DEPARTMENT OF PHYSICS
INDIAN INSTITUTE OF TECHNOLOGY, MADRAS

PH1020 Physics II **Problem Set 7** **April 2024**

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1. An infinitely long straight wire located along the z-axis carries a steady current I in the positive z-direction. A copper rod is located on the y-axis, such that its ends are at $y = a$ and $y = b$ $(b > a > 0)$. The rod moves with constant velocity $\mathbf{v} = v\hat{e}_z$. Find the emf induced in the rod.

2. An infinitely long straight wire located along the z-axis carries a current I in the positive z-direction. A square wire loop of side L lies in the yz-plane, with its centre at $(0, d, 0)$ (where $d > L/2$), and its sides parallel to the y and z axes.

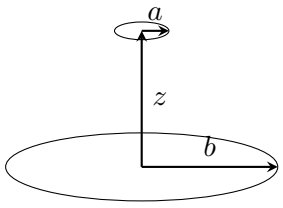
   (a) If the magnetic flux Φ_m through the square loop can be written as $\Phi_m = M\,I$, find the value of the constant M.

   (b) If the current through the wire has a time-dependence given by $I = I_0 e^{-\lambda\,t}$ where I_0 and λ are positive constants, find the direction and the value of the emf induced in the square loop.

3. The magnetic field in an infinitely long cylindrical region is given by $\mathbf{B} = B_0\,\hat{e}_z\,\cos(\omega\,t + \alpha)$ for $\varrho \leq a$, and $\mathbf{B} = 0$ for $\varrho > a$. Here ϱ is the usual cylindrical polar coordinate, and B_0, ω, α and a are positive constants. Find the induced electric field at all points in space.

4. A toroidal coil of rectangular cross-section with inner radius a and outer radius b has height h and n turns. If a current I flows through its windings, find the magnetic flux Φ_m and hence the self-inductance of the toroid.

5. A small circular loop of wire (of radius a) lies at a distance z above the centre of a larger circular loop (of radius $b \gg a$). The planes of the loop are parallel to each other and perpendicular to the common axis of symmetry (see figure).



   (a) Suppose a current I flows in the larger loop. Determine the magnetic flux through the smaller loop. (Assume that the field across the smaller loop is uniform.)

   (b) Suppose a current I flows in the small loop. Determine the magnetic flux through the big loop. (Assume the small loop as a point magnetic dipole.)

   (c) Find the mutual inductance.