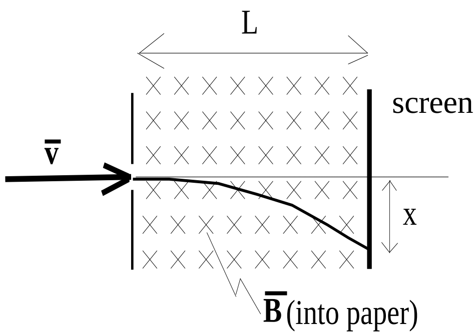
ELECTRIC AND MAGNETIC FIELDS
ASSIGNMENT 8

All questions carry equal marks

Q1 At a particular location, the Earth's magnetic field has a vertical component (downwards) of 1×10^{-4} T, and a horizontal component (Northwards) of 3×10^{-5} T. An electron in a TV tube is moving East $\rightarrow$ West with speed 2×10^{6} m s^{-1}. Find the magnitude and direction of the magnetic force on the electron.

Hint: Define an x, y, z co-ordinate system, and draw a diagram showing all the relevant vectors in terms of their components. Use the equation for the magnetic force on a moving charged particle, being careful to apply the right hand rule and take the negative charge of the electron into account.

Q2 A magnetic field is used to deflect a beam of electrons before it strikes a screen. The electrons, travelling at a speed v, enter a region in which the magnetic field, **B**, is perpendicular to the direction of motion, as shown.



As proved in the lectures, the path followed by the electrons is a circle of radius, r, given by

$$r = \frac{m_e v}{eB}.$$

In a particular case, v = 10^7 m s^{-1}, B = 3×10^{-4} T, and L = 100 mm. Find the distance, x, from the centre of the screen to the point where the electrons strike. **[Answer = 28 mm]**

Q3 The Hall coefficient of a material is defined as $R_H = E/JB$, where J is the current density (current per unit area) in the material, B is the magnitude of the externally applied magnetic field perpendicular to the direction of the current, and E is the magnitude of the Hall electric field.

(a) Using the result derived in the lectures for the Hall voltage, show that $R_H = 1/(ne)$, where n is the volume number density of charge carriers and e is the electronic charge.

(b) For copper, $R_H = 6 \times 10^{-11}$ V m A^{-1} T^{-1}.

(i) Find the volume number density of free electrons.

(ii) The mass density of copper is 8.9×10^{3} kg m^{-3} and the mass of a copper atom is 1.06×10^{-25} kg. On average, how many free electrons does each atom contribute?

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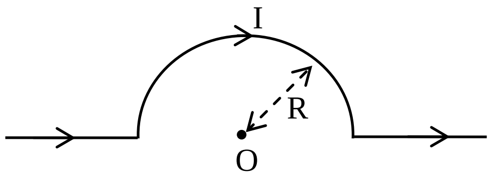
Q4 (a) Use the Biot Savart Law,

$$d\overline{\mathbf{B}} = \frac{\mu_o I}{4\pi r^2}\left[d\overline{\mathbf{L}} \times \hat{\mathbf{r}}\right],$$



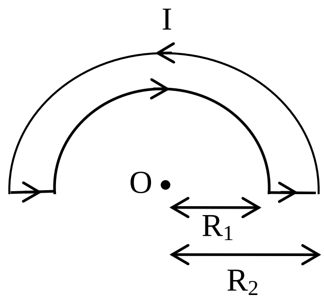
to show that the magnetic field, **B**, at the centre, O, of a semi-circular coil of radius R, carrying a current I, as shown, is given by

$$\overline{\mathbf{B}} = \frac{\mu_o I}{4R}\hat{\mathbf{a}}$$

where $\hat{\mathbf{a}}$ is a unit vector perpendicular to the plane of the coil.

In which direction does $\hat{\mathbf{a}}$ point (into or out of the paper)?

(b) A current loop consists of two semicircular arcs of radii R_1 and R_2, and two perpendicular sections as shown. Show that the magnetic field, **B**, at O is given by



$$\overline{\mathbf{B}} = \frac{\mu_0 I(R_2 - R_1)}{4R_1R_2}\hat{\mathbf{a}}.$$