Engineering Electromagnetics

Lecture 31

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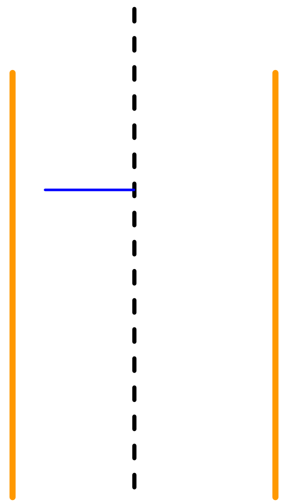
Problem-1

A wire of radius 2 cm carries a constant current 10A, uniformly distributed over the wire. A narrow gap in the wire forms a capacitor. Calculate the magnetic field in the gap, at a distance *1 cm* from the axis of the wire.



Solution-1

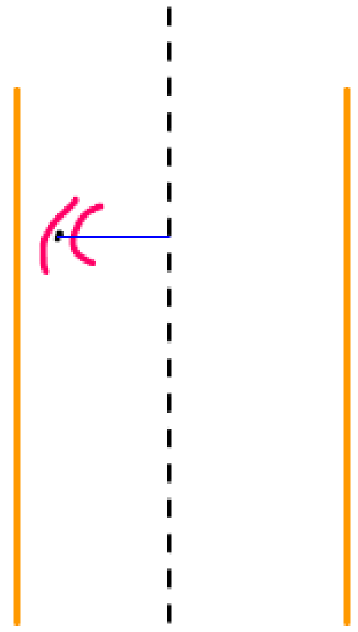
$$\int B.dl = \mu_0 I_{enc}$$

$$B.2\pi r = \mu_0 I_{enc}$$

$$I_{enc} = J_f.A = \frac{I}{\pi R^2}.\pi r^2 = \frac{Ir^2}{R^2}$$

$$B = \frac{\mu_0 I_{enc}}{2\pi r} = \frac{\mu_0 Ir}{2\pi R^2}$$

r = 1 cm
R = 2 cm
I = 10 A



Problem-2

Find the vector potential of an infinite solenoid with n turns per unit length, radius R, and current I.

Solution-2

$$\oint \mathbf{A} \cdot d\mathbf{l} = \int (\nabla \times \mathbf{A}) \cdot d\mathbf{a} = \int \mathbf{B} \cdot d\mathbf{a} = \Phi,$$

$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_{\text{enc}}$$

$$\oint \mathbf{A} \cdot d\mathbf{l} = A(2\pi s) = \int \mathbf{B} \cdot d\mathbf{a} = \mu_0 n I (\pi s^2),$$

$$\mathbf{A} = \frac{\mu_0 n I}{2} s \hat{\boldsymbol{\phi}}, \quad \text{for } s < R$$

$$\int \mathbf{B} \cdot d\mathbf{a} = \mu_0 n I (\pi R^2)$$

$$\mathbf{A} = \frac{\mu_0 n I}{2} \frac{R^2}{s} \hat{\boldsymbol{\phi}}, \quad \text{for } s > R$$

Problem-3

- Compute the flux density inside a bar of chromium that is positioned within a coil of wire 0.25 m long and having 400 turns, carrying a current of 15 A. Magnetic susceptibility of chromium is 3.13×10^{-4} . Also compute magnetization of bar of chromium

Problem-3

Magnetic filed strength, $H = \frac{Ni}{l} = \frac{400 X 15}{0.25} = 24000\, A/m$

Relative permeability, $\mu_r = \chi + 1 = 3.13 X 10^{-4} + 1 = 1.000313$

and permeability, $\mu = \mu_r \mu_0 = 1.000313\, X 4\pi X 10^{-7} = 12.56\, X 10^{-7}\, H/m$

Flux density inside the bar of chromium,

$$B = \mu H = 12.56\, X 10^{-7}\, X\, 24000 = 301440\, X 10^{-7}\, T$$

- Magnetization M = ?

Problem-4

An infinitely long cylinder has radius b, carries only magnetization $\mathbf{M} = br\hat{\mathbf{z}}$ (no free current). Calculate H, J_b, K_b, B_{in} and B_{out}

Solution-4

- $\mathbf{M} = br\hat{\mathbf{z}}$
- $\boldsymbol{J}_b = \nabla \times M = -b\widehat{\Phi}$
- $\boldsymbol{K}_b = M \times \hat{n} = br\widehat{\Phi}$

$$\oint \mathbf{H} \cdot d\mathbf{l} = I_{f_{\text{enc}}}$$

$$H = 0$$

- $B = \mu_0(H + M)$
- $B_{in} = \mu_0 M$
- $B_{out} = 0$

To apply Ampere's law for B_{in}:
Which amperian loop will you choose?
K_b is a function of r, can you ignore K_b's contribution to I_{enc} for the loop chosen?

Thank You