Mid-term Exam 1: PHYSICS 1C (Winter 2018)

Time: 2:00PM – 3:00PM, February 5, 2018, Instructor: Prof. Zhongbo Kang

Student Name: __

Student I.D. Number: ______________

Exam Version: **D**

Note:

- The exam is closed book, and closed notes.
- You can use a calculator. However, using a smart phone is NOT allowed.
- One page of physical equations is provided.
- Remember to write down each step of your calculations.

Score Sheet:

Problem 1 (10 points): 10

Problem 2 (10 points): 10

Problem 3 (10 points): 10

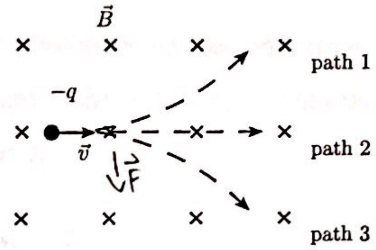
Problem 4 (10 points): 10

Problem 5 (10 points): 9

Total (50 points): 49

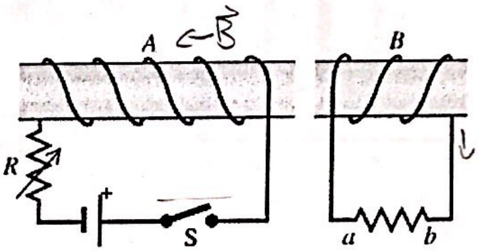
Problem 1 (10 pts):

(a) (3 pts) As shown in the figure on the right, a uniform magnetic field $\vec{B}$ is directed into the plane of the paper (shown as the cross). A particle with a negative charge moves in the plane. Which path does the particle follow? Your choice: A



a. path 3 b. path 2 c. path 1

(b) (3 pts) Please determine the direction of the current in resistor ab of the figure when switch S is opened after having been closed for several minutes. Your choice: A

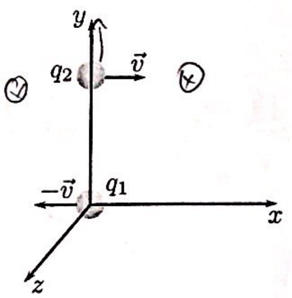


a. From point b to a

b. From point a to b

c. Cannot be determined, not enough information

(c) (4 pts) In the figure, two positive charges q_1 and q_2 move at the same speed v, but in the opposite direction. q_1 is moving along $-x$, while q_2 is along $+x$ direction. Determine the direction of the electric force F_E and magnetic force F_B on the upper charge q_2. Your choice: B



a. both along $-y$ b. both along $+y$ c. F_E is $+y$, F_B is $-y$

d. F_E is $-y$, F_B is $+y$ e. F_E is $+y$, F_B is $+z$ f. F_E is $+y$, F_B is $-z$

g. none of the above

$F_e = +y$

$F_b +y$

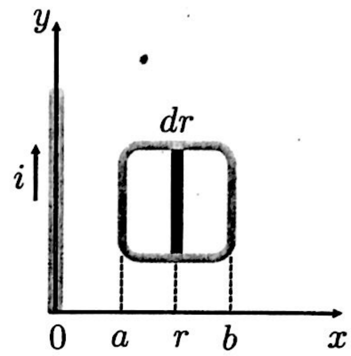
Problem 2 (10 pts)

A long, straight wire shown in the figure carries a current i, along $+y$ direction. At the same time, in the x-y plane, we have a conducting square loop with length L. Answer the following questions (Note: express your results in terms of given variables, i.e., a, b, r, dr, L, i.)

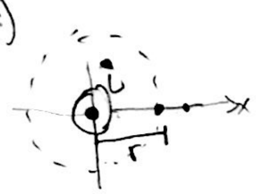
(a) (2 pts) What is the magnitude and direction of the magnetic field at a distance r to the right of the wire?

(b) (4 pts) What is the magnetic field flux $d\Phi_B$ through the narrow, shaded strip (the width of the strip is dr)?

(c) (4 pts) What is the total magnetic flux through the loop?



a)



$\int \vec{B}\cdot d\vec{l} = \mu_0 I_{enc}$

$B\int dl = \mu_0 I_{enc}$ $\quad B 2\pi r = \mu_0 I_{enc}$

$\vec{B} = \frac{\mu_0 I}{2\pi r}$ [into the page] ✓

$\vec{B} = -\frac{\mu_0 I}{2\pi r}\hat{k}$ ✓

b) $d\Phi_B = B\,dA\cos\phi = \frac{\mu_0 I L\,dr}{2\pi r}$ ✓ $\quad dA = L\,dr$

$\phi = 0$

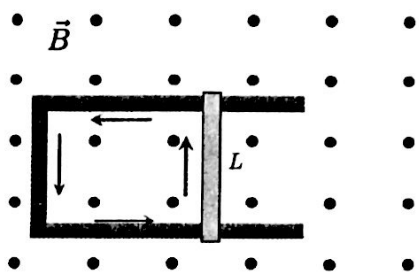
c) $\Phi_B = \int_a^b \frac{\mu_0 I L\,dr}{2\pi r} = \frac{\mu_0 I L}{2\pi}\int_a^b \frac{dr}{r} = \frac{\mu_0 I L}{2\pi}(\ln|b| - \ln|a|) = \frac{\mu_0 I L}{2\pi}\ln\left(\frac{b}{a}\right)$ ✓

Problem 3 (10 pts)

$L = 0.45\text{m}$

A conducting bar with mass m = 15 kg and length L = 45 cm slides over horizontal rails that are connected to a voltage source (imagine the plane of the figure is on a horizontal surface). The voltage source maintains a constant current I = 1800 A in the rails and bar. A constant, uniform magnetic field B = 0.90 T fills the region between the rails (directed out of the plane).

(a) (5 pts) Find the magnitude and the direction of the net force on the conducting bar. Note: calculate the final numerical value.



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(b) (5 pts) Find the distance d that the bar must move along the rails from rest to attain speed v = 10 km/s. Note: calculate the final numerical value.

$m = 15\text{kg}$ $L = 0.45\text{m}$ $I = 1800\text{A}$ $B = 0.90\text{T}$

a)

$\theta = 90°$

$F = BIL\sin\theta = BIL = (0.90\text{T})(1800\text{A})(0.45\text{m}) = \boxed{7.29\times10^2 \text{ N [Right]}}$ ✓

b)

$F = ma$ $\quad 729\text{N} = (15\text{kg})a \quad a = 48.6 \text{ m/s}^2$

$V_f = 10{,}000 \text{ m/s} \quad V_0 = 0 \text{ m/s}$

$V_f^2 = \cancel{V_0^2} + 2ad$

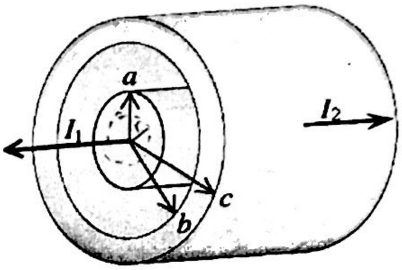
$\frac{V_f^2}{2a} = d = \frac{(10{,}000 \text{ m/s})^2}{2(48.6 \text{ m/s}^2)} = \boxed{1.03\times10^6 \text{ m}}$ ✓

Problem 4 (10 pts)

A solid conductor with radius a is supported by insulating disks on the axis of a conducting tube with inner radius b and outer radius c, see the figure. The central conductor and tube carry currents I_1 and I_2 correspondingly in the opposite direction. The currents are distributed uniformly over the cross sections of each conductor. Derive an expression for the magnitude of the magnetic field at the following points. Express your answer in terms of the given variables I_1, I_2, r, a, b, c.

(a) (4 pts) at points inside the central, solid conductor, i.e., $0 < r < a$.

(b) (3 pts) at points outside the central, solid conductor but inside the tube, i.e., $a < r < b$.



(c) (3 pts) at points outside the tube, i.e., $r > c$.

a) $0<r<a$

$J = \frac{I}{A}$ $J = \frac{I_1}{\pi a^2}$ $i = JA = J\pi r^2 = \frac{I_1}{\pi a^2}\pi r^2 = \frac{I_1 r^2}{a^2}$

$\int \vec{B}\cdot d\vec{l} = \mu_0 i$ $B\int dl = \mu_0 i$ $B 2\pi r = \frac{\mu_0 I_1 r^2}{a^2}$ $\boxed{B = \frac{\mu_0 I_1 r}{2\pi a^2}}$ ✓

b) $a<r<b$

$\int \vec{B}\cdot d\vec{l} = \mu_0 I_1$ $B\int dl = \mu_0 I_1$ $B 2\pi r = \mu_0 I_1$ $\boxed{B = \frac{\mu_0 I_1}{2\pi r}}$ ✓

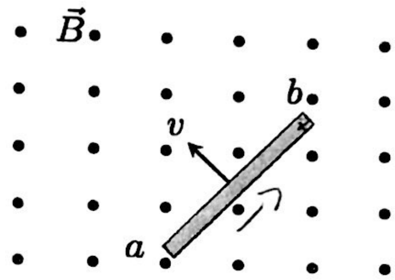
c) $\int \vec{B}\cdot d\vec{l} = \mu_0 I_{enc}$ $B\int dl = \mu_0 |I_1 - I_2|$ $\boxed{B = \frac{\mu_0 |I_1 - I_2|}{2\pi r}}$ ✓

$I_{enc} = |I_1 - I_2|$

Problem 5 (10 pts)

A conducting rod of length $L = 15.0$ cm moves in a magnetic field $\vec{B}$ of magnitude 0.550 T directed out of the plane, as shown in the dots in the figure. The rod moves with speed $v = 9.00$ m/s in the direction shown.

4 (a) (4 pts) What is the potential difference between the ends of the rod? Which point, *a* or *b*, is at higher potential?



2 (b) (3 pts) When the charges in the rod are in equilibrium, what are the magnitude and direction of the electric field within the rod?

3 (c) (3 pts) What is the potential difference across the rod if it moves parallel to *ab*?

$L = 0.15$m   0.550 T $v = 9$ m/s

a) $\mathcal{E} = BLv = (0.550T)(0.15m)(9.00 m/s) = $ [0.743V] ✓

[Point b is at higher potential], as the emf is directed towards point b and the positive charges inside the rod have a magnetic force towards point b.

b) $\mathcal{E} = V = \int \vec{E} \cdot d\vec{l}$ $0.743V = \int E\,dl = E(0.15m)$ [$E = 4.95 \frac{V}{m}$ [~~towards~~ b]] ✓

c) $\mathcal{E} = BLv = $ [0V]

$L \approx 0$ v. Since the width of the rod is essentially 0.