1. The figure shows a right-angle bend in a long straight wire carrying a current $I$. The bend forms a circular arc of a radius $r$. Determine the magnetic field at the center of the arc.

   a. $\frac{\mu_0 I}{r} \frac{2\pi}{(\pi+4)}$
   b. $\frac{\mu_0 I (\pi+4)}{8\pi r}$
   c. $\frac{\mu_0 I}{2\pi r^2}$
   d. $\frac{\mu_0 I}{r^2}$
   e. 0

Questions #2 and 3 refer to the diagram below

2. A long straight wire carrying a current $I_1$ lies in the same plane with a rectangular loop of a length $l$ and width $a$, carrying a current $I_2$. The distance between the straight wire and the closest side of the loop is $c$. What are the magnitude and the direction of the net force acting on the loop?

   a. 0
   b. $\frac{\mu_0 I_1 I_2 l}{2\pi} \left( \frac{1}{c} - \frac{1}{c+a} \right)$ to the right
   c. $\frac{\mu_0 I_1 I_2 l}{2\pi} \left( \frac{1}{c} - \frac{1}{c+a} \right)$ to the left
   d. $\frac{\mu_0 I_1 I_2 l}{2\pi c^2}$ to the right
   e. $\frac{\mu_0 I_1 I_2 l}{2\pi a^2}$ to the left

3. Assume the initial current in the rectangular loop shown here is zero and the current in the long straight wire changes as $I = I_1 \sin(\omega t)$. Here $\omega$ is the angular frequency in rad/sec. If the resistance of the loop is $R$, what is the induced current in the loop?

   a. $\frac{\mu_0}{2\pi R} I_1 \ln \left( \frac{c+a}{c} \right) \cos(\omega t)$
   b. $\frac{\mu_0}{2\pi R} I_1 a \omega \cos(\omega t)$
   c. $\frac{\mu_0}{R} I_1 a \omega \sin(\omega t)$

   d. $\frac{\mu_0}{2\pi} I_1 \ln \left( \frac{c+a}{c} \right) \sin(\omega t)$
   e. $\frac{\mu_0}{2\pi} I_1 \ln \left( \frac{a}{c} \right) \cos(\omega t)$

4. Given 25 cm of a wire carrying a current of 4.0 mA, you have to make a circular coil and place it into a uniform magnetic field in such a way that the torque on the coil is maximized. Determine the magnitude of the maximum torque you achieve by making and positioning the coil in a uniform magnetic field of 50 mT.

   a. 1.25x10^{-7} \text{ N} \cdot \text{m}
   b. 7.35x10^{-7} \text{ N} \cdot \text{m}
   c. 9.95x10^{-7} \text{ N} \cdot \text{m}
   d. need to know the number of turns
   e. need to know the orientation of the coil
5. A parallel-plate air-filled capacitor is being charged. The plates are circular with a radius of 33.0 cm. What is the rate at which the electric field between the plates is changing at the instant the conduction current in the wires is 0.027 A?

a. \(8.9 \times 10^5\) V/m·s  
b. \(6.5 \times 10^5\) V/m·s  
c. \(2.3 \times 10^5\) V/m·s  
d. \(3.6 \times 10^5\) V/m·s  
e. \(6.2 \times 10^5\) V/m·s

6. A parallel-plate air-filled capacitor is being charged. The plates are circular with a radius of \(R\). Assume that the charge density on the plates is uniform at any given time. Which of the graphs below best represents magnetic field induced inside and outside of the capacitor as a function of the perpendicular distance from its axis?

A. | B. | C. | D. | E. |
---|---|---|---|---|
\(B\) \(R\) \(r\) \(B\) \(R\) \(r\) \(B\) \(R\) \(r\)

a. A  
b. B  
c. C  
d. D  
e. E

7. A proton and an alpha particle (He\(^{++}\)) are accelerated from rest through a potential difference of 2000 V. What is the ratio of the speed of the proton to the speed of the alpha particle?

a. \(\sqrt{2}:1\)  
b. 2:1  
c. 4:1  
d. \(1:\sqrt{2}\)  
e. 1:2
8. A rail gun consists of a metal projectile of mass \( m \) that slides without friction between two horizontal rails spaced a distance \( D \) apart. The track lies in a vertical uniform magnetic field \( B \), as shown. Generator \( G \) produces a constant current \( I \) in the wire and the rails (even as the projectile moves). Find the velocity of the projectile as a function of time, \( t \), assuming the projectile is stationary at \( t = 0 \).

\[
a. \frac{lt^2}{Bm} \quad b. BIt^{-t/m} \quad c. \frac{Bdit^2}{2m} \quad d. BIt^{-t/2m} \quad e. \frac{Bdit}{m}
\]

9. Magnetic monopoles do not exist. This conclusion is a direct consequence of

a. Faraday's Law \hspace{1cm} b. Coulomb's Law \hspace{1cm} c. Ampere's Law \hspace{1cm} d. Gauss's Law \hspace{1cm} e. Ohm's Law

10. A metal strip, \( a \) wide and \( b \) thick, is placed in a uniform magnetic field \( B \) directed perpendicular to the strip. A current, \( I \), is then sent through the strip such that a Hall potential difference \( V \) appears across the width of the strip. Calculate the number of charge carriers per unit volume in the metal. Here, \( q_e \) is the charge of an electron.

\[
a. \frac{IB}{q_evb} \quad b. \frac{IBV}{q_eab} \quad c. \frac{IBa}{q_eV^2b} \quad d. \frac{IBb}{q_eVa} \quad e. \frac{q_eVIB}{ab}
\]

**For questions #11 and 12 use the following information:**

A charge \( q \) is distributed uniformly around a thin ring of a radius \( r \). The ring is rotating about an axis through its center and perpendicular to its plane, at an angular speed \( \omega \).

11. What is the magnitude of the magnetic moment \( \mu \) of the rotating charge?

\[
a. \frac{\omega r^2}{q} \quad b. q\omega r^2 \quad c. \frac{q\omega}{r^2} \quad d. \frac{1}{2} q\omega r^2 \quad e. \frac{q\omega}{2r^2}
\]

12. The rotating ring is placed into a uniform magnetic field \( B \). The vector \( B \) makes an angle \( \theta \) with the normal to the plane of the ring. The magnetic moment of the ring is \( \mu \). What is the torque applied by the magnetic field, \( B \), onto the rotating ring?

\[
a. \mu \cdot \vec{B} \quad b. \mu \times \vec{B} \quad c. \mu B \quad d. 0 \quad e. |\mu \cdot \vec{B}|
\]
13. Particles rotating around the magnetic field lines can be distinguished by recording the characteristic frequency of the cyclotron radiation they emit because of this rotation. The diagram shows a particle moving in a circle in a region of uniform magnetic field of magnitude \( B = 4.50 \text{ mT} \). The particle is either a proton or an electron. Mass of a proton is \( 1.67 \times 10^{-27} \text{ kg} \), mass of an electron is \( 9.1 \times 10^{-31} \text{ kg} \), and the electron charge is \( 1.6 \times 10^{-19} \). What is the period of the motion of the particle?

a. \( 8.1 \times 10^{-9} \text{s} \)  
   b. \( 9.2 \times 10^{-6} \text{s} \)  
   c. \( 4.5 \times 10^{-9} \text{s} \)  
   d. \( 6.1 \times 10^{-7} \text{s} \)  
   e. \( 1.46 \times 10^{-5} \text{s} \)

14. The circuit on the left consists of a battery and a solenoid wrapped on an iron core. The circuit on the right is simply a coil and a resistor. Choose the correct statement below.

a. When the switch is first closed, the current in the resistor R is to the left.

b. When the switch is first closed, the current in the resistor R is to the right.

c. When the switch is first closed, the current in the resistor R is zero.

d. After the switch has been closed for awhile, the current in the resistor R is to the right.

e. After the switch has been closed for awhile, the current in the resistor R is to the left.

For questions #15 and 16 use the following:
A rectangular coil of an area \( A = 0.01 \text{ m}^2 \) is positioned in \( z-y \) plane as shown. The magnetic field in the area is directed along the \( x \)-axis and equal to \( B = 0.2 \text{ T} \).

15. The coil rotates around one of its sides with an angular frequency \( \omega = 500 \text{ rad/sec} \). What is the maximum value of the emf induced in the coil as the coil rotates?

a. The emf can’t be determined without knowing the axis of rotation

b. 0.5 V  
   c. 0.8 V  
   d. 1.0 V  
   e. 1.5 V

16. Assume that the coil has a number of turns \( N \) and rotates at an angular frequency \( \omega \). The measured \( E(t) \) is shown here as a function of time. Then, the number of turns in the coil, \( N \) is increased by a factor of 2 and the frequency is halved. What are the new amplitude and period of \( E(t) \)?

a. 5 mV, 4 ms  
   b. 5 mV, 2 ms  
   c. 2.5 mV, 2 ms  
   d. 10 mV, 2 ms  
   e. 10 mV, 4 ms
17. Two infinitely long solenoids (seen in cross section) pass through a circuit as shown. The magnitude of $\mathbf{B}$ inside each is the same and is increasing at the rate of $d\mathbf{B}/dt = 90 \text{ mT/ sec}$. What is the direction of the current in the 3 $\Omega$ resistor?

a. up b. down c. 0 d. impossible to determine

For questions #18 and 19 use the following circuit:

The voltage on the battery is $E$, the resistance of both resistors is $R$ as shown, and the inductance of the coil is $L$.

18. Immediately after the switch is closed, the current through the battery is

a. $0$ b. $\frac{E}{L}$ c. $\frac{E}{2R}$ d. $\frac{E}{R}$ e. $\frac{2E}{R}$

19. A very long time after the switch is closed the current through the battery is

a. $0$ b. $\frac{E}{L}$ c. $\frac{E}{2R}$ d. $\frac{E}{R}$ e. $\frac{2E}{R}$

20. A 12.0 V battery is connected into a series circuit containing a 10.0 $\Omega$ resistor, a 2.00 mH inductor, and a switch. The switch is open at $t<0$. The switch is closed at $t=0$. How long will it take the current to reach 50.0% of its final value?

a. 0.2 ms b. 0.67 ms c. 0.14 ms d. 0.31 ms e. 0.5 ms

21. At some instant in an oscillating LC circuit, 67.0% of the total energy is stored in the magnetic field of the inductor. What multiple of the maximum charge $Q_{\text{max}}$ is on the capacitor?

a. 0.574 b. 0.819 c. 0.437 d. 0.67 e. 0.731
22. A long vertical wire carries an unknown current. Coaxial with the wire is a long, thin, cylindrical conducting surface that carries a current of 30 mA upward. The cylindrical surface has a radius of 3.0 mm. The magnitude of the magnetic field at a point 3.5 mm from a center of the wire is 1.0 μT and the direction of the field is shown in the diagram. What are the value and the direction of the current in the wire?

a. 10 mA, upward  b. 10 mA, downward  c. 12.5 mA, upward  d. 12.5 mA, downward  e. 0

23. If the magnetic field \( \vec{B} \) is constant and uniform over the area bounded by a square with edge length \( a \), the net current through the square is:

\[
\begin{align*}
\text{a. } & \frac{B}{\mu_0} \\
\text{b. } & \frac{Ba^2}{\mu_0} \\
\text{c. } & \frac{Ba}{2\mu_0} \\
\text{d. } & \frac{4Ba}{\mu_0} \\
\text{e. } & 0
\end{align*}
\]

24. Two parallel wires, 4 cm apart, carry currents of 2 A and 4 A respectively, in the same direction. The force per unit length in N/m of one wire on the other is:

a. \( 1 \times 10^{-3} \) N/m, attractive  
 b. \( 4 \times 10^{-5} \), attractive  
 c. \( 1 \times 10^{-3} \), repulsive  
 d. \( 4 \times 10^{-5} \), repulsive  
 e. 0

25. Each of the vector diagrams below show the direction of the velocity of an electron and the direction the magnetic field in the region.

(A) velocity out of the page  
(B) magnetic field into the page  
(C) magnetic field to the right

(D) magnetic field up the page  
(E) magnetic field to the left  
(F) magnetic field out of the page

Which of the diagrams shows a situation that results in a magnetic force on the electron directed to your left (when you are facing this page)?

a. D and E  
 b. F only  
 c. C and F  
 d. D only  
 e. A and B
<table>
<thead>
<tr>
<th>MECHANICS</th>
<th>ELECTRICITY AND MAGNETISM</th>
</tr>
</thead>
<tbody>
<tr>
<td>( v = \frac{\Delta x}{\Delta t} )</td>
<td>( F_e = k \frac{q_1 q_2}{r^2} )</td>
</tr>
<tr>
<td>( a = \frac{\Delta v}{\Delta t} )</td>
<td>( E = \frac{F}{q} )</td>
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<tr>
<td>( v_f = v_i + at )</td>
<td>( I = \frac{\Delta q}{\Delta t} )</td>
</tr>
<tr>
<td>( \Delta x = v_i t + \frac{1}{2} at^2 )</td>
<td>( V = \frac{W}{q} = Ed )</td>
</tr>
<tr>
<td>( 2a\Delta x = v_f^2 - v_i^2 )</td>
<td>( k = \frac{9 \times 10^9 \text{Nm}^2}{\text{C}^2} )</td>
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<tr>
<td>( \Sigma F = ma )</td>
<td>( G = 6.67 \times 10^{-11} \frac{\text{Nm}^2}{\text{kg}^2} )</td>
</tr>
<tr>
<td>( W = mg )</td>
<td>( P = \frac{V^2}{R} )</td>
</tr>
<tr>
<td>( F_g = G \frac{m_1 m_2}{r^2} )</td>
<td>( q = \text{charge} )</td>
</tr>
<tr>
<td>( p = mv )</td>
<td>( R = \text{resistance} )</td>
</tr>
<tr>
<td>( F_A t = m\Delta v )</td>
<td>( V = \text{electric potential difference} )</td>
</tr>
<tr>
<td>( \mu = \frac{F_f}{F_N} )</td>
<td>( W = \text{Work} )</td>
</tr>
<tr>
<td>( G = \text{Universal Gravitational Constant} )</td>
<td>( \mu = \text{coefficient of friction} )</td>
</tr>
<tr>
<td>( p = \text{momentum} )</td>
<td>( r = \text{distance between center of masses} )</td>
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<tr>
<td>( W = \text{weight} )</td>
<td>( I_f = I_1 + I_2 + I_3 + \ldots )</td>
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<td></td>
<td>( V_f = V_1 + V_2 + V_3 + \ldots )</td>
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<td></td>
<td>( R_f = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots} )</td>
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<tr>
<td>ENERGY</td>
<td>MOTION IN 2-D</td>
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<tr>
<td>$W = F \Delta x$</td>
<td>$a_c = \frac{v^2}{r}$</td>
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<tr>
<td>$P = \frac{W}{\Delta t} = F \nu$</td>
<td>$F_c = \text{centripetal force}$</td>
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<tr>
<td>$PE_g = mgh$</td>
<td>$\tau = \text{Torque}$</td>
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<tr>
<td>$KE = \frac{1}{2} mv^2$</td>
<td>$L = \text{ Angular Momentum}$</td>
</tr>
<tr>
<td>$F = -kx$</td>
<td>$I = \text{Moment of Inertia}$</td>
</tr>
<tr>
<td>$PE_s = \frac{1}{2} kx^2$</td>
<td>$\omega = \text{angular velocity}$</td>
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</table>

$\Delta L = \alpha L_o \Delta T$  
$| \begin{align*}
Q & = mc\Delta T \\
Q & = mL_f \\
Q & = mL_v \\
\Delta L & = \alpha L_o \Delta T \\
\end{align*} |  

<table>
<thead>
<tr>
<th>HEAT ENERGY</th>
<th>WAVE PHENOMENA</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c =$ specific heat</td>
<td>$c =$ speed of light in a vacuum</td>
</tr>
<tr>
<td>$L_f =$ latent heat of fusion</td>
<td>$d =$ distance between slits</td>
</tr>
<tr>
<td>$L_v =$ latent heat of vaporization</td>
<td>$f =$ frequency</td>
</tr>
<tr>
<td>$\alpha =$ coefficient of linear expansion</td>
<td>$\nu =$ speed</td>
</tr>
<tr>
<td>$L_o =$ original length</td>
<td>$n =$ index of absolute refraction</td>
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<tr>
<td>$c_{water} = 4186 \frac{J}{kg ^ {\circ} K}$</td>
<td>$T =$ period</td>
</tr>
<tr>
<td>$1 \text{ cal} = 4.184 \text{ joules}$</td>
<td>$\nu =$ speed</td>
</tr>
<tr>
<td>$\lambda =$ wavelength</td>
<td>$\theta =$ angle</td>
</tr>
<tr>
<td>$\theta_c =$ critical angle relative to air</td>
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$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$  
$f =$ focal length  
$d_i =$ image distance  
$d_o =$ object distance  
$h_i =$ object size  
$h_o =$ object size  

<table>
<thead>
<tr>
<th>ELECTROMAGNETIC APPLICATIONS</th>
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<tbody>
<tr>
<td>$F = Bqv$</td>
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<tr>
<td>$F = BLI$</td>
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<tr>
<td>$V = BLv$</td>
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<tr>
<td>$N_p = \frac{V_p}{V_s}$</td>
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<tr>
<td>$N_s = \frac{V_s}{V_s}$</td>
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<tr>
<td>$V_p I_p = V_s I_s$ (ideal)</td>
</tr>
<tr>
<td>efficiency $= \frac{V_s I_s}{V_p I_p}$</td>
</tr>
<tr>
<td>$L =$ length of conductor</td>
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Physics C Answer Key: **Orchid Test**
April 11, 2013

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>6</th>
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<td>D</td>
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<td>C</td>
<td>25</td>
<td>E</td>
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</table>

**Topics:**

**JANUARY:** kinematics in one and two dimensions; Newton's laws including resistance forces and dynamics of circular motion; vector algebra (mostly assumed as needed); energy and its conservation including potential energy and conservative forces, momentum and its conservation including two-dimensional situations

**FEBRUARY:** angular mechanics including rotational equilibrium, rotational dynamics, rotational energy, and angular momentum; oscillatory motion including kinematics, dynamics, energy, and damping; gravitation including kinematics and dynamics of planetary motion, angular momentum, and energy as applied to gravitation

**MARCH:** electrostatics including electrostatic forces, electrostatic field, electrostatic field flux and Gauss's Law; electrostatic potential and potential energy; dc electrical circuits including multi-loop circuits and power; capacitors, dielectrics, and circuits with capacitors

**APRIL:** Magnetic Fields and Forces including the applications of the Lorenz force, the Law of Biot-Savart, Ampere's Law, magnetic field flux and Faraday's Law, Lenz's Law for electromagnetic induction; magnetic materials, applications of electromagnetic induction, and circuits with inductors.

The April exam must be completed by April 30th. No area may take the April exam during the first week of April or during the first week of May.

**Dates for 2014 Season**

**Thursday January 9, 2014; Thursday February 13, 2013**
**Thursday March 13, 2014; Thursday April 10, 2014**

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