1. Gauss' Law is to be used to calculate the electric field near a charged body. In order for Gauss' Law to be used effectively which of the following conditions should be met?
   a. The electric field strength should be increasing uniformly.
   b. The magnitude of the electric field should be constant at all points of the selected Gaussian surface.
   c. The electric field strength should be decreasing in strength at an exponential rate.
   d. The electric field strength should increase by 4x when the distance from the charged body is doubled.
   e. The electric field should be zero everywhere on the Gaussian surface.
   f. The electric field should be perpendicular to the selected Gaussian surface at all points.
   A. a & b  B. b, c & f  C. b & f  D. c, d & e  E. a, c & d

2. The predominant electrical characteristic of a voltmeter is ____________________.
   A. that it has low resistance and should be connected in parallel
   B. that it has low resistance and should be connected in series
   C. that it has high resistance and should be connected in series
   D. that it has high resistance and should be connected in parallel
   E. that it draws very little current and should be connected in series

Questions 3-5
Each of the following questions refers to the circuit diagram to the right with the following values:

EMF=10.0 Volts, R₁=50Ω, R₂=100Ω, C₁=100μF

The switch S₁ is initially open and the internal resistance of the battery is insignificant.

3. What will be the current I₁ flowing through the resistor R₁ immediately after the switch S₁ is closed?
   A. 0.150A  B. 0.350A  C. 0.200A  D. 0.067A  E. 0.00A

4. What will be the current I₂ flowing through resistor R₂ immediately after the switch S₁ is closed?
   A. 0.150A  B. 0.350A  C. 0.200A  D. 0.067A  E. 0.00A

5. What will be the current I₁ flowing through the resistor R₁ a long time after the switch has been closed?
   A. 0.150A  B. 0.350A  C. 0.200A  D. 0.067A  E. 0.00A

Questions 6-7

Two positive charges of magnitude +q are each a distance d from the origin B of a coordinate system as shown to the right.

6. At which point is the electric field greatest in magnitude?
   A.  B.  C.  D.  E.

7. At which point is the electric potential greatest in magnitude?
   A.  B.  C.  D.  E.
Questions 8-9

A solid conducting sphere, which has a radius \( R \) and contains a charge \(-Q\), is surrounded by a conducting spherical shell, which has an inner radius \( 2R \), an outer radius \( 3R \) and contains a net charge of \(+2Q\).

8. Which of the following graphs best represents the electric field \( E \) as a function of distance from the center of the solid conducting sphere?

A.

B.

C.

D.

E.

9. Which of the following graphs best represents the electrostatic potential as a function of distance from the center of the solid conducting sphere?

A.

B.

C.

D.

E.
10. Two identical conducting spheres are charged to $+3q$ and $-q$, respectively, and separated by a distance $d$.

The magnitude of the force of attraction on the left sphere caused by the right sphere is $F_1$. The two spheres are made to touch and are then re-separated by a distance $2d$. The magnitude of the force on the left sphere by the right sphere is then $F_2$. Which of the following relationships is correct?

A. $4F_1 = F_2$  
B. $F_1 = 12F_2$  
C. $F_1 = 4F_2$  
D. $3F_1 = 4F_2$  
E. $4F_1 = 3F_2$

**Two parallel plates are separated by a distance $d$. These two plates are then attached to a battery which has an emf $V$ as shown to the right. A small particle with a charge $q$ is initially located at point A.**

11. How much work must be done in moving this charged particle from point A to point C?

A. $V \cdot q \cdot \frac{y}{d}$  
B. $V \cdot q \cdot \frac{x}{d}$  
C. $\frac{V \cdot q}{\sqrt{x^2+y^2}}$  
D. $V \cdot q \cdot \frac{x}{\sqrt{x^2+y^2}}$  
E. $V \cdot q \cdot \frac{y}{\sqrt{x^2+y^2}}$

12. A sheet of mica ($K = 6$) is inserted between the plates of an isolated charged parallel-plate capacitor. Which of the following statements is true?

A. The capacitance decreases.  
B. The potential difference across the capacitor increases.  
C. The energy stored in the capacitor decreases.  
D. The charge on the capacitor plates decreases.  
E. The electric field between the capacitor plates increases.

**Two metal spheres that are initially uncharged are mounted on insulating stands, as shown to the right. A positively charged glass rod is brought close to, but does not make contact with, sphere X. Sphere Y is then brought close to X on the side opposite to the glass rod. Y is allowed to touch X and then is removed some distance away. The glass rod is then moved far away from X and Y.**

13. What are the final charges on the two spheres?

<table>
<thead>
<tr>
<th>Sphere X</th>
<th>Sphere Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) Zero</td>
<td>Zero</td>
</tr>
<tr>
<td>B) Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>C) Negative</td>
<td>Positive</td>
</tr>
<tr>
<td>D) Positive</td>
<td>Negative</td>
</tr>
<tr>
<td>E) Positive</td>
<td>Positive</td>
</tr>
</tbody>
</table>
Questions 14-15

Negative charge \(-q\) is uniformly distributed over a thin ring of radius \(R\) that lies in a plane perpendicular to the \(x\)-axis with its center at the origin \(0\), as shown above.

14. Which of the following graphs best plots the electrostatic potential as a function of distance from the origin along the \(x\) axis?

A.  

\[
\begin{array}{c}
\text{V} \\
-2R & -R & 0 & R & 2R
\end{array}
\]

B.  

\[
\begin{array}{c}
\text{V} \\
-2R & -R & 0 & R & 2R
\end{array}
\]

C.  

\[
\begin{array}{c}
\text{V} \\
-2R & -R & 0 & R & 2R
\end{array}
\]

D.  

\[
\begin{array}{c}
\text{V} \\
-2R & -R & 0 & R & 2R
\end{array}
\]

E.  

\[
\begin{array}{c}
\text{V} \\
-2R & -R & 0 & R & 2R
\end{array}
\]

15. Which of the following expressions correctly describes the magnitude of the electric field as a function of the distance \(x\) from the origin?

A.  

\[
\frac{k\cdot q}{\sqrt{x^2 + R^2}}
\]

B.  

\[
\frac{k\cdot q\cdot x}{\sqrt{x^2 + R^2}}
\]

C.  

\[
\frac{k\cdot q}{(x^2 + R^2)^{3/2}}
\]

D.  

\[
\frac{k\cdot q\cdot R}{\sqrt{x^2 + R^2}^2}
\]

E.  

\[
\frac{k\cdot q\cdot x}{\sqrt{x^2 + R^2}^3}
\]

16. If the only force acting on a proton is due to a uniform electric field, the proton moves with ________________.

A. a constant acceleration in a direction opposite to that of the electric field
B. an increasing acceleration in the direction of the electric field
C. a decreasing acceleration in a direction perpendicular to that of the electric field
D. a constant speed in a direction parallel to that of the electric field
E. a constant acceleration in the direction of the electric field
17. Six identical light bulbs are connected to a battery which has an emf \( V \) as shown to the right. Which of the following correctly ranks the currents through these light bulbs from greatest to least current?

A. \( I_1 > I_2 > I_3 = I_4 = I_5 > I_6 \)
B. \( I_6 > I_3 > I_2 > I_1 = I_4 = I_5 \)
C. \( I_6 > I_1 > I_2 > I_3 > I_4 > I_5 \)
D. \( I_2 > I_6 > I_1 > I_3 = I_4 = I_5 \)
E. \( I_6 > I_1 > I_2 > I_3 = I_4 = I_5 \)

18. A wire has a length \( L \) and a resistance \( R \). What will be the new resistance of this wire if it is stretched to a uniform length \( 5L \) while maintaining the same volume?

A. \( 125 \cdot R \)  
B. \( 5 \cdot R \)  
C. \( 25 \cdot R \)  
D. \( R/25 \)  
E. \( R/50 \)

**Questions 19-20**

A capacitor of 2400 micro Farads is initially connected to a battery which has an emf of 12.0 Volts until equilibrium is reached. This capacitor is then removed from the battery and is connected to a load resistance of \( R = 1000 \) Ohms.

19. What is the time constant for this resulting circuit?

A. \( 12 \) s  
B. \( 2.4 \) s  
C. \( 1.2 \) s  
D. \( 18 \) s  
E. \( 180 \) s

20. What will be the instantaneous power being delivered to the load resistance 4.8 seconds after being connected to the capacitor?

A. \( 1.45 \) W  
B. \( 0.082 \) W  
C. \( 0.00264 \) W  
D. \( 0.0135 \) W  
E. \( 0.024 \) W
Questions 21-23
A battery, which has an emf of $E = 30.4$ Volts and an internal resistance $r$, is connected to three resistors as shown to the right where: $R_1 = 200 \ \Omega$, $R_2 = 450 \ \Omega$, $R_3 = 150 \ \Omega$
An ammeter is connected in series with the battery and has a reading of 0.200 A.

21. What is the equivalent resistance of the three load resistances?
   A. 150 $\ \Omega$  B. 800 $\ \Omega$  C. 225 $\ \Omega$  D. 500 $\ \Omega$  E. 450 $\ \Omega$

22. What is the internal resistance of the battery?
   A. 3.5 $\ \Omega$  B. 1.25 $\ \Omega$  C. 2.0 $\ \Omega$  D. 0.35 $\ \Omega$  E. 1.15 $\ \Omega$

23. What will be the reading on the voltmeter connected across the battery?
   A. 14.4 V  B. 18.2 V  C. 36.2 V  D. 28.4 V  E. 30.0 V

Questions 24-25
Consider the equipotential diagram shown to the right caused by an unknown distribution of static charges.

24. Which of the following vectors best describes the direction of the electric field at point E?
   A.  
   B.  
   C.  
   D.  
   E.  

25. How much work must be done to move an alpha particle ($q_{\text{alpha}} = 3.2 \times 10^{-19} \text{C}$) from point B to point D?
   A. $-2.4 \times 10^{-14} \text{J}$
   B. $1.8 \times 10^{-16} \text{J}$
   C. $-1.8 \times 10^{-18} \text{J}$
   D. $3.6 \times 10^{-18} \text{J}$
   E. $-4.8 \times 10^{-18} \text{J}$
### PHYSICS FORMULAE

#### MECHANICS

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( v = \frac{\Delta x}{\Delta t} )</td>
<td>( \Delta x ) = displacement (change of position)</td>
</tr>
<tr>
<td>( v = \frac{\Delta y}{\Delta t} )</td>
<td>( v ) = average velocity</td>
</tr>
<tr>
<td>( a = \frac{\Delta v}{\Delta t} )</td>
<td>( a ) = average acceleration</td>
</tr>
<tr>
<td>( v_f = v_i + at )</td>
<td>( v_i ) = initial velocity</td>
</tr>
<tr>
<td>( \Delta x = v_i t + \frac{1}{2} at^2 )</td>
<td>( v_f ) = final velocity</td>
</tr>
<tr>
<td>( 2a\Delta x = v_f^2 - v_i^2 )</td>
<td></td>
</tr>
<tr>
<td>( \Sigma F = ma )</td>
<td>( F ) = force</td>
</tr>
<tr>
<td>( W = mg )</td>
<td>( F_f ) = force of friction</td>
</tr>
<tr>
<td>( F_g = G \frac{m_1 m_2}{r^2} )</td>
<td>( F_N ) = normal force</td>
</tr>
<tr>
<td>( \rho = \frac{mv}{v} )</td>
<td>( F_g ) = gravitational force</td>
</tr>
<tr>
<td>( F \Delta x = m \Delta v )</td>
<td>( G ) = Universal Gravitational Constant</td>
</tr>
<tr>
<td>( \mu = \frac{F_f}{F_N} )</td>
<td>( \rho ) = momentum</td>
</tr>
<tr>
<td></td>
<td>( \mu ) = coefficient of friction</td>
</tr>
<tr>
<td></td>
<td>( r ) = distance between center of masses</td>
</tr>
<tr>
<td></td>
<td>( W ) = weight</td>
</tr>
</tbody>
</table>

#### ELECTRICITY AND MAGNETISM

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( F_c = k \frac{q_1 q_2}{r^2} )</td>
<td>( E ) = electric field intensity</td>
</tr>
<tr>
<td>( E = \frac{F}{q} )</td>
<td>( I ) = electric current</td>
</tr>
<tr>
<td>( V = \frac{W}{q} = Ed )</td>
<td>( k ) = electrostatic constant</td>
</tr>
<tr>
<td>( I = \frac{\Delta q}{\Delta t} )</td>
<td>( k = 9 \times 10^9 \text{ Nm}^2 \text{ C}^{-2} )</td>
</tr>
<tr>
<td>( G = 6.67 \times 10^{-11} \text{ Nm}^2 \text{ kg}^{-2} )</td>
<td></td>
</tr>
<tr>
<td>( V = IR )</td>
<td>( P ) = Power</td>
</tr>
<tr>
<td>( P = VI = I^2 R = \frac{V^2}{R} )</td>
<td>( q ) = charge</td>
</tr>
<tr>
<td>( R_T = R_1 + R_2 + R_3 + \ldots )</td>
<td>( R ) = resistance</td>
</tr>
<tr>
<td>( V_T = V_1 + V_2 + V_3 + \ldots )</td>
<td>( V ) = electric potential difference</td>
</tr>
<tr>
<td>( W = Work )</td>
<td>( W ) = Work</td>
</tr>
</tbody>
</table>

#### ENERGY

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( W = F \Delta x )</td>
<td>( h ) = height</td>
</tr>
<tr>
<td>( P = \frac{W}{\Delta t} = \frac{\Delta E}{\Delta t} = Fv )</td>
<td>( k ) = spring constant</td>
</tr>
<tr>
<td>( P = \frac{W}{\Delta t} = \frac{\Delta E}{\Delta t} = Fv )</td>
<td>( KE ) = kinetic energy</td>
</tr>
<tr>
<td>( PE_g = mgh )</td>
<td>( PE_g ) = gravitational potential energy</td>
</tr>
<tr>
<td>( KE = \frac{1}{2} mv^2 )</td>
<td>( PE_s ) = potential energy stored in a spring</td>
</tr>
<tr>
<td>( F = -kx )</td>
<td>( P ) = power</td>
</tr>
<tr>
<td>( PE_s = \frac{1}{2} kx^2 )</td>
<td>( W ) = work</td>
</tr>
<tr>
<td></td>
<td>( x ) = change in spring length from the equilibrium position</td>
</tr>
</tbody>
</table>

#### MOTION IN 2-D

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha_c = \frac{v^2}{r} )</td>
<td>( \alpha_c ) = centripetal acceleration</td>
</tr>
<tr>
<td>( \alpha_c = \frac{v^2}{r} )</td>
<td>( F_c ) = centripetal force</td>
</tr>
<tr>
<td>( l \text{ rev} = 2\pi rad = 360^\circ )</td>
<td>( \tau ) = Torque</td>
</tr>
<tr>
<td>( \tau = Fx\theta )</td>
<td>( L = I\omega )</td>
</tr>
<tr>
<td>( L = I\omega )</td>
<td>( L ) = Angular Momentum</td>
</tr>
<tr>
<td>( I = \text{Moment of Inertia} )</td>
<td>( \omega ) = angular velocity</td>
</tr>
<tr>
<td>( \omega = \text{angular velocity} )</td>
<td></td>
</tr>
</tbody>
</table>
### PHYSICS FORMULAE

<table>
<thead>
<tr>
<th>Heat Energy</th>
<th>Wave Phenomena</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Q = mc\Delta T )</td>
<td>( T = \frac{1}{f} )</td>
</tr>
<tr>
<td>( Q = mL_f )</td>
<td>( \nu = f\lambda \text{ OR } V = \nu\lambda )</td>
</tr>
<tr>
<td>( Q = mL_v )</td>
<td>( n = \frac{c}{\nu} )</td>
</tr>
<tr>
<td>( \Delta L = \alpha L_o \Delta T )</td>
<td>( n, \sin \theta_i = n_r \sin \theta_r )</td>
</tr>
<tr>
<td>( \Delta T = ) change in temperature</td>
<td>( \lambda = \frac{xd}{L} )</td>
</tr>
<tr>
<td>( \alpha = ) coefficient of linear expansion</td>
<td>( n \lambda = d \sin \theta )</td>
</tr>
<tr>
<td>( L_o = ) original length</td>
<td>( \sin \theta_c = \frac{1}{n} )</td>
</tr>
<tr>
<td>( c_{water} = 4186 \frac{J}{kg^oK} )</td>
<td>( \theta = ) angle</td>
</tr>
<tr>
<td>( 1 \text{ cal} = 4.184 \text{ joules} )</td>
<td>( \theta_c = ) critical angle relative to air</td>
</tr>
</tbody>
</table>

### Geometric Optics

<table>
<thead>
<tr>
<th>Application</th>
<th>Electromagnetic Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o} )</td>
<td>( B = \text{magnetic field strength} )</td>
</tr>
<tr>
<td>( f = ) focal length</td>
<td>( I_p = \text{current in primary} )</td>
</tr>
<tr>
<td>( d_i = ) image distance</td>
<td>( I_s = \text{current in secondary} )</td>
</tr>
<tr>
<td>( d_o = ) object distance</td>
<td>( N_p = \text{number of turns in primary coil} )</td>
</tr>
<tr>
<td>( h_i = \frac{d_i}{d_o} )</td>
<td>( N_s = \text{number of turns in secondary coil} )</td>
</tr>
<tr>
<td>( h_o = ) object size</td>
<td>( V_p = \text{voltage of primary} )</td>
</tr>
<tr>
<td>( h_i = ) image size</td>
<td>( V_s = \text{voltage of secondary} )</td>
</tr>
<tr>
<td>( \frac{V_p I_p}{V_s I_s} = ) (ideal) efficiency</td>
<td>( L = \text{length of conductor} )</td>
</tr>
<tr>
<td>( V = ) electric potential difference</td>
<td></td>
</tr>
</tbody>
</table>
### AP Physics C Test

**Key March 8, 2012**

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 C</td>
<td>6 C</td>
<td>11 B</td>
<td>16 E</td>
<td>21 A</td>
</tr>
<tr>
<td>2 D</td>
<td>7 B</td>
<td>12 C</td>
<td>17 E</td>
<td>22 C</td>
</tr>
<tr>
<td>3 C</td>
<td>8 D</td>
<td>13 C</td>
<td>18 C</td>
<td>23 E</td>
</tr>
<tr>
<td>4 E</td>
<td>9 B</td>
<td>14 B</td>
<td>19 B</td>
<td>24 B</td>
</tr>
<tr>
<td>5 D</td>
<td>10 B</td>
<td>15 E</td>
<td>20 C</td>
<td>25 E</td>
</tr>
</tbody>
</table>

**PHYSICS C:** For all students taking Physics C who are currently enrolled in a Physics C course.

**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 Lorentz 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 2012

**Thursday March 8, 2012; *Thursday April 12, 2012**

*The April 2012 exam can be changed based upon the School's spring break.

New Jersey Science League
PO Box 65 Stewartsville, NJ 08886-0065
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### Testing Dates 2013

**Thursday January 10, 2013, Thursday Feb 14, 2013; Thursday March 14, 2013; *Thursday April 11, 2013**

*The April 2013 exam can be changed based upon the School’s spring break.