

1) b)

8 marks

$$M_{sat} = 2.5 \times 10^6 \text{ Am}^{-1} \rightarrow \text{Magnetic Saturation}$$

$$\rho = 10.868 \text{ cm}^{-3} \rightarrow \text{Atomic Density}$$

$$m = 65.88 \rightarrow \text{Atomic mass}$$

$$\beta = 9.27 \times 10^{-24} \text{ Am}^2 \rightarrow \text{Bohr magneton.}$$

$$\text{No. of atoms/m}^3 \quad N = \frac{\rho A}{m} = \frac{10.86 \times 6.023 \times 10^{23}}{65.88}$$

$$= \underline{9.941 \times 10^{22} \text{ atoms/cm}^3}$$

$$\text{Effective no. of Bohr magneton per atom } \chi = \frac{M_{sat}}{N \times \beta}$$

$$\chi = \frac{2.5 \times 10^6}{9.941 \times 10^{22} \times 9.27 \times 10^{-24}}$$

$$\boxed{\chi = 2.71} \times 10^6$$

2) b)

5 marks

$$d = 5 \text{ cm}, \quad r = 2.5 \text{ cm}$$

$$H_c = H_0 \left[1 - \frac{T^2}{T_c^2} \right]$$

$$= 8.5 \times 10^5 \left[1 - \frac{3.5^2}{6.27^2} \right]$$

$$H_c = 5.85 \times 10^5 \text{ A/m.}$$

$$I_c = 2\pi r H_c$$

$$= 2\pi \times (2.5 \times 10^{-2}) \times 5.85 \times 10^5$$

$$= 91891.58 \text{ A}$$

2) c)

5 marks

$$H = 1800 \text{ A/m}, \quad \chi = -0.5 \times 10^{-4}$$

$$M = ?, \quad B = ?$$

$$M = \chi H = -0.5 \times 10^{-4} \times 1800 = -0.9 \text{ Am}^{-1}$$

$$B = B_0 + \mu_0 M$$

$$B = \mu_0 \mu_r H, \quad \mu_r = 1 + \chi = 1 - 0.5 \times 10^{-3} = 0.9995$$

$$B = 4\pi \times 10^{-7} \times 0.9995 \times 1800$$

$$= 2.261 \times 10^{-3} \text{ Wb/m}^2$$

Diamagnetic material.

4)

10 marks

$$\frac{\epsilon_r - 1}{\epsilon_r + 2} = \frac{N a_e}{3 \epsilon_0} \rightarrow a_e = \frac{(2.2 \times 10^{-40}) + (1.93 \times 10^{-40})}{(4.2 \times 10^{-40})} \text{ Fm}^2$$

At low frequency

$$1 \text{ m}^3 \rightarrow N_i = \frac{6}{0.7553 \times 10^{-27}} = 1.394 \times 10^{28} \text{ atoms}$$

$$\frac{\epsilon_r - 1}{\epsilon_r + 2} = \frac{1.394 \times 10^{28} \times (2.2 \times 10^{-40} + 1.93 \times 10^{-40} + 4.2 \times 10^{-40})}{3 \times 8.85 \times 10^{-12}}$$

$$= 0.4374$$

$$\epsilon_r = \underline{\underline{3.3323}}$$

At High frequency

$$\frac{\epsilon_r - 1}{\epsilon_r + 2} = \frac{1.394 \times 10^{28} \times (2.2 \times 10^{-40} + 1.93 \times 10^{-40})}{3 \times 8.85 \times 10^{-12}}$$

$$\epsilon_r = \underline{\underline{1.8304}}$$

5)
Material A

$$W_{\text{vol}} = \omega E^2 \epsilon_0 \epsilon_r' \tan \delta$$

$E = \frac{50 \times 10^3}{10^{-2}} \text{ V/m}$

$$= 2\pi \times 10 \times 10^6 \times (50 \times 10^3)^2 \times 8.854 \times 10^{-12} \times 2.5 \times 4 \times 10^{-4}$$

$$= \underline{13901547.49} \text{ W/m}^3$$

$$= 13.902 \text{ W/cm}^3$$

Material B

$$W_{\text{vol}} = 2\pi \times 10 \times 10^6 \times (50 \times 10^3)^2 \times 8.854 \times 10^{-12} \times 8.5 \times 1 \times 10^{-3}$$

$$= 118.16 \times 10^6 \text{ W/m}^3$$

$$= 118.16 \text{ W/cm}^3$$

Material A has lower loss per unit volume,
So, Material A should be used for insulation.