PH 102 : Electromagnetism | **Department of Physics**
Tutorial 4 | **Indian Institute of Technology Guwahati**
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1. A rectangular loop of wire is situated so that one end (height h) is between the plates of a parallel plate capacitor (shown in figure 3), oriented parallel to the field $\vec{E}$. The other end is way outside, where the field is essentially zero. What is the emf in this loop? If the total resistance is R, what current flows? Explain.

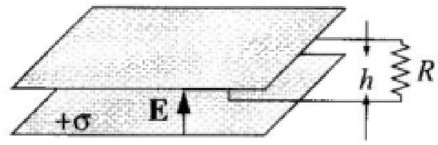

Figure 1: Figure for take home problem 2.

2. A square loop is cut out of a thick sheet of aluminium. It is then placed so that the top portion is in a uniform magnetic field $\vec{B}$, and allowed to fall under gravity (shown in figure 2 where the shading indicates the field region and $\vec{B}$ points into the page). If the magnetic field is 1 T, find the terminal velocity of the loop (in m/s). Find the velocity of the loop as a function of time. How long does it take (in seconds) to reach, say, 90% of the terminal velocity? What would happen if you cut a tiny slit in the ring, breaking the circuit? Write your final answer in numbers by using acceleration due to gravity $g = 9.8$ m/s^2, mass density of aluminium $\eta = 2.7 \times 10^3$ kg/m^3, resistivity of aluminium $\rho = 2.8 \times 10^{-8}$ Ωm.

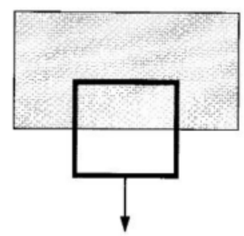

Figure 2: Figure for take home problem 3.

3. Find the energy stored in a section of length l of a long solenoid (radius R, current I, n turns per unit length) using the following formulas discussed in the class:
(a) $W = \frac{1}{2}LI^2$ where L is the inductance.
(b) $W = \frac{1}{2}\oint(\vec{A}\cdot\vec{I})dl$ where $\vec{A}$ is the magnetic vector potential.
(c) $W = \frac{1}{2\mu_0}\int_{\text{all space}} B^2 d\tau$.
(d) $W = \frac{1}{2\mu_0}\left[\int_V B^2 d\tau - \oint_S (\vec{A}\times\vec{B})\cdot d\vec{a}\right]$, where S is the surface bounding the volume V. Take as your volume the cylindrical tube from radius $a < R$ out to radius $b > R$.

4. A circular loop of radius a is at a distance D above a tiny magnetic dipole of infinitesimal area dS carrying a current I_1, as shown in figure 3. Assume current through the circular loop $I_2 = 0$, for the time being. Also, the distance D and loop radius a are related as $D = \sqrt{3}a$. Write your final answers only in terms of I_1, dS, a and fundamental constants.

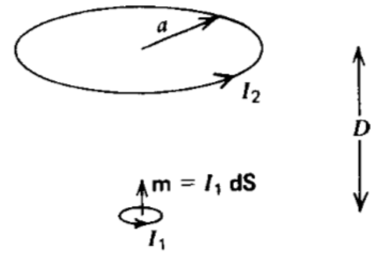

Figure 3: Figure for problem 5

(i) How much magnetic flux of the dipole passes through the circular loop?
(ii) What is the mutual inductance between the dipole and the loop?
(iii) Now, consider the loop to be carrying a current $I_2 \neq 0$. The relation between D and a remains same as before $D = \sqrt{3}a$. How much magnetic flux due to I_2 passes through the magnetic dipole? What is the mutual inductance between the loop and the dipole in this case?

5. Replace the tiny magnetic dipole in above problem by a loop L_1 with no current. It is now placed on top (at the axis which coincides with z-axis) of a loop L_2 of radius a, as shown in figure 4. If the loop L_1 is made up from a paramagnetic material, which direction it will move once a current I_2 is sent through loop L_2 in anticlockwise direction?

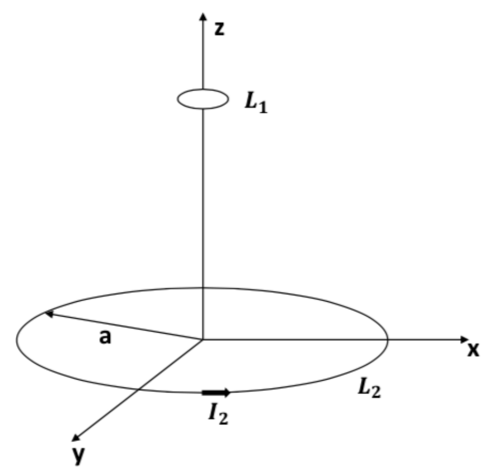

Figure 4: Figure for problem 6

6. Consider a rectangular loop of wire of width a, length b, rotating with an angular velocity ω about the axis PQ (dashed line in figure 5) and lying in a uniform, time dependent magnetic field $B = B_0 \sin \omega t$ perpendicular to the plane of the loop at $t = 0$. Find the angular frequency at which the induced emf of the loop alternates.

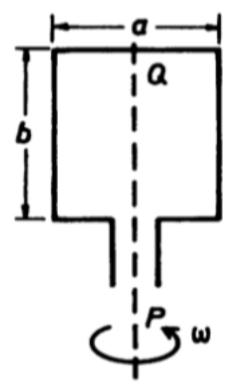

Figure 5: Figure for problem 7