Instructor(s): Acosta/Qiu

PHY 2049, Fall 2011
Midterm 2
November 8, 2011

On my honor, I have neither given nor received unauthorized aid on this examination.

YOUR TEST NUMBER IS THE 5-DIGIT NUMBER AT THE TOP OF EACH PAGE.

(1) Code your test number on your answer sheet (use lines 76–80 on the answer sheet for the 5-digit number). Code your name on your answer sheet. DARKEN CIRCLES COMPLETELY. Code your UFID number on your answer sheet.

(2) Print your name on this sheet and sign it also.

(3) Do all scratch work anywhere on this exam that you like. Circle your answers on the test form. At the end of the test, this exam printout is to be turned in. No credit will be given without both answer sheet and printout.

(4) Blacken the circle of your intended answer completely, using a #2 pencil or blue or black ink. Do not make any stray marks or some answers may be counted as incorrect.

(5) The answers are rounded off. Choose the closest to exact. There is no penalty for guessing. If you believe that no listed answer is correct, leave the form blank.

(6) Hand in the answer sheet separately.

Constants:
\[ e = 1.6 \times 10^{-19} \text{ C} \]
\[ m_p = 1.67 \times 10^{-27} \text{ kg} \]
\[ m_e = 9.1 \times 10^{-31} \text{ kg} \]
\[ \epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{N} \cdot \text{m}^2 \]
\[ k = \frac{1}{4\pi \epsilon_0} = 9 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 \]
\[ \text{nano} = 10^{-9} \quad \text{micro} = 10^{-6} \quad \text{pico} = 10^{-12} \]
\[ \mu_0 = 4\pi \times 10^{-7} \text{ T} \cdot \text{m}/\text{A} \]
\[ c = \sqrt{\epsilon_0 \mu_0} = 3 \times 10^8 \text{ m/s} \]

1. A horizontal power line carries a current of 2900 A from south to north Earth’s magnetic field, with a magnitude of 60 µT, is directed toward the north with a dip angle 60° downward into the Earth relative to the horizontal. Find the magnitude and direction (use compass directions) of the magnetic force acting on a 100 m length of power line.
   (1) 15 N, West (2) 15 N, East (3) 17.5 N, West (4) 8.7 N, East (5) 17.5 N, East

2. A beam of electrons (“cathode rays”) is sent between two parallel electric plates with an electric field between them of \( \vec{E} = 2 \times 10^4 \hat{j} \text{ N/C} \). If the electron beam travels perpendicular to the electric field with a velocity of \( \vec{v} = 4.2 \times 10^7 \hat{i} \text{ m/s} \), what magnetic field is necessary (direction and magnitude) so that the electrons continue traveling in a straight line without deflection by the electric field?
   (1) \( 4.8 \times 10^{-4} \hat{k} \text{ T} \) (2) \( -4.8 \times 10^{-4} \hat{k} \text{ T} \) (3) \( 2.0 \times 10^4 \hat{j} \text{ T} \) (4) \( -2.0 \times 10^4 \hat{j} \text{ T} \) (5) \( 2.1 \times 10^3 \hat{i} \text{ T} \)

3. The magnetic field of a solenoid (long compared to its radius) is used to keep a proton in a perfectly circular orbit. The solenoid has 1000 windings per meter of length and has a radius of 1 m. If the proton has a velocity magnitude of \( v = 1.5 \times 10^6 \text{ m/s} \), what is the minimum current needed to keep the proton orbiting within the confines of the solenoid in a plane perpendicular to the solenoid axis? The proton mass is \( m_p = 1.67 \times 10^{-27} \text{ kg} \) and its charge is \( q = +1.6 \times 10^{-19} \text{ C} \).
   (1) 12.5 A (2) 78,000 A (3) 25,000 A (4) 12,500 A (5) \( 1.6 \times 10^{-7} \text{ A} \)

4. A series RLC circuit is driven by sinusoidally-varying EMF source with a maximum amplitude of 125 V. The resistance \( R = 100 \Omega \), the inductance \( L = 2 \times 10^{-3} \text{ H} \), and the capacitance \( C = 0.1 \mu \text{F} \). At what frequency (cycles/sec) will the amplitude of the current be a maximum?
   (1) 11 kHz (2) 11 Hz (3) 7.1 kHz (4) \( 2 \times 10^{-5} \text{ Hz} \) (5) \( 1 \times 10^{-5} \text{ Hz} \)
5. An alternating EMF source drives a series RLC circuit with a maximum amplitude 9.0 V. The phase angle of the current is +45°. When the potential difference across the capacitor reaches its maximum positive value of +6 V, what is the potential difference across the inductor (including sign)?

(1) −12.4 V  (2) −8 V  (3) 6.4 V  (4) −0.4 V  (5) 0 V

6. A square metal loop of side length $\ell = 0.5$ m is pulled out of a uniform magnetic field with a velocity of magnitude $v = 2$ m/s. The magnetic field has a strength of $B = 0.25$ T and is directed perpendicular to the surface of the loop. One side of the square is aligned with the edge of the field region when the pulling first starts. What is the magnitude of the induced EMF in the loop as it is pulled?

(1) 0.25 V  (2) 5 V  (3) 0.125 V  (4) 0.0625 V  (5) 1 V

7. An inductor of inductance $L = 10$ H and resistance $R = 2\Omega$ is plugged into a DC source of EMF at $t = 0$. How long does it take for the current through the inductor to reach 80% of its maximum?

(1) 8.0 s  (2) 5.0 s  (3) 1.1 s  (4) 10 s  (5) 2.0 s

8. The current through an inductor with inductance $L = 0.1$ H is shown by the graph, with the direction from left to right through the inductor as shown. What is the EMF across the inductor ($V_L = V_{right} - V_{left}$), including sign, at $t = 1$ ms?

(1) −350 V  (2) 0.35 V  (3) −7 V  (4) 3500 V  (5) −35 V

9. A parallel plate capacitor has circular plates with a radius $R = 2$ cm and a time-dependent uniform electric field between them of $(3 \times 10^6 \text{ V/m-s})t$. What is the magnitude of the induced magnetic field at a radius of $r = 3$ cm from the central axis connecting the centers of the plates, which is larger than the radius $R$ covered by electric field?

(1) $2.2 \times 10^{-13}$ T  (2) $1.5 \times 10^{-13}$ T  (3) $3.3 \times 10^{-13}$ T  (4) $1.8 \times 10^{-10}$ T  (5) 0 T

10. A constant current of $i = 5$ A is used to charge a parallel plate capacitor with circular plates of radius $R = 1$ cm. What is the magnitude of the magnetic field at a radius of $r = 0.5$ cm, which is less than $R$, in the region between the plates?

(1) $5 \times 10^{-5}$ T  (2) $1 \times 10^{-4}$ T  (3) $2 \times 10^{-4}$ T  (4) $6.3 \times 10^{-6}$ T  (5) 0 T

11. A transformer is designed to provide a 5 V output EMF when the input is 120 V with a 60 Hz frequency. If there are 144 primary windings around the transformer core, how many secondary windings are necessary to provide the correct output voltage?

(1) 6  (2) 3450  (3) 144  (4) 24  (5) 30

12. It takes an energy of $7.4 \times 10^{-23}$ J to flip the alignment of the spin of an electron from parallel to anti-parallel to the direction of a magnetic field. What is the magnitude of the magnetic field? ($\mu_B = 9.27 \times 10^{-24}$ J/T)

(1) 4 T  (2) 8 T  (3) 2 T  (4) $3 \times 10^{-17}$ T  (5) $1.3 \times 10^4$ T
13. Two long straight current-carrying parallel wires cross the $x$ axis and carry currents $I$ and $3I$ in the same direction, as shown. At what value of $x$ is the net magnetic field zero?

(1) 3  (2) 1  (3) 0  (4) 5  (5) 7

14. Two long straight wires pierce the plane of the paper at vertices of an equilateral triangle as shown below. They each carry 2 A, out of the paper. The magnetic field at the third vertex (P) has magnitude (in T):

(1) $1.7 \times 10^{-5}$  (2) $1.0 \times 10^{-5}$  (3) $2.0 \times 10^{-5}$  (4) $5.0 \times 10^{-6}$  (5) $8.7 \times 10^{-6}$

15. The magnetic field at any point is given by $\vec{B} = A\vec{r} \times \hat{k}$, where $\vec{r}$ is the position vector of the point and $A$ is a constant. The net current through a circle of radius $R$, in the $xy$ plane and centered at the origin is given by:

(1) $2\pi AR^2/\mu_0$  (2) $2\pi AR/\mu_0$  (3) $4\pi AR^3/3\mu_0$  (4) $\pi AR^2/\mu_0$  (5) $\pi AR^2/2\mu_0$

16. A hollow cylindrical conductor (inner radius = $a$, outer radius = $b$) carries a current $i$ uniformly spread over its cross section. Which graph below correctly gives $B$ as a function of the distance $r$ from the center of the cylinder?

(1)  (2)  (3)  (4)  (5)

17. A loop of current-carrying wire has a magnetic dipole moment of $5 \times 10^{-4} \text{ A} \cdot \text{m}^2$. The moment initially is aligned with a 0.5-T magnetic field. To rotate the loop so its dipole moment is perpendicular to the field and hold it in that orientation, you must do work of:

(1) $2.5 \times 10^{-4}\text{J}$  (2) 0  (3) $-2.5 \times 10^{-4}\text{J}$  (4) $1.0 \times 10^{-3}\text{J}$  (5) $-1.0 \times 10^{-3}\text{J}$

18. The circuit shown is in a uniform magnetic field that is pointing into the page. The current in the circuit is 0.20 A. At what rate is the magnitude of the magnetic field changing? Is it increasing or decreasing?

(1) 140 T/s, decreasing  (2) zero  (3) 140 T/s, increasing  (4) 420 T/s, decreasing  (5) 420 T/s, increasing

19. The total energy in an $LC$ circuit is $5.0 \times 10^{-6}\text{J}$. If $L = 25 \text{ mH}$ and $C = 15\mu\text{F}$, the maximum current is:

(1) 20 mA  (2) 14 mA  (3) 10 mA  (4) 28 mA  (5) 40 mA
20. Four closed surfaces are shown. The areas $A_{\text{top}}$ and $A_{\text{bot}}$ of the top and bottom faces and the magnitudes $B_{\text{top}}$ and $B_{\text{bot}}$ of the uniform magnetic fields through the top and bottom faces are given. The fields are perpendicular to the faces and are either inward or outward. Rank the surfaces according to the magnitude of the magnetic flux through the curved sides, least to greatest.

(1) 3, 4, 1, 2
(2) 1, 2, 3, 4
(3) 1, 2, 4, 3
(4) 4, 3, 2, 1
(5) 2, 1, 4, 3