

2002-2003 Physics Olympiad Preparation Program
- University of Toronto -
Problem Set 5: Electricity and Magnetism
Due: 10 March 2003

1. A current of one ampere flows through a wire made of copper and aluminum. See Figure 1. They have the same cross section A . The resistivity of copper (aluminum) is $\rho_{Cu} = 1.7 \times 10^{-8} \Omega \cdot m$ ($\rho_{Al} = 2.8 \times 10^{-8} \Omega \cdot m$). The permittivity of free space is $\epsilon_0 = 8.85 \times 10^{-12} F/m$. Does any charge accumulate at the boundary between the metals? If yes, how much charge? Discuss your result.
2. A capacitor consists of two parallel metal plates of area A separated by a distance d . A dielectric slab of area A , thickness b , and dielectric constant κ is placed inside the capacitor. What is the capacitance of the empty capacitor (C) and the capacitor with the dielectric (C_κ)? How must κ and b be restricted so that $C_\kappa = 2C$?
3. A toroid is a solenoid wrapped into a doughnut. See Figure 2. There N turns of wire wound around the surface of the toroid. The wire carries a current I . (a) What is the magnetic field \mathbf{B} inside the toroid? (b) At $t = 0$, an electron inside the toroid has a velocity $\mathbf{v}_0 = v_0 \hat{z}$. What is the path of the electron for $t > 0$?
4. A large circular loop (L) of radius a is centred at $(0,0,0)$ in the xy -plane. See Figure 3. A current I flows counterclockwise through L. A small circular loop (S) of radius b ($b \ll a$) falls along the z -axis starting from $(0, 0, z_0)$ such that $z_0 \gg a$. The mass (resistance) of S is m (R). Find the current induced in S and describe the motion of S.
5. Design an electric motor using a battery, tape, and some pieces of conducting wire. Draw a diagram showing how your motor is assembled and functions. Explain the physics behind the operation of your device.

