NJSL AP Physics C April 2008

1. Protons, electrons, and other charged particles flying in from the sun are deflected by Earth’s magnetic field. Determine the ratio of the revolution frequencies (called Larmor frequency) of the electron to that of a proton trapped in earth’s magnetic field B.
   a. \( \frac{m_e}{m_p} \)  b. \( \frac{m_p}{m_e} \)  c. \( \frac{q_e}{q_p} \)  d. \( \frac{q_p}{q_e} \)  e. 1

2. The region marked a has uniform magnetic field and the region marked b has uniform electric field only between two parallel plates. A particle enters region a as shown and deflects toward the plate at higher potential in region b. Determine the direction of the magnetic field in the region a.
   a. up  b. down  c. to the right  d. into the page  e. out of the page

For problems #3 and 4 use the following information:

A mass spectrometer consists of a region with electric and magnetic fields at right angles to each other (velocity selector) and a region with only the magnetic field (mass separator). The magnetic field in both regions is the same uniform field \( B_{in} = 0.5 \) T into the page as shown. Ions exit the velocity selector at a speed of \( 1.6 \times 10^5 \) m/s.

3. The magnitude of the electric field used in the velocity selector is
   a. \( 3.2 \times 10^5 \) N/C  b. \( 8.0 \times 10^4 \) V/m  c. \( 2.56 \times 10^{-14} \) V/m  d. \( 5.24 \times 10^{-3} \) N/C  e. \( 6.4 \times 10^4 \) V/m

4. From the velocity selector, the ions pass into the mass separator and hit the detector wall after traveling through exactly half a circle as shown. Use the information above and determine the separation between the places where singly ionized \( ^{20}\text{Ne} \) and \( ^{22}\text{Ne} \) hit the detector wall. (One atomic mass unit \( u = 1.66 \times 10^{-27} \) kg)
   a. 5 mm  b. 8 mm  c. 13 mm  d. 22 mm  e. 30 mm

5. The primary and secondary windings of an isolation transformer are linked by the magnetic flux through an iron core, usually stainless steel. The core is not made out of a solid chunk of metal but is constructed instead out of sheets of steel with layers of insulating material between the metal sheets. The core is made out of sheets because
   a. that prevents the electric field from penetrating through the core
   b. prevents magnetic field from penetrating the core
   c. prevents the core from rattling due to magnetic force
   d. prevents the induced currents in the core that would overheat the core
   e. there is no practical purpose of doing this
6. Consider the transformer shown above. Assume that the primary is designed to be plugged into a regular 120 V outlet and rated for 60 W of power. The number of turns in the secondary winding is 10 times less than the number of turns in the primary. Determine the maximum current in the secondary winding.
   a. 50 A   b. 5 A   c. 0.5 A   d. 2 A   e. 20 A

7. A proton (mass=1.67x10^{-27} kg) enters a region of uniform magnetic field |B| = 3.14 T at a velocity |v| = 5x10^6 m/s at an angle of 37° to the direction of the field. How far forward does the electron travel for each revolution it makes around the magnetic field? (This is the pitch of its spiral trajectory)
   a. 14 mm   b. 18 mm   c. 27 mm   d. 83 mm   e. 62 mm

8. A wire with a circular cross section of a radius R carries a current of uniform density j (in A/m²). Determine the ratio of the magnetic field strength at a distance r = R/2 to the magnetic field strength at a distance r = 2R from the center of the wire. \( \frac{B_{at \ R/2}}{B_{at \ 2R}} = \)
   a. 1   b. 2   c. 0.5   d. 0.25   e. 4

9. A small rectangular piece of a conducting material falls downwards without rotation remaining parallel to the ground as it falls. Magnetic field is uniform \( \mathbf{B}_{out} \), the mass of the piece is m, the length l, and the resistance R. Determine the terminal velocity of the conductor.
   \( \frac{mgR}{Bl} \quad b. \quad \frac{mgR}{B^2 l^2} \quad c. \quad \frac{B^2 l^2}{mg} \quad d. \quad \frac{mgB}{lR} \quad e. \) none of these is correct

10. Two long concentric hollow cylindrical conductors have radii \( r_1 \) and \( r_2 \) as shown. The two conductors carry currents of equal magnitude in opposite directions. Select the graph that best represents the magnetic field of the wires as a function of the distance from the axis.
11. A square loop (side length $a$) carrying a current $I$ is placed in a uniform magnetic field $B$. Determine the net force and the net torque on a rectangular current loop.

a. $\Sigma F = 0; \Sigma \tau = 0$

b. $\Sigma F = Bla; \Sigma \tau = 0$

c. $\Sigma F = 0; \Sigma \tau = Bla^2$

d. $\Sigma F = 2Bla; \Sigma \tau = 0$

e. $\Sigma F = 2Bla; \Sigma \tau = Bla^2$

12. In the figure, the primary coil is connected to a battery through a switch $S$. Initially, the switch is open. Determine the direction of the current induced in the resistor $R$ when the switch $S$ is closed.

a. up  b. down  c. out of the page  d. into the page  e. to the left

13. A long solenoid has $n$ turns per unit length and carries a current given by $I = I_0 \sin \omega t$. The solenoid has a circular cross section of a radius $R$. Find the induced electric field at a point a distance $r < R$ from the axis of the solenoid.

a. $E = \mu_0 n I_0 \omega \cos \omega t$

b. $E = \mu_0 n I_0 \omega \cos \omega t$

c. $E = 0.5 \mu_0 n I_0 \omega \cos \omega t$

d. $E = \mu_0 n I_0 \sin \omega t$

e. $E = \mu_0 n I_0 \omega \cos \omega t$

14. A coil with inductance 4 mH and resistance 150 $\Omega$ is connected across a battery of emf 12V and negligible internal resistance. What is the rate of increase when the current is half its final value?

a. 0  b. $1.2 \times 10^3$ A/sec  c. $1.5 \times 10^3$ A/sec  d. $2.4 \times 10^3$ A/sec  e. not enough information given

15. A rectangular loop of a generator of dimensions $a$ and $b$ has $N$ turns. The loop is connected to slip rings and rotates with an angular velocity $\omega$ in a uniform magnetic field $B$. Determine the potential difference between the two slip rings.

a. $NB\omega \sin \omega t$  b. $NB\omega \cos \omega t$  c. $NB\omega \sin (\omega t + \phi)$  d. $N\omega \sin \omega t$  e. $NB\omega \cos \omega t$

16. The diagrams show five possible orientations of a magnetic dipole $\mu$ in a uniform magnetic field $B$. For which of these does the magnetic torque on the dipole have the greatest magnitude?

a. I  b. II  c. III  d. IV  e. V

17. Electrons (mass $m$, charge $-e$) are accelerated from rest through a potential difference $V$ and are then deflected by a magnetic field $B$ that is perpendicular to their velocity. The radius of the resulting electron trajectory is:

a. $\sqrt{2eV/m}/B$  b. $B\sqrt{2eV/m}$  c. $B\sqrt{2mV/e}$  d. $\sqrt{2mV/e}/B$  e. none of these

18. A circuit containing an ideal 9V battery has an inductance of 1.0 mH and a resistance of 1.0 $\Omega$. At $t=0$ the switch $S$ is closed. Estimate the current in the circuit 2.0 ms after the switch is closed.

a. 8 A  b. 9 A  c. 6 A  d. 3 A  e. 0 A
19. Two parallel long wires carry the same current and repel each other with a force $F$ per unit length. If both these currents are doubled and the wire separation tripled, the force per unit length becomes: a. $\frac{2F}{3}$  b. $6F$  c. $F/9$  d. $4F/9$  e. $4F/3$

![Diagram of two parallel wires](image)

20. The closed loop shown carries a current of 10 A in the counterclockwise direction. The radius of the outer arc is 50 cm, that of the inner arc is 20 cm. Find the magnetic field at point $P$. ($\mu_0$ – magnetic permeability of free space)
   a. 0  b. $\mu_0/4$  c. $\mu_0/3$  d. $\mu_0/2$  e. $\mu_0$

![Diagram of a closed loop with current](image)

21. Which graph correctly gives the magnitude of the magnetic field outside an infinitely long straight current-carrying wire as a function of the distance $r$ from the wire?
   a. I  b. II  c. III  d. IV  e. V

![Graphs of magnetic field magnitude vs. distance](image)

22. Figure (a) shows a length of wire carrying a current $i$ and bent into a circular coil of one turn. In Figure (b) the same length of wire has been bent more sharply, to give a coil two turns, each of half the original radius. If $B_a$ and $B_b$ are the magnitudes of the magnetic fields at the centers of the two coils, what is the ratio $B_b/B_a$?
   a. 1  b. 2  c. 3  d. 4  e. 6

![Figures of coiled wires](image)

23. 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?
   a. 0  b. 1  c. 3  d. 5  e. 7

![Diagram of parallel wires](image)

24. Each of the four conductors shown here carries 2.0 A of current into or out of the page as indicated by dots and crosses. Determine the integral of the magnetic field $\oint B \cdot ds$ along the path shown. ($\mu_0$ – magnetic permeability of free space)
   a. 0  b. $2\mu_0$  c. $-6\mu_0$  d. $4\mu_0$  e. $\mu_0$

![Diagram of current-carrying conductors](image)

25. Three straight very long wires 1, 2, and 3 carry currents in and out of the page as shown. The wires are equidistant from each other as indicated. What is the direction of the resultant force by currents 2 and 3 on current #1?
   a. +y  b. $-y$  c. +x  d. $-x$  e. toward the current #3

![Diagram of three current-carrying wires](image)

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### MECHANICS

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( v = \frac{\Delta x}{\Delta t} )</td>
<td>velocity</td>
</tr>
<tr>
<td>( a = \frac{\Delta v}{\Delta t} )</td>
<td>acceleration</td>
</tr>
<tr>
<td>( v_f = v_i + at )</td>
<td>final velocity</td>
</tr>
<tr>
<td>( \Delta x = v_i t + \frac{1}{2} at^2 )</td>
<td>displacement</td>
</tr>
<tr>
<td>( 2a\Delta x = v_f^2 - v_i^2 )</td>
<td>change in position</td>
</tr>
</tbody>
</table>

\[ \Sigma F = ma \]

- \( F \): force
- \( W \): work
- \( F_g = G \frac{m_1 m_2}{r^2} \): gravitational force
- \( F_f = \frac{F_g}{\mu} \): force of friction
- \( F_N = \frac{F_g}{\mu} \): normal force

### ELECTRICITY AND MAGNETISM

\[ F_e = \frac{k q_1 q_2}{r^2} \]

- \( E \): electric field intensity
- \( I \): electric current
- \( q \): charge
- \( k \): electrostatic constant

\[ V = \frac{W}{q} = Ed \]

- \( P \): Power
- \( I = \frac{\Delta q}{\Delta t} \)

### SERIES CIRCUIT

\[ V = IR \]

\[ I_T = I_1 = I_2 = I_3 = \ldots \]

### PARALLEL CIRCUITS

\[ V_T = V_1 = V_2 = V_3 = \ldots \]

\[ R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots} \]

### ENERGY

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( W = F\Delta x )</td>
<td>work</td>
</tr>
<tr>
<td>( P = \frac{W}{\Delta t} = \frac{\Delta E}{\Delta t} = Fv )</td>
<td>power</td>
</tr>
<tr>
<td>( PE_g = mgh )</td>
<td>gravitational energy</td>
</tr>
<tr>
<td>( KE = \frac{1}{2} mv^2 )</td>
<td>kinetic energy</td>
</tr>
<tr>
<td>( F = -kx )</td>
<td>force</td>
</tr>
<tr>
<td>( PE_s = \frac{1}{2} kx^2 )</td>
<td>stored in a spring</td>
</tr>
</tbody>
</table>

### MOTION IN 2-D

- \( a_c = \frac{v^2}{r} \): centripetal acceleration
- \( F_c = \frac{mv^2}{r} \): centripetal force
- \( \tau \): Torque

\[ L = I\omega \]

\[ KE = \frac{1}{2} I \omega^2 \]

- \( L \): Angular Momentum
- \( I \): Moment of Inertia
- \( \omega \): angular velocity

\[ 1 \text{ rev} = 2\pi \text{ rad} = 360^\circ \]
PHYSICS FORMULAE UPDATED

**HEAT ENERGY**
- \( Q = mc \Delta T \)
- \( Q = mL_f \)
- \( Q = mL_v \)
- \( \Delta L = \alpha L_o \Delta T \)

**WAVE PHENOMENA**
- \( T = \frac{1}{f} \)
- \( v = f \lambda \) OR \( v = n \lambda \)
- \( n = \frac{c}{v} \)
- \( n_i \sin \theta_i = n_r \sin \theta_r \)
- \( \lambda = \frac{xd}{L} \)
- \( n \lambda = d \sin \theta \)
- \( \sin \theta_c = \frac{1}{n} \)

**GEOMETRIC OPTICS**
- \( \frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o} \)
- \( f = \text{focal length} \)
- \( d_i = \text{image distance} \)
- \( d_o = \text{object distance} \)
- \( h_i = \text{image size} \)
- \( h_o = \text{object size} \)

**ELECTROMAGNETIC APPLICATIONS**
- \( F = -Bqv \)
- \( F = BIL \)
- \( V = BLv \)
- \( \frac{N_p}{V_p} = \frac{V_p}{V_s} \)
- \( N_S = \frac{V_s I_S}{V_p I_p} \) \text{(ideal)}

**WAVE PHENOMENA (continued)**
- \( \lambda = \text{wavelength} \)
- \( \theta = \text{angle} \)
- \( \theta_c = \text{critical angle} \)
  - relative to air

**GEOMETRIC OPTICS (continued)**
- \( \frac{h_i}{h_o} = \frac{d_i}{d_o} \)

**ELECTROMAGNETIC APPLICATIONS (continued)**
- \( B = \text{magnetic field strength} \)
- \( I_p = \text{current in primary} \)
- \( I_S = \text{current in secondary} \)
- \( N_p = \text{number of turns in primary coil} \)
- \( N_S = \text{number of turns in secondary coil} \)
- \( V_p = \text{voltage of primary} \)
- \( V_S = \text{voltage of secondary} \)
- \( L = \text{length of conductor} \)
- \( V = \text{electric potential} \)

**Additional Formulae:**
- **Moments of Inertia of Uniform Bodies:**
  1. Thin cylindrical shell about axis \( I = MR^2 \).
  2. Thin cylindrical shell about diameter through center \( I = \frac{1}{2} MR^2 + \frac{1}{12} ML^2 \).
  3. This spherical shell about diameter \( I = \frac{2}{3} MR^2 \).
  4. Solid cylinder about axis \( I = \frac{1}{2} MR^2 \).
  5. Solid sphere about diameter \( I = \frac{2}{5} MR^2 \).

\[ x = A \cos(\omega t + \phi) \]
\[ n \lambda = \omega \sin \theta \]
\[ E_{\text{total}} = \frac{1}{2} mv^2 + \frac{1}{2} kx^2 \]

\[ y = A \sin \left[ 2\pi \left( \frac{x}{\lambda} - ft \right) \right] \]

\[ \frac{1}{f} = (n - 1) \left( \frac{1}{R_1} - \frac{1}{R_2} \right) \]
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.

TESTING DATES FOR THE NEW JERSEY SCIENCE LEAGUE

**April 10, 2008**

Each area may select a date in April, other than the first week, for all schools in the area to take the exam.

No schools may take the April exam during the first week of April.

Preliminary Testing Dates for 2008-2009 Season

Jan 15, 2009; Feb 12, 2009; Mar 12, 2009; April 9, 2009