Tutorial Sheet 3

1. Calculate the skin depth for the following materials and excitation frequencies:

   (i) Copper at 50 Hz ($\rho = 1.72 \times 10^{-8}\Omega$m)
   (ii) Mild steel at 50 Hz ($\mu_r = 2000$, $\rho = 2.8 \times 10^{-7}\Omega$m)

   (ans (i) $\delta = 9.34$ mm (ii) $\delta = 0.84$ mm)

2. Starting from the expression for the current density induced in a semi-infinite plate when it is exposed to a sinusoidally time-varying magnetic field, calculate the approximate ac resistance of a copper conductor of diameter 4 mm when it carries a current of 10A at a frequency of 20kHz. The resistivity of copper is $1.72 \times 10^{-8}\Omega$m. Compare the ac resistance with the dc value.

$$\begin{pmatrix} \text{ans. } R_{ac} = 2.9 \times 10^{-3}\,\Omega/m \\ \dfrac{R_{ac}}{R_{dc}} = 2.11 \end{pmatrix}$$

3. Figure 1 shows a simplified model for one-dimensional eddy current flow in a thin plate. The plate, having conductivity σ and permeability μ, is exposed to a sinusolidally time-varying magnetic field in the z direction, whose magnitude is H_s and angular frequency is ω.

   (i) Calculate the skin depth of the eddy current at 50 Hz given $\mu = 8\pi\text{x}10^{-4}$ (H/m), $\sigma = 0.45\text{x}10^{6}$ ($\Omega^{-1}m^{-1}$).

   (ii) Show that the magnetic field strength in steady state inside the plate is governed by:

$$\frac{\partial^2 H_z}{\partial y^2} = \alpha^2 H_z$$

   where $\alpha = \sqrt{j}\sqrt{\omega\sigma\mu}$

   (iii) Derive expressions for the eddy current density J_x and the eddy current loss density per unit surface area.

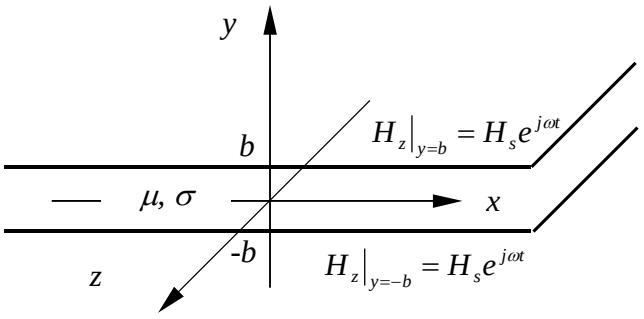

Fig. 1 One-dimensional model for time-varying electromagnetic field in thin plate