Test 2 Spring 2003 PS250 Show work, put best answer in the blank.
_____1. A particle travels through a velocity selector in the positive y-direction. If $\vec{E} = 5000\hat{z}$ and $\vec{B} = 0.1\hat{x}$, and the particle makes a semi-circle of radius 1 cm 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.

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

$$(0, 0, E) + (0, 0, -vB) = (0, 0, 0) \rightarrow v = \frac{E}{B} = 50,000\ m/s$$

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

This is consistent with Helium-4, with two neutrons and two protons.

2. A solenoid with 500 turns/meter has steadily increasing current, $I = 2t$ in amperes. What is the induced EMF (in volts) in 4 loops wrapped around outside the solenoid? (solenoid cross section is 1 m^2) (A) 0.005 (B) 0.02 (C) 0.003 (D) 0.14 (E) none of these

Solution: This problem proceeds in several steps. Step 1: find the magnetic field in the solenoid with Ampere's law. Step 2: Find the flux through the set of four loops. Step 3: Use Faraday's law to get the EMF.

Step 1: $BL = \mu_0 I_{in} = \mu_0(2t)N \rightarrow B = 2\mu_0 tN/L$
Step 2: $\phi_B = N_2 BA = 2N_2\mu_0(N/L)At$
Step 3: $EMF = -d\phi_B/dt = 2N_2\mu_0(N/L)A = 2 \cdot 4 \cdot 4\pi \times 10^{-7} \cdot 500 \cdot 1 = 0.005\ V$

_____3. Find the magnitude of the magnetic field at the indicated point. Answer as a multiple of $\mu_0 I/r$ in MKS units. (A) 0.34 (B) 0.11 (C) 0.72 (D) 0.45 (E) none of these

Solution:

$$B = B_1 + B_2 + B_3 = -\frac{1}{2}\frac{\mu_0 I}{2\pi R} - \frac{3}{8}\frac{\mu_0 I}{2R} = 0.108\frac{\mu_0 I}{R}$$

_____4. What's the magnetic field between the two cylinders? Answer as a multiple of $\mu_0/\pi r$ (A) 2.25 (B) 1.75 (C) 1.0 (D) 1.25 (E) none of these

Solution:

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

$$B(2\pi r) = \mu_0(4 - 1.5) = 2.5\mu_0 \rightarrow B = 1.25\frac{\mu_0}{\pi r}$$

_____5. An airplane is traveling horizontally North at 100 m/s. If the magnetic field is $\vec{B} = \left(0, 2 \times 10^{-4}, -3 \times 10^{-4}\right)\ T$, what is the induced EMF

across the wings? Assume it's 12 meters tip to tip. N = +y, up=+z, E=+x. Answer in Volts. (A) 0.072 (B) 0.024 (C) 0.36 (D)0.0009 (E) none of these

Solution:

$$\Delta V = \int \vec{v} \times \vec{B} \cdot d\vec{s} = \int_{-6}^{6} \left(-300 \times 10^{-4}, 0, 0\right) \cdot (dx, 0, 0) = -0.36$$

_____6. A coil with 5 loops is rotated at a rate of 10 times per second in a fixed magnetic field of 0.2 T. What maximum current is created, if the loop has area $0.3m^2$ and resistance in the five loops is one ohm. Pick closest in Amperes (A) 10 (B) 12 (C) 15 (D) 19 (E) 25

$$\Delta V = -\frac{d}{dt}\phi_B = -\frac{d}{dt} NBA\cos\theta = NBA\omega\sin\theta$$
$$NBA\omega = NBA2\pi f = 5 \cdot 0.2 \cdot 0.3 \cdot 2\pi/10 = I \cdot 1 \rightarrow I = 18.84\ A$$

_____7. Current is increasing with time in the long wire, as shown. In the loop to the left of the wire.(A) induced current flows clockwise (B) induced current flows counterclockwise (C) there is no induced current at any time (D) current flows clockwise, then counterclockwise (E) none of these (answer– clockwise)

_____8. Suppose in a disk-shaped region centered on the origin in the x-y plane the electric field is given by $\vec{E} = 10\sin(\pi t)\hat{z}$. Find the induced magnetic field inside the region, if any, when $t = 2\ s$. Answer in Tesla, as a multiple of $\mu_0\epsilon_0$. (A) 15 (B) 21 (C) 36 (D) 12 (E) none of these

Solution: First find the flux:

$$\phi_E = EA$$
$$N(2\pi r) = \mu_0\epsilon_0 \frac{d\phi_E}{dt} A = \mu_0\epsilon_0\pi \cdot 10\cos(\pi t) \cdot \pi 2^2$$
$$B = \mu_0\epsilon_0(20.84)$$

_____9. What is the voltage drop across the inductor after 1 second? There is a 2 H Inductor in series with a 3 ohm resistor and a 6 V. battery. (A) 4.5 V (B) 2.3 V (C) 1.34 V (D) 3.2 V (E) none of these

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

Just plug in. Multiply times R and get the voltage drop across the resistor, and subtract that from 6 V to get the drop across the inductor.

_____10. Find the angular wave number for a light wave with frequency of $2 \times 10^7 Hz$. Answer in radians/meter. (A) 0.25 (B) 0.77 (C) 1.45 (D) 1.07 (E) 0.42

$$c = f\lambda = \frac{\omega}{2\pi}\lambda$$