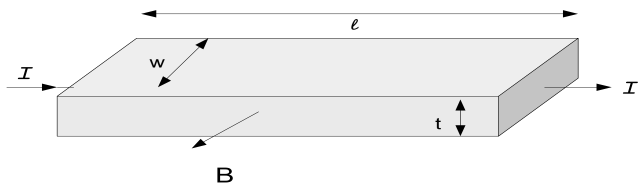
IITK/PHY103 **Problem set-8** **Date: February 20, 2015** [TKG/DpC]

1. Suppose that the magnetic field in some region has the form $\vec{B} = kz\,\hat{x}$ (k is a constant). Find the force on a square loop of side l, lying in the y-z plane and centered at the origin, if it carries a current I, flowing in the counterclockwise direction. Write down the area $\vec{a}$ of the loop and check that the force $\vec{F} = \vec{\nabla}(I\vec{a}\cdot\vec{B})$. [*Compare with the force of an electric dipole $\vec{p}$ in electric field $\vec{E}$ i.e., $\vec{F} = \vec{\nabla}(\vec{p}\cdot\vec{E})$.*]

2. A current I flows to the right through a rectangular bar (conductor) of length l, width w and thickness t, in the presence of a uniform magnetic field $\vec{B}$ pointing out of the page.
(a) If the moving charges are positive, in which way are they deflected by the magnetic field? This deflection results in an accumulation of charge on the upper and lower surfaces of the bar which in turn produces an electric force to counter the magnetic one. Equilibrium occurs when the two exactly cancel. *This phenomenon is known as the Hall effect.*
(b) Find the resulting potential difference (Hall voltage) between the top and bottom of the bar in terms of B, speed of the charges v(or current I and charge density) and the dimension of the bar.
(c) How would your analysis change if the moving charges are negative? [*This enables us to find out if a semiconductor is p-type or n-type.*]



3. Find the magnetic field at a point on the axis of a solenoid of length L and radius R having n number of turns per unit length carrying current I.

4. Consider a slab extends between $-a \leq z \leq a$ and is infinite in the x and y directions. Find the magnetic field due to a constant volume current density $\vec{J} = J_0\hat{i}$ flowing in the slab. Plot the field as a function of z.

Practice problems

1. Suppose a particle of mass m with charge q is released in a space filled with a magnetic field $\vec{B} = B\ \hat{i}$ and an electric field $\vec{E} = E\ \hat{k}$. What path will follow, if it starts at the origin with velocity
   (a) $\vec{v}(0) = (E/B)\hat{j}$
   (b) $\vec{v}(0) = (E/B)(\hat{j} + \hat{k})$. Sketch the paths.

2. Find the magnetic field of on the axis of a square loop of wire of sides $2a$ carrying a steady current I. Find $\vec{B}$ at the centre of the loop and on the axis at a distance much much greater than a.

3. A steady current I flows down a long cylindrical wire of radius R. Find the magnetic field, both inside and outside the wire, if the current is distributed in such a way that J is proportional to s, the distance from the axis.

4. Consider two circular loops each of radius R placed in parallel at a distance d as shown in the figure, each carrying current I in the same direction. Find the magnetic field as a function of z and show that $\frac{\partial B}{\partial z}$ is zero at the the point midway between them($z = 0$). Determine the value of d such that $\frac{\partial^2 B}{\partial z^2} = 0$ at the midpoint and find the resulting magnetic field at the centre.