PHYSICS DEPARTMENT

PHY 2049, Spring 2008 Midterm II March 5, 2008

Name (print): ____________________ Signature: ____________________

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.

DIRECTIONS

(1) **Code your test number on your answer sheet (use 76–80 for the 5-digit number)**. Code your name on your answer sheet. **Darken circles completely (errors can occur if too light)**. Code your student 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. 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 with scratch work most questions demand.
(4) Work the questions in any order. Incorrect answers are not taken into account in any way; you may guess at answers you don't know. Guessing on all questions will most likely result in failure.
(5) If you think that none of the answers is correct, please choose the answer given that is closest to your answer.
(6) **Blacken the circle of your intended answer completely, using a number 2 pencil**. Do not make any stray marks or the answer sheet may not read properly. Completely erase all incorrect answers, or take a new answer sheet.
(7) As an aid to the examiner (and yourself), in case of poorly marked answer sheets, please circle your selected answer on the examination sheet. Please remember, however, that in the case of a disagreement, the answers on the bubble sheet count, NOT what you circle here.
(8) Good luck!!!

>>>>>>>>**WHEN YOU FINISH** <<<<<<<<
Hand in the answer sheet separately.

Constants: $e = 1.6 \times 10^{-19}\,C$ $m_p = 1.67 \times 10^{-27}\,kg$ $m_e = 9.1 \times 10^{-31} kg$
$\epsilon_o = 8.85 \times 10^{-12}\,C^2/N \cdot m^2$ $1/(4\pi\epsilon_o) = 9 \times 10^9\,N \cdot m^2/C^2$ $\mu_o = 4\pi \times 10^{-7} T \cdot m/A$
nano $= 10^{-9}$ micro $= 10^{-6}$

Coulomb's Law: $|\vec{F}| = \frac{|q_1||q_2|}{4\pi\epsilon_o r^2}$ (point charge)

Electric field: $\vec{E} = \frac{\vec{F}}{q}$ $\vec{E} = \frac{q}{4\pi\epsilon_o r^2}\hat{r}$ (point charge) $\vec{E} = \int \frac{dq}{4\pi\epsilon_o r^2}\hat{r}$ (general)

Gauss' law: $\Phi = \hat{n} \cdot \vec{E}\,A = \oint \hat{n} \cdot \vec{E}\,dA = \frac{q_{enc}}{\epsilon_o}$

Energy: $W = \int \vec{F} \cdot d\vec{s} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = K_f - K_i$

For conservative forces $U_f - U_i = -\int \vec{F} \cdot d\vec{s} \rightarrow K_i + U_i = K_f + U_f$

Electric potential: $V = \frac{U}{q}$ $V = \frac{q}{4\pi\epsilon_o r}$ (point charge) $V = \int \frac{dq}{4\pi\epsilon_o r}$ (general)

$V_b - V_a = -\int_a^b E_x dx = -\int_a^b \vec{E} \cdot d\vec{s}$ $E_x = -\frac{\partial V}{\partial x}$, $E_y = -\frac{\partial V}{\partial y}$, $E_z = -\frac{\partial V}{\partial z}$

Capacitors: $q = CV$ $C = \frac{\epsilon_o A}{d}$ (parallel-plate) $C = C_1 + C_2$ (parallel)
$U = \frac{q^2}{2C}$ $u = \frac{1}{2}\epsilon_o E^2$ $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$ (series)

Resistors: $i = \frac{dq}{dt} = jA$ $R = \frac{V}{i}$ $R = \frac{\rho L}{A}$ (wire) $P = iV$
$R = R_1 + R_2$ (series) $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ (parallel) $\tau_{RC} = RC$

Magnetism: $\vec{F} = q\vec{v} \times \vec{B}$ $\vec{F} = i\vec{L} \times \vec{B}$ $\mu = NiA$ $\vec{\tau} = \vec{\mu} \times \vec{B}$ $U = -\vec{\mu} \cdot \vec{B}$
$d\vec{B} = \frac{\mu_o}{4\pi}\frac{id\vec{s} \times \hat{r}}{r^2}$ $\oint \vec{B} \cdot d\vec{s} = \mu_o i_{enc}$ $B = \frac{\mu_o i}{2\pi R}$ (wire), $\frac{\mu_o i}{2R}$ (loop center), $\frac{\mu_o iN}{L}$ (solenoid)

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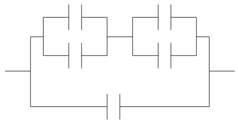
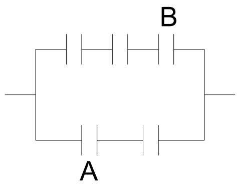
1. Assume that all the capacitors in the circuit at right have capacitance $C = 1\mu F$. What is the effective capacitance of this circuit?



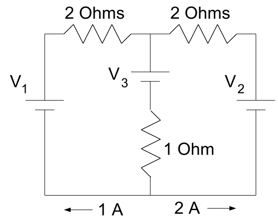
(1) 2μF (2) 1μF (3) 4μF (4) 5μF (5) 3μF

2. In the circuit at right all the capacitors have capacitance $C = 2\mu F$. If the charge on the capacitor marked A is $6\mu C$, what is the voltage across the capacitor marked B?



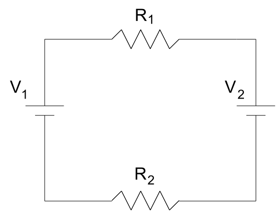
(1) 2 V (2) 3 V (3) 4 V (4) 6 V (5) 1 V

3. In the circuit at right what is $V_1 - V_3$?



(1) 5 V (2) 7 V (3) 6 V (4) 3 V (5) 4 V

4. In the circuit at right what is the current and direction of current flow if $V_1 = 3V$, $V_2 = 6V$, $R_1 = 1$ Ohm, and $R_2 = 2$ Ohm?



(1) 1A counterclockwise (2) 1A clockwise (3) 3A counterclockwise (4) 3A clockwise (5) 2A clockwise

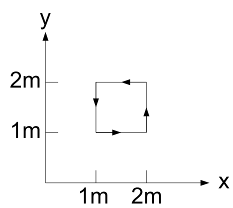
5. What is the resistance of a 60W light bulb connected to a 120V power supply?

(1) 240 Ω (2) 120 Ω (3) 60 Ω (4) 2 Ω (5) $4 \times 10^{-3}\Omega$

6. An electron moves with velocity $(2\hat{\imath} + 3\hat{\jmath})$ m/s in a uniform magnetic field of $(\hat{\imath} + 4\hat{\jmath})$ Tesla. What is the force on the electron due to the magnetic field?

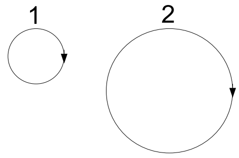
(1) $-8.0 \times 10^{-19}\hat{k}$ N (2) $8.0 \times 10^{-19}\hat{k}$ N (3) $17.6 \times 10^{-19}\hat{k}$ N (4) $-17.6 \times 10^{-19}\hat{k}$ N (5) $-22.4 \times 10^{-19}\hat{k}$ N

7. A square loop of wire in the x-y plane (see figure) has current $I = 0.5A$ flowing counterclockwise. If the magnetic field varies with position as $\vec{B} = x\hat{k}$ Tesla with x measured in meters, what is the net force on the wire? Hint: Compute the net force on each segment of the loop.



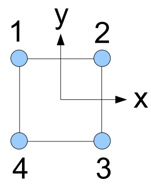
(1) $0.5\hat{\imath}$ N (2) $-0.5\hat{\imath}$ N (3) $1.5\hat{\imath}$ N (4) $-1.5\hat{\imath}$ N (5) $1.0\hat{\imath}$ N

8. As shown in the figure two identical charged particles with charge q and mass m travel in the plane of the page with a uniform magnetic field coming out of the page. Which of the following statement is true about their charge, q, and velocities, v_1 and v_2?



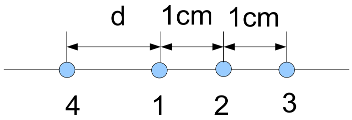
(1) $q > 0$ and $v_1 < v_2$ (2) $q < 0$ and $v_1 < v_2$ (3) $q < 0$ and $v_1 > v_2$ (4) $q > 0$ and $v_1 > v_2$ (5) $q = 0$ and $v_1 < v_2$

9. As shown in the figure, four wires have current flowing perpendicular to the plane of the page. The wires go through the corners of a square. If I_1 and I_2 have current I flowing out of the page, and I_3 and I_4 have current I flowing into the page, what is the direction of the magnetic field at the center of the square?



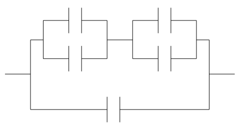
(1) $\hat{i}$ (2) $-\hat{i}$ (3) $\hat{j}$ (4) $-\hat{j}$ (5) $\hat{k}$

10. As shown in the figure, four wires carry current perpendicular to the plane of the page and are located in a line. All four wires carry the same magnitude of the current. If wires 1, 2, and 3 all have current going out of the page, what is d for wire 4 so that there is no net force on wire 1?



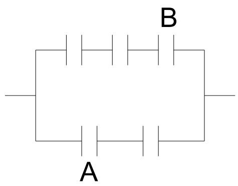
(1) 0.67 cm (2) 1.5 cm (3) 0.33 cm (4) 3 cm (5) 2 cm

11. Assume that all the capacitors in the circuit at right have capacitance $C = 2\mu F$. What is the effective capacitance of this circuit?



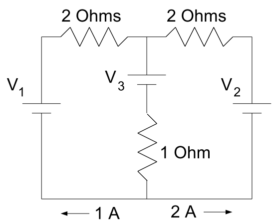
(1) 4μF (2) 1μF (3) 2μF (4) 5μF (5) 3μF

12. In the circuit at right all the capacitors have capacitance $C = 1\mu F$. If the charge on the capacitor marked A is $6\mu C$, what is the voltage across the capacitor marked B?



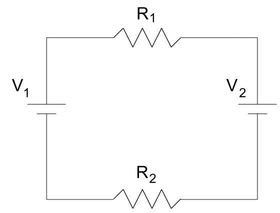
(1) 1 V (2) 3 V (3) 4 V (4) 6 V (5) 2 V

13. In the circuit at right what is $V_2 - V_3$?



(1) 7 V (2) 5 V (3) 6 V (4) 3 V (5) 4 V

14. In the circuit at right what is the current and direction of current flow if $V_1 = 6V$, $V_2 = 3V$, $R_1 = 1$ Ohm, and $R_2 = 2$ Ohm?

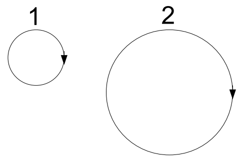


(1) 1A clockwise (2) 1A counterclockwise (3) 3A counterclockwise (4) 3A clockwise (5) 2A clockwise

15. A proton moves with velocity $(2\hat{\imath} + 3\hat{\jmath})$ m/s in a uniform magnetic field of $(\hat{\imath} + 4\hat{\jmath})$ Tesla. What is the force on the electron due to the magnetic field?

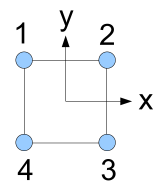
(1) $8.0 \times 10^{-19}\hat{k}$ N (2) $-8.0 \times 10^{-19}\hat{k}$ N (3) $17.6 \times 10^{-19}\hat{k}$ N (4) $-17.6 \times 10^{-19}\hat{k}$ N (5) $-22.4 \times 10^{-19}\hat{k}$ N

16. As shown in the figure two identical charged particles with charge q and mass m travel in the plane of the page with a uniform magnetic field going into the page. Which of the following statement is true about their charge, q, and velocities, v_1 and v_2?



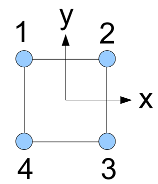
(1) $q < 0$ and $v_1 < v_2$ (2) $q > 0$ and $v_1 < v_2$ (3) $q < 0$ and $v_1 > v_2$ (4) $q > 0$ and $v_1 > v_2$ (5) $q = 0$ and $v_1 < v_2$

17. As shown in the figure, four wires have current flowing perpendicular to the plane of the page. The wires go through the corners of a square. If I_1 and I_2 have current I flowing into the page, and I_3 and I_4 have current I flowing out of the page, what is the direction of the magnetic field at the center of the square?



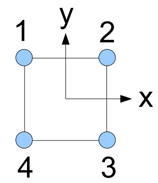
(1) $-\hat{\imath}$ (2) $\hat{\imath}$ (3) $\hat{\jmath}$ (4) $-\hat{\jmath}$ (5) $\hat{k}$

18. As shown in the figure, four wires have current flowing perpendicular to the plane of the page. The wires go through the corners of a square. If I_1 and I_4 have current I flowing out of the page, and I_2 and I_3 have current I flowing into the page, what is the direction of the magnetic field at the center of the square?



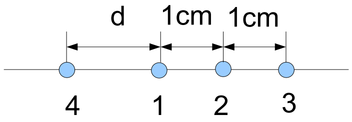
(1) $\hat{\jmath}$ (2) $-\hat{\jmath}$ (3) $\hat{\imath}$ (4) $-\hat{\imath}$ (5) $\hat{k}$

19. As shown in the figure, four wires have current flowing perpendicular to the plane of the page. The wires go through the corners of a square. If I_1 and I_4 have current I flowing into the page, and I_2 and I_3 have current I flowing out of the page, what is the direction of the magnetic field at the center of the square?



(1) $-\hat{\jmath}$ (2) $\hat{\jmath}$ (3) $\hat{\imath}$ (4) $-\hat{\imath}$ (5) $\hat{k}$

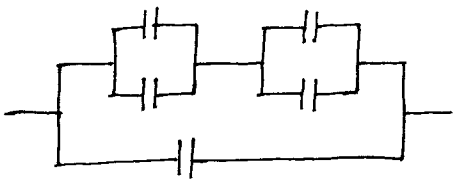
20. As shown in the figure, four wires carry current perpendicular to the plane of the page and are located in a line. All four wires carry the same magnitude of the current. If wires 1 and 2 have current going out of the page and wire 3 has current going into the page, what is d for wire 4 so that there is no net force on wire 1?



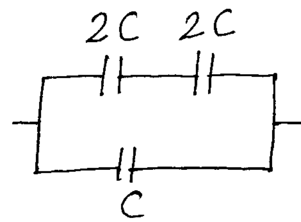
(1) 2 cm (2) 1.5 cm (3) 0.33 cm (4) 3 cm (5) 0.67 cm

FOLLOWING GROUPS OF QUESTIONS WILL BE SELECTED AS ONE GROUP FROM EACH TYPE
TYPE 1
Q# S 1
Q# S 2
TYPE 2
Q# S 3
Q# S 4
TYPE 3
Q# S 5
Q# S 6
TYPE 4
Q# S 7
Q# S 8
TYPE 5
Q# S 10
Q# S 11
TYPE 6
Q# S 13
Q# S 14
TYPE 7
Q# S 15
Q# S 16
Q# S 17
Q# S 18
TYPE 8
Q# S 19
Q# S 20

Exam 2 Solution

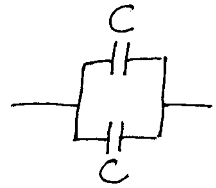


is equivalent to



,

which in turn is equivalent to



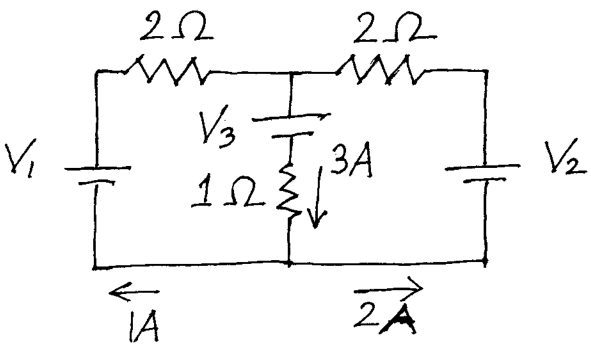
.

$\Rightarrow C_{eff} = 2C$. $\begin{cases} \text{For } C = 1\mu F, & C_{eff} = 2\mu F. \\ \text{For } C = 2\mu F, & C_{eff} = 4\mu F. \end{cases}$

The voltage across capacitor A is Q_A/C Thus, the voltage across the entire circuit is $2Q_A/C$ This voltage drop is divided equally between the top 3 capacitors. $\rightarrow$

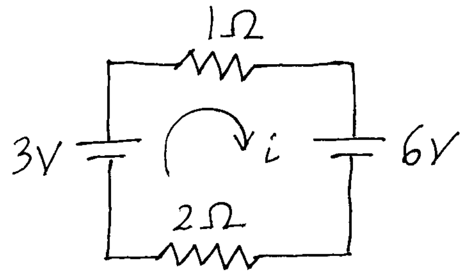
$$V_B = \frac{1}{3}\frac{2Q_A}{C} = \begin{cases} 2V \text{ for } C = 2\mu F \\ 4V \text{ for } C = 1\mu F \end{cases}$$

Alternately, the top 3 capacitors have effective capacitance $\frac{C}{3}$ $\rightarrow$ $Q_B = \left(\frac{C}{3}\right)\left(\frac{2Q_A}{C}\right) = \frac{2}{3}Q_A \rightarrow V_B = \frac{2}{3}\frac{Q_A}{C}$.



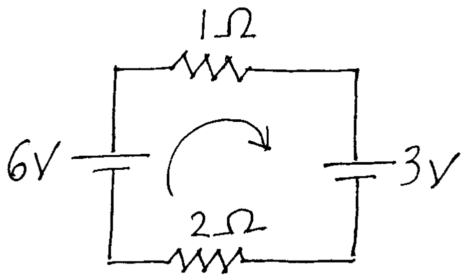
left loop: $0 = V_1 - 2\Omega(1A) - V_3 - 3A(1\Omega) \rightarrow V_1 - V_3 = 5V$

right loop: $0 = V_2 - 2\Omega(2A) - V_3 - 1\Omega(3A) \rightarrow V_2 - V_3 = 7V$



$$0 = 3V - 1\Omega(i) - 6V - 2\Omega(i)$$

$\rightarrow i = -1A$, i.e. 1A counterclockwise



$$0 = 6V - 1\Omega(i) - 3V - 2\Omega(i)$$

$\rightarrow i = 1A$, i.e. 1A clockwise

$$\text{Power} = \frac{V^2}{R} = 60\,W = \frac{(120V)^2}{R} \rightarrow R = 240\Omega$$

$\vec{v} = (2\hat{i} + 3\hat{j})\frac{m}{s}$, $\vec{B} = (\hat{i} + 4\hat{j})T$, $q = -1.6\times10^{-19}C$ (electron)

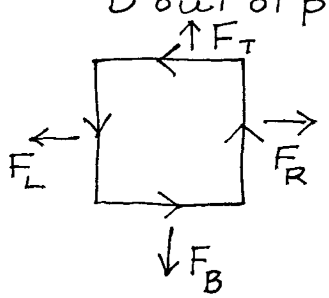
$$\rightarrow \vec{F} = (-1.6\times10^{-19}C)(2\hat{i} + 3\hat{j})\frac{m}{s} \times (\hat{i} + 4\hat{j})T$$

$$= (-1.6\times10^{-19})(8\hat{k} - 3\hat{k})N$$

$$= -8\times10^{-19}\hat{k}\,N$$

For a proton, $\vec{F} = 8\times10^{-19}\hat{k}\,N$.

B out of page ($\hat{k}$ direction)

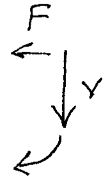


Because $\vec{B}$ only depends on x, $\vec{F}_T + \vec{F}_B = 0$. The other two forces are: $\vec{F}_R = i\vec{L}\times\vec{B} = (0.5A)(1m\,\hat{j})\times(2\hat{k}T) = \hat{i}\,N$

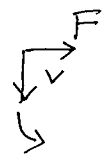
$$\vec{F}_L = i\vec{L}\times\vec{B} = (0.5A)(-1m\hat{j})\times(1\hat{k}T) = -\frac{1}{2}\hat{i}\,N$$

$$\Rightarrow \vec{F}_{net} = \frac{1}{2}\hat{i}\,N.$$

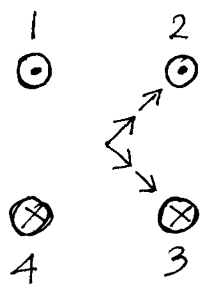
B out of page:

If $q > 0$,  implying clockwise rotation. $\rightarrow q > 0$ in exam

B into page:

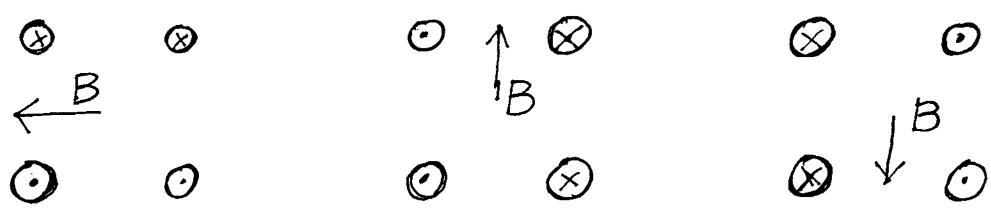
If $q > 0$,  implying counterclockwise rotation. $\rightarrow q < 0$ in exam

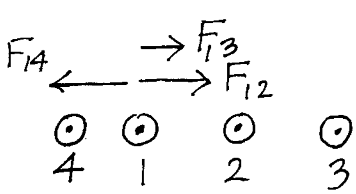
In both cases $v_1 < v_2$ because $r_1 < r_2$ and $\frac{v}{r} = \frac{qB}{m}$.



net $\vec{B}$ in $\hat{i}$ direction

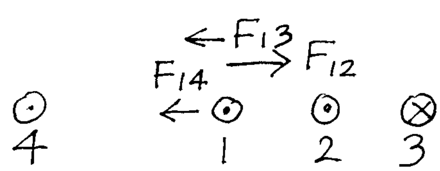
The other cases are





$$\frac{\mu_0 i^2}{d} = \frac{\mu_0 i^2}{1\,cm} + \frac{\mu_0 i^2}{2m}$$

$\rightarrow d = \frac{2}{3}\,cm$



$$\frac{\mu_0 i^2}{d} = \frac{\mu_0 i^2}{1\,cm} - \frac{\mu_0 i^2}{2\,cm}$$

$\rightarrow d = 2\,cm$