Test 5.1 Magnetic Force

Solution: **(c)** The magnetic force acting on a charged particle is given by

$$\mathbf{F}_{\mathrm{m}} = q\mathbf{u} \times \mathbf{B}.$$

For $\mathbf{F}_{\mathrm{m}}$ to be nonzero, both $\mathbf{u}$ and $\mathbf{B}$ need to be nonzero and $\mathbf{u}$ cannot be parallel (or antiparallel) to $\mathbf{B}$.

Test 5.2 Magnetic Force

Solution: **(b)**

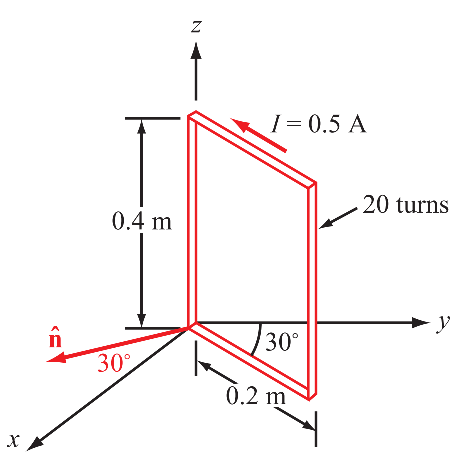
$$\begin{aligned}\mathbf{F}_{\mathrm{m}} &= q\mathbf{u} \times \mathbf{B} \\ &= -e\hat{\mathbf{y}}u \times \hat{\mathbf{x}}B = -euB(-\hat{\mathbf{z}}) = \hat{\mathbf{z}}euB.\end{aligned}$$

Test 5.3 Magnetic Moment

Solution: **(d)**

$$\mathbf{m} = \hat{\mathbf{n}}NIA,$$

with $\hat{\mathbf{n}}$ governed by the right-hand rule: when the four fingers of the right hand advance in the direction of the current I, the direction of the thumb specifies the direction of $\hat{\mathbf{n}}$.



Hence,

$$\hat{\mathbf{n}} = \hat{\mathbf{x}}\cos 30^\circ - \hat{\mathbf{y}}\sin 30^\circ.$$

$$\begin{aligned}\mathbf{m} &= (\hat{\mathbf{x}}\cos 30^\circ - \hat{\mathbf{y}}\sin 30^\circ) \times 20 \times 0.5 \times (0.4 \times 0.2) \\ &= \hat{\mathbf{x}}0.69 - \hat{\mathbf{y}}0.4 \ (\text{A}\cdot\text{m}^2).\end{aligned}$$

Test 5.4 Magnetic Torque

Solution: (a)

$$\mathbf{T} = \mathbf{m} \times \mathbf{B}.$$

Here, per the right-hand rule, $\mathbf{m}$ points along $-\hat{\mathbf{x}}$. Hence,

$$\mathbf{T} = -\hat{\mathbf{x}}m \times \hat{\mathbf{z}}B = \hat{\mathbf{y}}mB.$$

Test 5.5 Magnetic Force

Solution: (b) For two linear conductors to experience attractive magnetic forces acting on them, the conductors have to be parallel to one another and their currents have to flow in the same direction.

Test 5.6 Magnetic Force

Solution: (c)

$$\begin{aligned}\mathbf{B} &= \frac{\hat{\boldsymbol{\phi}}\mu_0 I_1}{2\pi(2.5)} - \frac{\hat{\boldsymbol{\phi}} I_2}{2\pi(0.5)} \\ &= \frac{\hat{\boldsymbol{\phi}}\mu_0}{2\pi}\left(\frac{6}{2.5} - \frac{6}{0.5}\right) = -\hat{\boldsymbol{\phi}}4.8\frac{\mu_0}{\pi}\ .\end{aligned}$$

Test 5.7 Magnetic Field

Solution: (d) The magnetic field is confined to the toroidal tube; no magnetic field exists in the regions $r < a$ and $r > b$.

Test 5.8 Boundary Conditions

Solution: (a)

$$B_m = B_{2n} \quad \Rightarrow \quad \mu_1 H_{1z} = \mu_2 H_{2z}.$$

Hence,

$$H_{2z} = \frac{\mu_1}{\mu_2} H_{1z} = \frac{\mu_0}{8\mu_0} \times 16 = 2 \text{ (A/m)}.$$

Also,

$$H_{1x} + H_{2x}.$$

Hence, $H_{2x} = 4$ and

$$\mathbf{H}_2 = \hat{\mathbf{x}} H_{2x} + \hat{\mathbf{z}} H_{2z} = (\hat{\mathbf{x}}4 + \hat{\mathbf{z}}2) \text{ (A/m)}.$$

Test 5.9 LVDT

Solution: (d) LVDT = **L**inear **v**ariable **d**ifferentiable **t**ransformer.

Test 5.10 Solenoid

Solution: (c) For a long solenoid with $1 \gg a$,

$$\mathbf{B} \approx \hat{\mathbf{z}} \mu \frac{NI}{l} .$$

Hence,

$$\mathbf{B}_1 \approx \hat{\mathbf{z}} \mu \frac{30 \times 4}{0.2} = \hat{\mathbf{z}} \mu 600 \text{ (Wb/m}^2\text{)},$$

$$\mathbf{B}_2 \approx \hat{\mathbf{z}} \mu \frac{45 \times 2}{0.15} = \hat{\mathbf{z}} 600 \text{ (Wb/m}^2\text{)}.$$

Hence, $\mathbf{B}_1 = \mathbf{B}_2$ and the correct answer is (c).

Test 5.11 Coaxial Line

Solution: (b) For a coaxial line,

$$L = \frac{\mu}{2\pi} l \ln\left(\frac{b}{a}\right).$$

The ratio of the second coax to that of the original is

$$\frac{L_2}{L_1} = \frac{\ln(4)}{\ln(2)} ,$$

or

$$L_2 = L_1 \frac{\ln(4)}{\ln(2)} = 500 \text{ nH} \times \frac{1.386}{0.693} = 1000 \text{ nH}.$$

Hence, the correct answer is (b).

Test 5.12 Boundary Conditions

Solution: (a) From Eq. (5.2),

$$\vec{H}_1 = \frac{\vec{B}_1}{\mu_1} = \frac{1}{\mu_1}(\hat{\mathbf{x}}2 - \hat{\mathbf{y}}3 + \hat{\mathbf{z}}8).$$

The z component is the normal component to the boundary at $z = 0$. Therefore, from Eq. (5.79), $B_{2z} = B_{1z} = 8$ while, from Eq. (5.85),

$$H_{2x} = H_{1x} = \frac{1}{\mu_1}2, \qquad H_{2y} = H_{1y} = -\frac{1}{\mu_1}3,$$

or

$$B_{2x} = \mu_2 H_{2x} = \frac{\mu_2}{\mu_1}2, \qquad B_{2y} = \mu_2 H_{2y} = -\frac{\mu_2}{\mu_1}3,$$

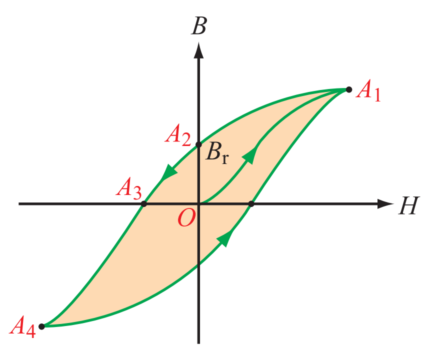
where $\mu_2/\mu_1 = \mu_r = 5000$. Therefore,

$$\vec{B}_2 = \hat{\mathbf{x}}10000 - \hat{\mathbf{y}}15000 + \hat{\mathbf{z}}8.$$

Hence, the correct answer is (a).

Test 5.13 Magnetic Hysteresis

Solution: (b) Magnetic hysteresis refers to the “lag behind” behavior of ferromagnetic materials as portrayed by the hysteresis curve shown in the figure.



Hence, the correct answer is (b).

Test 5.14 Proximity Sensor

Solution: (d) The proximity sensor consists of two coils, as shown. The sensing coil senses perturbations to its own magnetic field due to any nearby magnetic field which may be generated by current sources or eddy currents in conductors.

Hence, the correct answer is (d).

Test 5.15 Magnetic Energy

Solution: (c) From Eq. (5.30),

$$\mathbf{B} = \hat{\boldsymbol{\phi}}\,\frac{\mu_0 I}{2\pi r}\,.$$

At $r = b$,

$$H = \frac{B}{\mu_0} = \frac{I}{2\pi b}\,.$$

The energy in the tube's volume $\mathcal{V}$ is

$$\begin{aligned}
W_{\mathrm{m}} &= \frac{1}{2}\,\mu_0 H^2 \mathcal{V} \\
&= \frac{1}{2}\,\mu_0 \left(\frac{I}{2\pi b}\right)^2 (2\pi b \times \pi a^2) \\
&= \frac{1}{4}\,\mu_0\,\frac{I^2 a^2}{b} \\
&= \frac{1}{4}\,\frac{\mu_0 \times 4 \times (2 \times 10^{-2})^2}{1} = 4\mu_0 \times 10^{-4} \text{ (J)}.
\end{aligned}$$

Hence, the correct answer is (c).