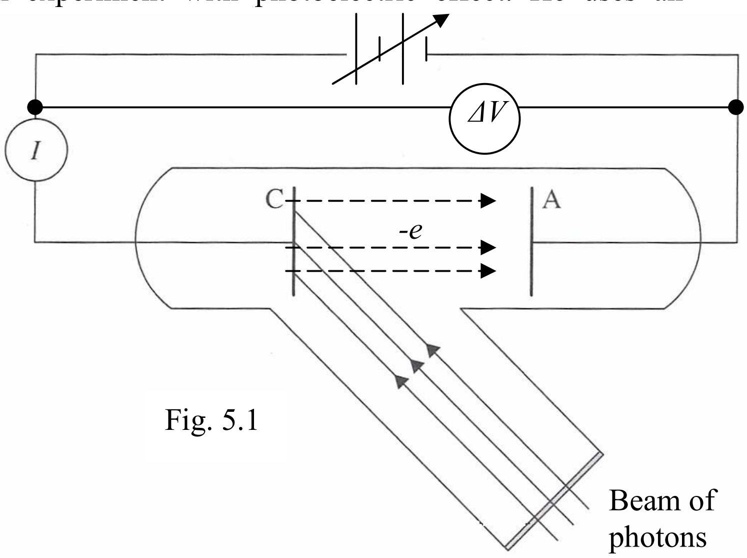

Fig. 5.1

The potential difference between the cathode and the anode A may very. The student connects the negative terminal of the power supply to the anode and tries to "stop" electrons by increasing the applied voltage. The student measured current and voltage in the external circuit as shown. For each wavelength of the incident beam of photons the student finds such potential difference $-\Delta V$ that the current I becomes zero. This threshold value is called the *stopping potential*.

The following table shows data obtained by the student in the experiment.

Wavelength of the light, nm	Stopping potential, V
588	**0.67**
505	**0.98**
445	**1.35**
399	**1.63**

Using these data, determine
(a) an experimental value for Planck's constant (in joule-seconds) and
(b) the work function (in electron volts) for the surface.