PH4132H1F
Test 2 Answers

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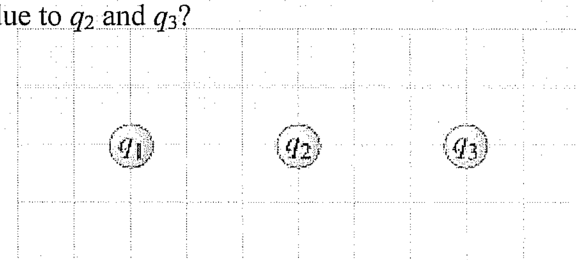
$\pi = 3.14159$

MULTIPLE CHOICE (16 points total)

#5 on Version 2

1. In the diagram below, there are three point charges, all along the same line: q_1, q_2 and q_3. The distance between q_1 and q_2 is the same as that between q_2 and q_3. Consider the Coulomb force on q_1. Define positive force as toward the right, and negative force as toward the left. Of the following five combinations of possible electric charges, which will produce the greatest positive Coulomb force on q_1 due to q_2 and q_3?



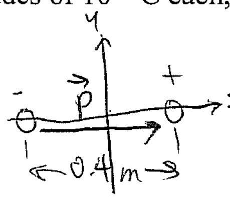
$F_{on 1} = \left[-\frac{q_1 q_2}{1^2} - \frac{q_1 q_3}{2^2}\right]\frac{k}{r^2}$

$\sim -q_1 q_2 - \frac{q_1 q_3}{4}$

A. $q_1 = +1$ nC, $q_2 = -1$ nC, $q_3 = +1$ nC $1 - 1/4 = +3/4$
B. $q_1 = +1$ nC, $q_2 = +1$ nC, $q_3 = -1$ nC $-1 + 1/4 = -3/4$
C. $q_1 = -1$ nC, $q_2 = -1$ nC, $q_3 = -1$ nC $-1 - 1/4 = -5/4$
(D.) $q_1 = +1$ nC, $q_2 = -1$ nC, $q_3 = -1$ nC $1 + 1/4 = +5/4$ biggest
E. $q_1 = +1$ nC, $q_2 = +1$ nC, $q_3 = +1$ nC $-1 - 1/4 = -5/4$

#1 on Version 2

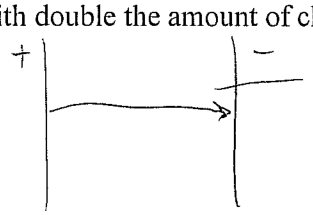
2. A particular dipole consists of a positive charge at $x = 0.2$ m, $y = 0$ m and a negative charge at $x = -0.2$ m, $y = 0$ m. If the charges have magnitudes of 10^{-9} C each, what is the dipole moment?
A. -4×10^{-10} C m $\hat{x}$
B. -2×10^{-10} C m $\hat{x}$
C. $+2 \times 10^{-10}$ C m $\hat{x}$
D. $+2 \times 10^{-10}$ C m $\hat{y}$
(E.) $+4 \times 10^{-10}$ C m $\hat{x}$



$p = qs = 0.4 \times 10^{-9}$ Cm
$\vec{p} = +4 \times 10^{-10}$ Cm $\hat{x}$

#6 on Version 2

3. A proton is released from rest at the positive plate of a parallel-plate capacitor. A vacuum separates the two plates. The proton crosses the capacitor, and just before it hits the negative plate, it has a final speed of 1.0×10^4 m/s. What will be the proton's final speed if the experiment is repeated with double the amount of charge on each capacitor plate?
A. 5.0×10^3 m/s
B. 1.0×10^4 m/s
(C.) 1.4×10^4 m/s
D. 2.0×10^4 m/s
E. 4.0×10^4 m/s



Conservation of Energy
$E_i = E_f$
$qV_i = \frac{1}{2} m v_f^2$

$V_i = \frac{Q_i}{C}$

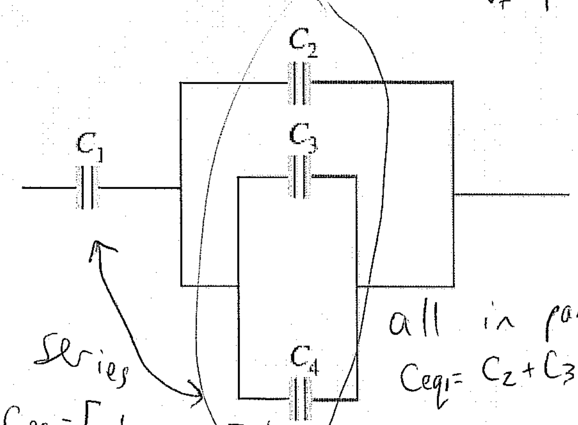
$v_f = \sqrt{\frac{2q Q_i}{Cm}}$

double Q_i, $v_f \uparrow$ by $\sqrt{2} = 1.4$

#2 on Version 2

4. Consider the combination of capacitors shown in the diagram, where $C_1 = 5.0$ µF, $C_2 = 1.0$ µF, $C_3 = 2.0$ µF and $C_4 = 3.0$ µF. Find the equivalent capacitance of the network of capacitors.

A. 0.49 µF
(B.) 2.7 µF
C. 5.5 µF
D. 5.8 µF
E. 11 µF



all in parallel,
$C_{eq1} = C_2 + C_3 + C_4 = 6\,\mu F$

Series

$C_{eq} = \left[\frac{1}{C_1} + \frac{1}{C_{eq1}}\right]^{-1} = \left[\frac{1}{5\,\mu F} + \frac{1}{6\,\mu F}\right]^{-1} = 2.73\,\mu F$

#7 on Version2

5. How much power is lost as heat along the length of a 15 m long wire in the walls of your house? [The wire is made of solid aluminum, has a diameter of 2.0 mm, and carries 12 A of current. The resistivity of aluminum is $2.8 \times 10^{-8}\ \Omega$ m.]
   - A. 4.0×10^{-6} W
   - B. 0.13 W
   - C. 1.6 W
   - D. 4.8 W
   - (E.) 19 W

$R = \rho \frac{L}{A}$ $A = \pi r^2$ $r = \frac{D}{2} = 0.001\ m$

$P = I^2 R = (12\ A)^2 \cdot \frac{(2.8 \times 10^{-8}\ \Omega m)(15\ m)}{\pi (0.001\ m)^2} = 19.2\ W$ A lot!

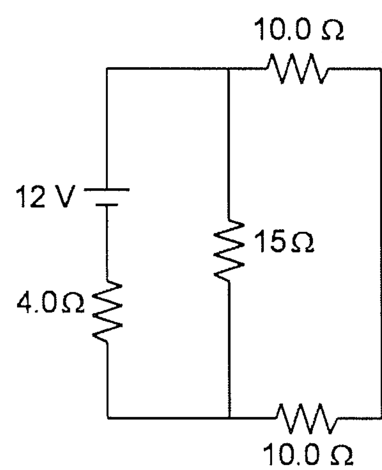
#3 on Version2

6. The digital multimeters you used in practicals can be set to either *voltmeter* mode, to measure voltage, or *ammeter* mode, to measure current. You have a battery which is currently illuminating a light bulb. You wish to use your multimeter to measure the voltage drop across this light bulb, or the current running through it. You should connect the multimeter to the light bulb in
   - A. series to measure voltage, in *voltmeter* mode, or parallel to measure current, in *ammeter* mode.
   - (B.) parallel to measure voltage, in *voltmeter* mode, or series to measure current, in *ammeter* mode.
   - C. series to measure voltage, in *voltmeter* mode, or series to measure current, in *ammeter* mode.
   - D. series to measure voltage, in *voltmeter* mode, or series to measure current, in *ammeter* mode.
   - E. series to measure voltage, in *voltmeter* mode, but you cannot use the multimeter to measure current.

See E&M Module 2, Activities 5 and 6.

#8 on Version2

7. What is the current being drawn through the battery of the circuit shown?
   - A. 0.31 A
   - (B) 0.95 A
   - C. 1.5 A
   - D. 4.4 A
   - E. 6.2 A



$\left(\frac{1}{15} + \frac{1}{20}\right)^{-1} = 8.575$

$R_{eq} = 12.57\ \Omega$

$I = \frac{V}{R_{eq}} = \frac{12}{12.57} = 0.95\ A$

#4 on Version2

8. An electric power line carries a steady current of 150 A toward the North. At a distance of 5 m below the wire, a golf-ball flies by, traveling directly West. The golf ball has a net negative charge on it. What is the direction of the magnetic force on the ball due to the current in the wire?
   - A. North
   - B. South
   - C. up
   - D. down
   - (E) the wire produces zero magnetic force on the ball

under: $\vec{B}$ is West

$\vec{B} \parallel \vec{v} \Rightarrow \vec{F}_B = 0$.

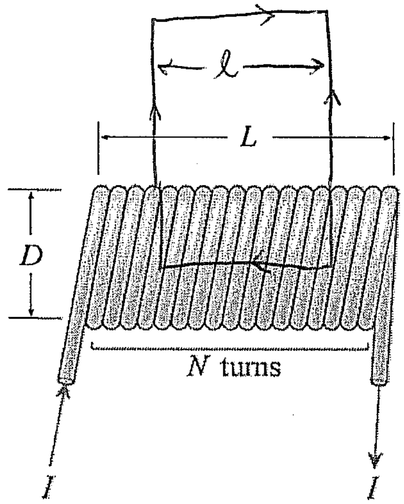
FREE-FORM IN TWO UNRELATED PARTS (12 points total)

Clearly show your reasoning and work as some part marks may be awarded. Write your final answers in the boxes provided.

PART A

A solenoid has length L, diameter D, and N turns, each carrying current I.

$l < L$ to ensure that $\vec{B}$ is perpendicular to vertical legs of the integration path.



~ Integration path (2 points)
Rectangle. $l < L$.
Clockwise direction shown so $\vec{B} \cdot d\vec{s}$ in loop is positive.

A1. (1 point) Assuming I is a positive number, what is the direction of the magnetic field at the centre of the solenoid? [Circle the best choice from the following six possibilities:]

UP DOWN (LEFT) RIGHT INTO-PAGE OUT-OF-PAGE

A2. (5 points) If L is much greater than D, then far from the ends of the solenoid, the magnetic field is axial, which means it is parallel to the axis of the solenoid. Assume L is much greater than D, and use Ampère's law to find the magnitude of the magnetic field at the centre of the solenoid, in terms of L, D, N, I and universal constants. Please add to the picture above a sketch of the integration path you are using in your line integral.

Ampère's Law: $\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{through}$

$Bl = \mu_0 I \times$ (number of loops in rectangle)

$n_{loops} = l \times$ number density $= \frac{lN}{L}$

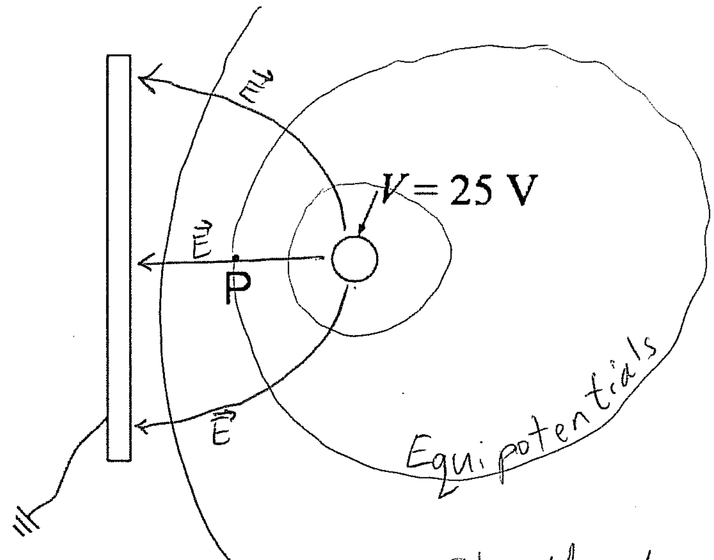
$Bl = \mu_0 I \left(\frac{lN}{L}\right)$

$$B = \frac{\mu_0 N I}{L}$$

(3 points)

PART B

A large, flat conducting plate is grounded, so that its electric potential is 0. A nearby small conducting sphere is held at an electric potential of 25 V. The shortest distance between the edge of the plate and the sphere is 6.0 cm. A mid-way point P is 3.0 cm away from the plate and 3.0 cm away from the sphere. The situation is shown from the side in the sketch below.



B1. (2 points) Estimate the electric potential at the point P. Should be about half-way between 0 and 25, or 12.5 V.

13 V ← to 2 sig figs.

B2. (1 point) What is the direction of the electric field at point P?
[Circle the best choice from the following six possibilities:]

(LEFT) RIGHT UP DOWN INTO-PAGE OUT-OF-PAGE

B3. (3 points) Estimate the magnitude of the electric field at point P.

$$|\vec{E}| \approx \frac{\Delta V}{\Delta x} = \frac{25\ V}{0.06\ m} = 420\ V/m$$

or $420\ N/C$ ← either unit is fine.