Name: Key

Midterm Exam 2, February 28, 2017 Physics 152-000

THE HONOR CODE IS IN EFFECT FOR THIS EXAM – IT IS YOUR RESPONSIBILITY TO HELP MAINTAIN HONESTY AND FAIRNESS.

Instructions:

1. When told to begin, please write your name on the top of every page.
2. **Write neatly and show your solution methods clearly**.
3. You will be graded on how you got your answers. Little or no credit will be given for answers that do not show how you got them.
4. Partial credit will be given if you have minor errors, but not for answers that incorrectly solve the problem.
5. Do your work for each problem on the page for that problem.
6. Point totals are noted by each question.
7. This exam is closed book and closed notes. You may use the summary sheets I provided.
8. You have up to 75 minutes to complete this exam.
9. You must stop and turn in your exam when I announce the exam is over.

Good Luck!

****

Emory Honor Pledge:

I, ______________________**(print name)**, by signing this examination, acknowledge that I have abided by the provisions and spirit of the **EMORY COLLEGE HONOR CODE** in my completion of this examination. This exam represents my own work, and I have neither given or received aid in completing this exam.

Signature:______________________

****

1.	**2.**	**3.**	**4.**	**Total:**
out of 25	**out of 20**	**out of 25**	**out of 30**	**Out of 100**

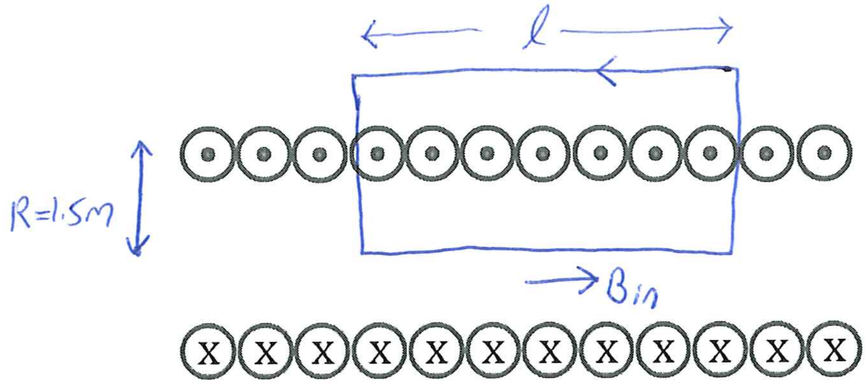
Name:______________________________________

Permittivity constant	$\varepsilon_0 = 8.854 \times 10^{-12}\ C^2 / N\ m^2$ $k = 8.99 \times 10^9\ N\ m^2 / C^2$
Permeability of free space	$\mu_0 = 4\pi \cdot 10^{-7}\ T \cdot m/Amp$
Elementary charge	$e = 1.602 \times 10^{-19}\ C$
Electron mass	$m_e = 9.109 \times 10^{-31}$ kg
Proton mass	$m_p = 1.673 \times 10^{-27}$ kg
Neutron mass	$m_n = 1.675 \times 10^{-27}$ kg

circumference of a circle	$2 \pi r$	1 km = 10^3 m
area of a circle	πr^2	1 mm = 10^{-3} m
surface area of sphere	$4 \pi r^2$	1 μm = 10^{-6} m
volume of a sphere	$4/3 \pi r^3$	1 nm = 10^{-9} m
volume of a cylinder	$\pi r^2 L$	
area of a triangle	½ base x height	

Name: Key

1) A section of an infinite ideal cylindrical solenoid (of radius R=1.5 meters) is measured to have a total of N=20000 turns in a length L=200 cm. A current of 3 amps runs in the solenoid wire. The diagram below shows a section of the solenoid (in cross section) with the axis of the solenoid from left to right (dots and x's represent current out of and into the page, respectively).



a. On the diagram, draw an Amperian loop that will allow you to calculate the magnetic field inside of the solenoid, B_{in}, and use the right hand rule to draw an arrow specifying the direction of B_{in}. (5 points)

b. Assuming the cylinder is ideal and infinitely long, what is the magnitude of the magnetic field outside of the solenoid? (5 points)

Zero

c. Apply Ampere's Law to find B_{in}. You should solve for a numerical value. (5 points)

$$\int B \cdot dl = B_{in} l = \mu_0 I_{encl} = \mu_0 l \frac{N}{L} I$$

$$B_{in} = \frac{\mu_0 N I}{L} = 4\pi \times 10^{-7} \frac{T \cdot m}{Amp} \cdot \frac{20{,}000}{2\,m} \cdot 3\,Amp$$

$$= .038\,T$$

d. A planer square loop of side length 40 cm is positioned inside of the solenoid such that the plane of the loop is perpendicular to B_{in} (i.e. oriented to maximize the flux of B). What is the flux of B (magnetic flux) through the loop? (5 points)

$$\Phi_B = B \cdot A = (.038\,T)(.4\,m)^2 = .006\ T \cdot m^2$$

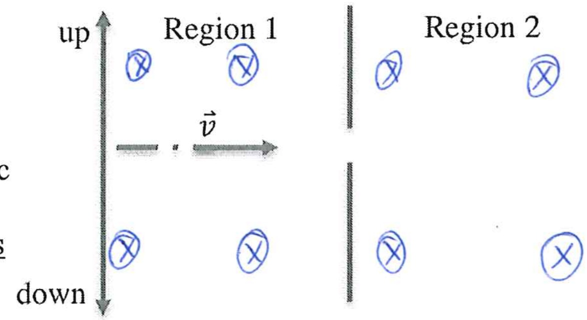
e. The square planer loop is then flipped 180 degrees (to face the opposite direction) over the course of 3 seconds. What is the average induced EMF in the square loop? (5 points)

$$Emf = -\frac{\Delta\Phi}{\Delta t} = \frac{2\Phi_B}{\Delta t} = \frac{2 \times .006\ T \cdot m^2}{3\ sec} = 4\,mV$$

$$[T] = \frac{N}{Amp \cdot m} \cdot \frac{m^2}{s} = \frac{N \cdot m}{coul} = Volts$$

Name: Key

2) Both gravity (down) and a uniform B field of 0.1 T (into the page) exist throughout both regions I and II of the velocity selector shown in the diagram. A uniform electric field exists in Region I only. A particle of weight 10^{-3} N, charge $3x10^{-9}$ C, and constant velocity of 10^7 m/sec travels in a straight line through Region I.



a) Determine the magnitude and direction (state as: "up" or "down") of the electric field, $\vec{E}$, in Region I. (Do **not** neglect gravity) [Hint: a free body diagram might help] (10 points)

$$qvB + qE - mg = 0$$

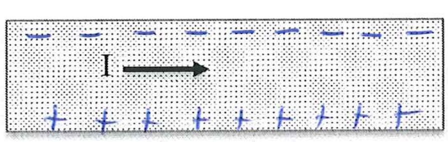
$$qE = mg - qvB = 10^{-3}N - (3\times10^{-9}C)\,10^{7}\,m/s\cdot(0.1T)$$

$$= 10^{-3}N - 3\times10^{-3}N = -2\times10^{-3}N$$

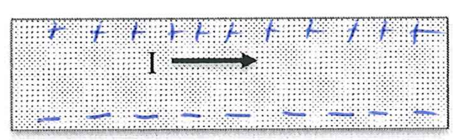
$$E = \frac{-2\times10^{-3}N}{3\times10^{-9}Coul} = -6.7\times10^{5}\,N/C$$

Since $|E| < 0 \Rightarrow E$ points down

b) The Hall Effect is an important experiment that can be used to determine the sign (+ or -) of the mobile charge carriers. In the two thin film wires shown below, the current is to the right and the magnetic field, **B, is oriented out of the page**. For each diagram below, you are to illustrate (using multiple + and – symbols) which edge of the film accumulates a net positive charge and which accumulates a net negative charge. Your drawings should make clear how the charge distribution is different for the two cases. (5 points)



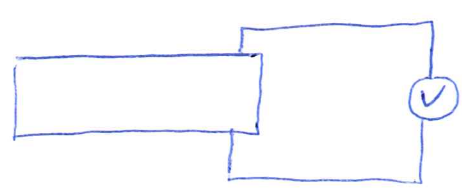
(positive charges moving right)



(negative charges moving left)

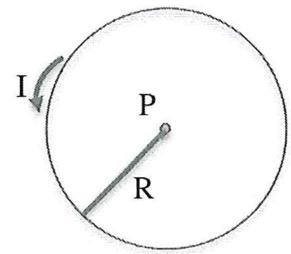
c) What experimental quantity would you measure to determine which of the above Hall Effect scenarios applies for a given material, i.e. what is the sign of the mobile charge carriers? In other words, since we can't "see" which surface has which sign charges, what easily measurable quantity would tell us that information? (5 points)

Measure the Hall Voltage, i.e. the voltage difference between top and bottom edges.



Name: Key

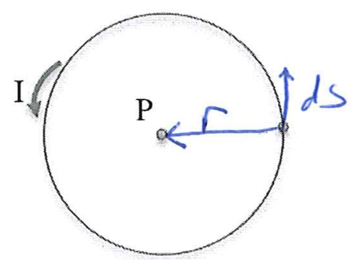
3) A plane circular loop of radius R carries a counterclockwise current, I, as shown.



a. What direction does the B-field point at the center of the loop (point P) in the plane of the loop? Select an answer: (5 points)

   i. Into the page
   ii. Out of the page
   iii. Towards the top of the page
   iv. Towards the bottom of the page
   v. To the right
   vi. To the left

b. You are going to use the Biot-Savart law to find the B-field in the plane of the loop at its center (point P). To get started, draw and label arrows representing the vectors $d\vec{s}$ and $\vec{r}$ on the diagram below for the location marked (with a dot) on the right edge of the loop. (6 points)



c. Use the Biot-Savart law to find the B-field in the plane of the loop at its center (point P). (14 points)

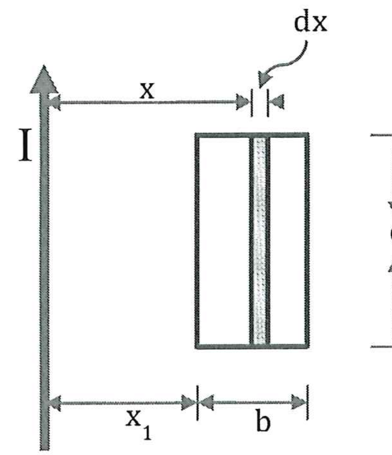
$$dB = \frac{\mu_0}{4\pi} I \frac{d\vec{s} \times \hat{r}}{r^2} = \frac{\mu_0 I}{4\pi} \frac{ds}{R^2} \text{ out of the page}$$

$$B = \int dB = \frac{\mu_0 I}{4\pi R^2} \int ds = \frac{\mu_0 I}{4\pi R^2} \cdot 2\pi R$$

$$\boxed{B = \frac{\mu_0 I}{2R}}$$

Name: Key

4) A rectangular loop is coplanar with, and has two sides parallel to, an infinite straight wire which carries a current I. Dimensions are given in the figure.



a. Use Ampere's Law to find the magnetic field from the infinite straight wire in the region of the loop (as a function of x)? Specify magnitude and direction. (5 points)

$$\oint B \cdot dl = \mu_0 I_{encl}$$

$$B \cdot 2\pi r = \mu_0 I$$

$$B = \frac{\mu_0 I}{2\pi r} \quad \text{or} \quad \frac{\mu_0 I}{2\pi X}$$

b. Find the magnetic flux, $\int \vec{B} \cdot d\vec{A}$, through the small shaded area. Be sure to use the specific notation from the figure. (5 points)

B is constant for shaded area. $\Rightarrow \int B \cdot dA = BA$

$$\Phi_B = \frac{\mu_0 I}{2\pi X} \cdot c\, dX$$

must be x, not r!

c. Find the magnetic flux through the full loop. (This requires a simple integral. If you do not know how to evaluate the integral then at least set it up clearly, including limits of integration. (10 points)

$$\Phi_B = \frac{\mu_0 I c}{2\pi} \int_{x_1}^{x_1+b} \frac{dx}{x} = \frac{\mu_0 I c}{2\pi} \ln x \Big]_{x_1}^{x_1+b} = \frac{\mu_0 I c}{2\pi}\left[\ln(x_1+b) - \ln x_1\right]$$

$$= \frac{\mu_0 I c}{2\pi} \ln \frac{x_1+b}{x_1}$$

d. The loop is moved rigidly along the direction of the current (shape of the loop and distance from infinite wire do not change). Will a current be induced in the loop? If so, find the direction of the induced current using Lenz's Law. (answer clockwise or counterclockwise, or draw the loop with an arrow to specify the direction of the induced current) (5 points)

$\Delta \Phi_B = 0 \Rightarrow$ no current.

e. The loop is moved rigidly straight toward the wire with constant velocity v (x1 decreases with time.) Will a current be induced in the loop? If so, find the direction of the induced current using Lenz's Law. (answer clockwise or counterclockwise, or draw the loop with an arrow to specify the direction) (5 points)

yes. Φ_B increases, $\Rightarrow$ induced current creates B pointing out of the page, which requires counterclockwise current