

2007-2008 Physics Olympiad Preparation Program
University of Toronto

Problem set 5: Electricity and Magnetism

Due: March 03, 2008

We continue the competition for the best original problems created by POPTOR contestants. Name your self-made problem as “MY PROBLEM” and mail it along with its solution on a separate sheet of paper, along with your solutions of the POPTOR problems. You may send us any number of problems, but only the self-made unique ones will be considered. The authors of the best problems will be awarded during the POPTOR Weekend.

- 1.** In the circuit shown in Figure 1(a) the e.m.f. of the ideal battery is $U_0 = 2.4\text{ V}$, and the values of the resistors are $R = 600\ \Omega$, $r = 200\ \Omega$. The diodes D_1 and D_2 have identical U-I characteristics, as shown in Figure 1(b). Find the intensity of the current through D_2 .

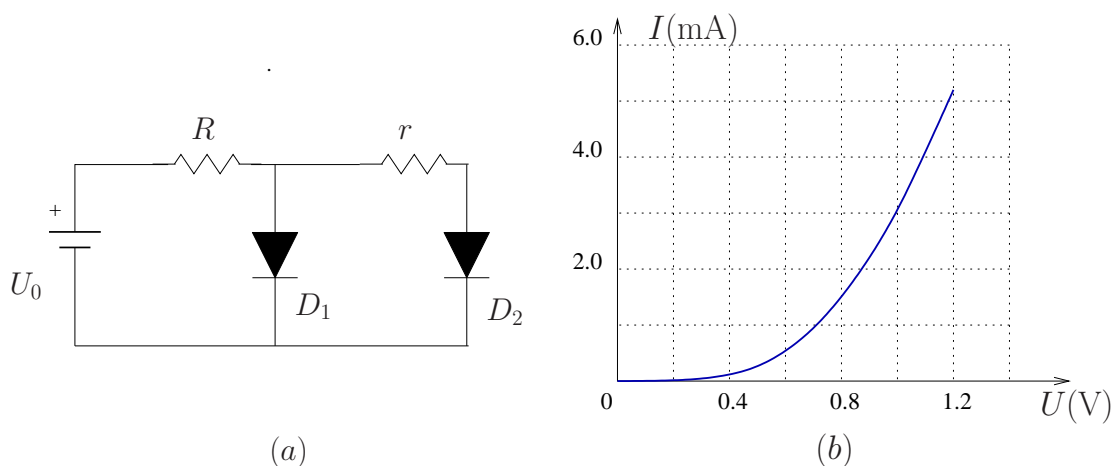


Figure 1: (a) the circuit, and (b) the U-I characteristic of the diode.

- 2.** Three identical metal spheres of radius r are located at the vertices of an isosceles right triangle, as shown in Figure 2 (assume $r \ll a$). The spheres are initially charged with charge q each. Spheres 1 and 2 are connected for a short time with a wire, then the wire is taken away. Next, the spheres 2 and 3 are connected with a wire, then the wire is taken away. Last, the spheres 3 and 1 are connected with a wire, then the wire is taken away. What are the electric charges on the spheres after all these operations?

- 3.** A straight conducting bar of mass m and length l is suspended horizontally with two non-conducting springs of stiffness k as shown in Figure 3. The bar is located in a region of uniform magnetic field of intensity \mathbf{B} . The capacitor C is initially charged to the potential difference U . At time $t = 0$ the switch S is closed and the capacitor discharges. The bar starts oscillating in

the vertical plane. Find the amplitude of these oscillations. Assume the time of discharge of the capacitor is much smaller than the period T of the mechanical oscillations of the bar.

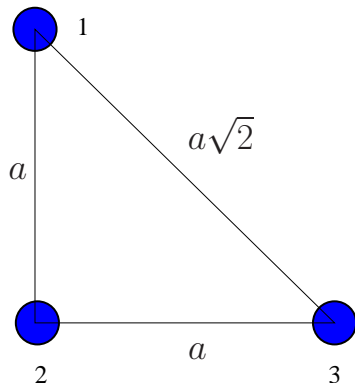


Figure 2:

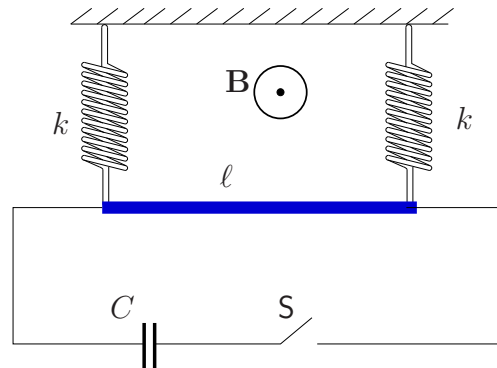


Figure 3:

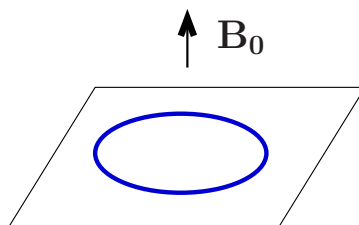


Figure 4:

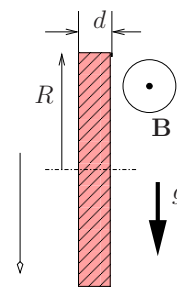


Figure 5:

4. The electric charge Q is uniformly distributed on a thin dielectric ring of mass m . The ring lays on a frictionless table, as shown in Figure 4. The magnetic field perpendicular to the plane of the ring changes from 0 to some value B_0 .

What is the angular speed ω the ring reaches after this change in the magnetic field? Does the ring rotate clockwise or counter-clockwise (as viewed from above)? Provide a numerical estimate for ω , using your own (realistic) values for the relevant parameters.

5. A circular metal plate falls straight vertically in a region of uniform magnetic field of intensity B , as shown in Figure 5 (side view). The magnetic field is parallel to the surface of the Earth and to the plane of the plate, the acceleration of free fall is g , the plate has mass m , and its thickness d is much smaller than its radius, R .

Find the acceleration a of the plate. By how much, in %, does a differ from g (you need to come up with some realistic values for the parameters involved)?