PS250 Practice Test 2

March 18, 2003

____*E*____1. A particle travels through a velocity selector in the positive x-direction. If $\vec{E} = 3000\hat{z}$ and $\vec{B} = -.1\hat{y}$, and the particle makes a semi-circle of radius 9.4 mm upon exiting the velocity selector, identify the particle. All atoms are bare nucleii. (A) proton (B) Helium-3 (C) Helium-4 (D) Li-7 (E) triton

Solution: Use the Lorentz Force Law and magnetic force law.

$$F = q\left(\vec{E} + \vec{v} \times \vec{B}\right) = 0$$

$$(0,0,E) + (0,0,-vB) = (0,0,0) \rightarrow v = \frac{E}{B} = 30,000\ m/s$$

$$-\frac{mv^2}{r} = -qvB \rightarrow \frac{m}{q} = \frac{rB}{v} = 3.13 \times 10^{-8}\ kg/Coul$$

This is consistent with a triton–heavy hydrogen with two neutrons and one proton.

____*B*____2. Consider four loops carrying 0.5 amperes of current in the x-y plane, going in a circle of radius 1 m centered on the origin. What magnetic field in the x-direction will create a torque of 30 N-m? Answer in Tesla.(A) 3.5 (B) 4.8 (C) 8.6 (D) 12.5 (E) none of these

Solution: Use the magnetic moment, and the torque equation.

$$\vec{\mu} = IAN\hat{n} = 0.5 \cdot \pi \cdot 1^2 \cdot 4\hat{z} = 2\pi\hat{z}$$

$\vec{B} = B\hat{x}$. Take the cross product and set equal to 30, getting $B = 4.77\ Tesla$.

____*A*____3. Find the magnitude of the magnetic field at the indicated point. Answer as a multiple of $\mu_0 I$ in MKS units. (A) 0.34 (B) 0.5 (C) 0.67 (D) 0.75 (E) none of these

Solution:

$$B = B_1 + B_2 + B_3 + B_4 + B_5 = -\frac{1}{2}\frac{\mu_0 I}{2\pi R} - \frac{1}{2}\frac{\mu_0 I}{2R} - \frac{1}{2}\frac{\mu_0 (I/2)}{2\pi R} + 0 + \frac{1}{4}\frac{\mu_0 (I/2)}{2(2R)} = 0.34\mu_0 I$$

____*B*____4. A coaxial cable consists of a wire carrying 2 amps, a gap, and then a surrounding thick cable with inner radius 1 m and outer radius 2 m, carrying a total of 3 A. in the same direction. Assuming the permeability in the cable is only negligibly different from free space, find the magnetic field outside the cable at r=3 meters. Answer as a multiple of mu_0/π (A) 0.33 (B) 0.83 (C) 1.1 (D) 1.7 (E) none of these

Solution:

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{in}$$

$$B(2\pi r) = \mu_0(2+3) = 5\mu_0 \rightarrow B = \frac{5\mu_0}{2\pi r}$$

____*C*____5. Same as the previous question. Find the magnetic field at r=1.5 meters. Answer as a multiple of μ_0/π. (A) 0.33 (B) 0.83 (C) 1.1 (D) 1.7 (E) none of these

Solution: First find the current density in the wire.

$$J = \frac{I}{A} = \frac{I}{\pi 2^2 - \pi 1^2} = \frac{3}{3\pi} = \frac{1}{\pi}\ Amperes$$

The total current inside a dotted circular line partway across the annular region is

$$I_{in} = I_c + JA = 2 + \frac{1}{\pi}\left(\pi 1.5^2 - \pi 1^2\right) = 3.25\ A.$$

So the magnetic field is given by

$$B = \frac{\mu_0}{2\pi r}\left(I_c + JA\right) = \frac{\mu_0}{2\pi \cdot 1.5}\left(2 + 1.5^2 - 1^2\right) = 1.083\frac{\mu_0}{\pi}$$

____*A*____6. A horizontal bar aligned in the x-direction is dropped from a height of ten meters through a magnetic field of $\vec{B} = (0, 4\times 10^{-4}, 0)$. What is the induced EMF just before the bar hits the ground? Answer in Volts. (A) 0.007 (B) 0.02 (C) 0.003 (D)0.0006 (E) none of these

Solution: First, use conservation of energy to find the speed.

$$\Delta K + \Delta U = \frac{1}{2}mv^2 - 0 + 0 - mgh = 0 \rightarrow v = \sqrt{2gh} = 14\ m/s$$

$$\Delta V = \int \vec{v} \times \vec{B} \cdot d\vec{s} = \left(56 \times 10^{-4}, 0, 0\right) \cdot (1.3, 0, 0) = 0.007$$

____*B*____7. How fast must a single loop of area 0.5 m^2 rotate in order to create a current with maximum of 3 amperes? Pick the closest in cycles per second. (A) 1 (B) 2 (C) 3 (D) 4 (E) 5

$$\Delta V = -\frac{d}{dt}\phi_B = \frac{d}{dt}NBA\cos\theta$$

$$BA\omega \sin\theta \rightarrow BA\omega = IR$$

Plug in, get $f = 1.91\ Hz$.

____*B*____8. Current starts to flow in a loop as shown (loop on the left, current moves counter clockwise. There is also a loop on the right, not attached to a battery.) When a switch is thrown. Choose the best statement concerning the second loop. What direction is the induced current in the second loop? (A) induced current flows clockwise (B) induced current flows counterclockwise (C) there is no induced current at any time (D) current flow clockwise, then counterclockwise (E) none of these

____*D*____9. Suppose in a disk-shaped region centered on the origin in the x-y plane the electric field is given by $\vec{E} = 10e^{-2t}\hat{z}$. Find the induced magnetic field inside the region, if any. Answer in Tesla. (A) $-5\mu_0\epsilon_0 r$ (B) $-\mu_0\epsilon_0 r$ (C) $-2\mu_0\epsilon_0 r$ (D) $-10\mu_0\epsilon_0 r$ (E) none of these

Solution: First find the flux:

$$\phi_E = EA$$

$$-\frac{d\phi_E}{dt} = B(2\pi r) = -20\pi r^2 \mu_0\epsilon_0$$

$$B = -10r\mu_0\epsilon_0$$

____*E*____10. What is the current through the 3-ohm resistor after 0.5 seconds? After a very long time? There is a 0.5 H Inductor.

$$I = \frac{\Delta V}{R}\left(1 - e^{-Rt/L}\right)$$

Just plug in. Get 2.33 Amperes and 3 Amperes respectively.

____*E*____11. Find the direction of propagation of the electromagnetic field, if initially the electric field is in the direction of (2,0,3) and the magnetic field is in the direction of (0,1,0).

Solution: Do the cross product. Get $(-3, 0, 2)$