Name ___________________________________ **Student ID Number** ____________

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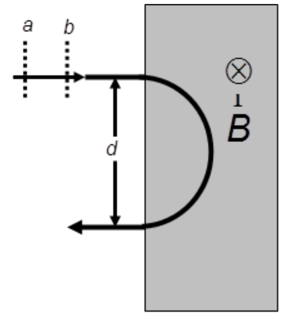
Part I. Lecture Multiple Choice (43 points total)



The next two questions pertain to the situation described below.
A charged particle is accelerated through a potential difference from *a* to *b.* The particle then enters a uniform magnetic field B directed into the plane of the paper. While in this magnetic field, the particle travels in a semicircle of diameter *d*.

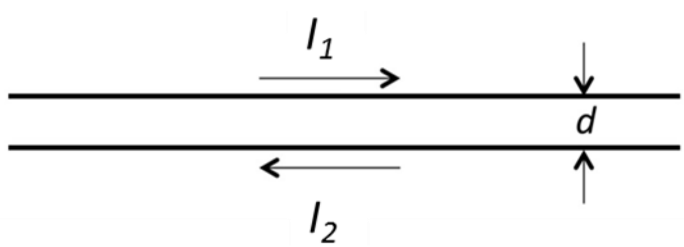
1. (4 pts.) If we were to double the magnitude of the potential difference between *a* and *b*, what would happen to the diameter *d*?

A. *d* would double
B. *d* would increase by a factor of $\sqrt{2}$
C. *d* would stay the same
D. *d* would quadruple

2. (4 pts.) Let *T* be the amount of time the particle is in the shaded region that contains the magnetic field. If we were to double the particle velocity as it enters the field, what would happen to *T*?

A. *T* would double
B. *T* would increase by a factor of $\sqrt{2}$
C. *T* would stay the same
D. *T* would quadruple

This figure is used for the next two problems



3. (5 pts) Two thin wires carry currents I_1 = 1.5 A, and I_2= 3.4 A, as shown. They are separated by a distance d = 0.003 m. What is the force per unit length on the lower wire?

A. 1.0×10^{-4} N/m
B. 1.5×10^{-4} N/m
C. 3.4×10^{-4} N/m
D. 7.7×10^{-4} N/m
E. 4.3×10^{-3} N/m

4. (4 pts) Suppose an electron was shot into the page at a location exactly between the two wires; that is, d/2 above the bottom wire. Which way would the electron be deflected when it is in the plane of the wires?

A. Up
B. Down
C. Left
D. Right
E. It would not be deflected

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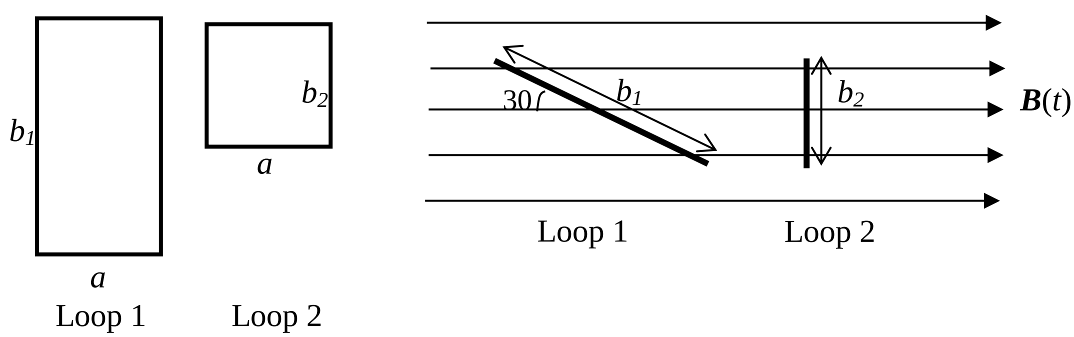
5. (5 pts.) A beam of electrons (q = -1.6 x 10^{-19} C) is moving through a region of space in which there is an electric field of intensity 3.4 x 10^4 V/m and a magnetic field of 2.0 x 10^{-3} T. The electric and magnetic fields are so oriented that the beam of electrons is not deflected. The velocity of the electrons is approximately

A. 6.8 x 10^6 m/s
B. 3.0 x 10^8 m/s
C. 6.0 x 10^{-9} m/s
D. 0.68 x 10^3 m/s
E. 1.7 x 10^7 m/s

The following two questions refer to the figure below:
Two rectangular loops are placed at different angles in a spatially uniform but time-dependent magnetic field $\boldsymbol{B}(t)$ as shown in the figure below. In the figure with the magnetic field, the loops appear in profile. The side that is perpendicular to the page is $\boldsymbol{a}$ for both loops. The side that is parallel to the page is $\boldsymbol{b_1}$ for loop 1 and $\boldsymbol{b_2}$ for loop 2.



6. (4 pts) If $b_1 = 2\, b_2$, the induced emf

A. is greater in loop 1.
B. is greater in loop 2.
C. is the same in both cases

7. (5 pts) Let R_2 = 2 Ω be the resistance of loop 2 and $B = B_0 \exp(-t/\tau)$. For a = 1 cm, b_2 = 2.5 cm, B_0 = 2 mT, τ = 3 μs, find the induced current in **loop 2** at t = 6 μs.

A. $I_2(t = 6\ \mu s)$ = 10.45 mA
B. $I_2(t = 6\ \mu s)$ = 11.28 mA
C. $I_2(t = 6\ \mu s)$ = 13.20 mA
D. $I_2(t = 6\ \mu s)$ = 14.93 mA
E. $I_2(t = 6\ \mu s)$ = 16.07 mA

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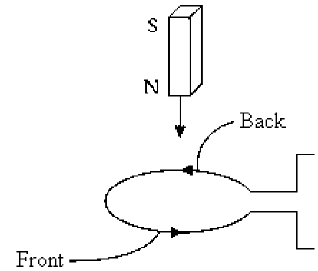
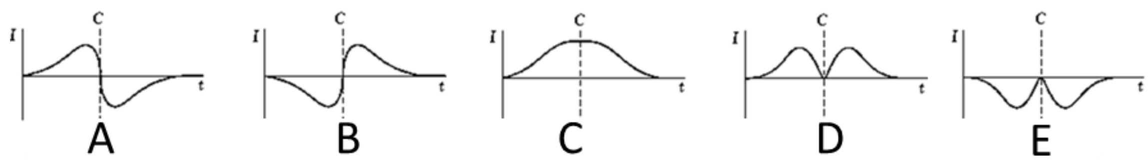
8. (4 pts) A bar magnet is dropped through a loop of copper wire as shown.

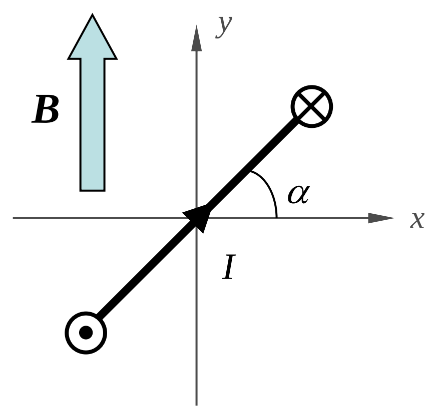


If the positive direction of the induced current I in the loop is as shown by the arrows on the loop, the variation of I with time as the bar magnet falls through the loop is illustrated qualitatively by which of the following graphs? (The time when the midpoint of the magnet passes through the loop is indicated by *C*.)



The next 2 questions refer to the situation described below:

The figure at right depicts a square wire coil which is situated in a region of constant magnetic field ***B*** pointing in the +*y* direction. A current *I* flows in the coil in the direction shown (the black arrowhead indicates the current direction on the side of the square nearest you.) The square coil makes an angle of α with the *xz*-plane.



9. (3 pts) At which angle α does the coil have the <u>lowest</u> potential energy?

A. $\alpha = 0°$
B. $\alpha = 90°$
C. $\alpha = 180°$

10. (5 pts) If the square coil has a magnetic dipole moment $\mu = 35$ A·m^2 and the magnitude of the magnetic field is $B = 0.2$ T, how much work must be done <u>by you</u> to rotate the coil from $\alpha = 30°$ to $\alpha = 0°$?

A. $W = -6.06$ J
B. $W = -3.50$ J
C. $W = -0.94$ J
D. $W = +0.94$ J
E. $W = +6.06$ J

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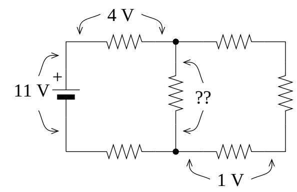
II. Lab questions [12 pts] **<u>ENTER ALL CHOICES ON YOUR SCANTRON SHEET</u>**

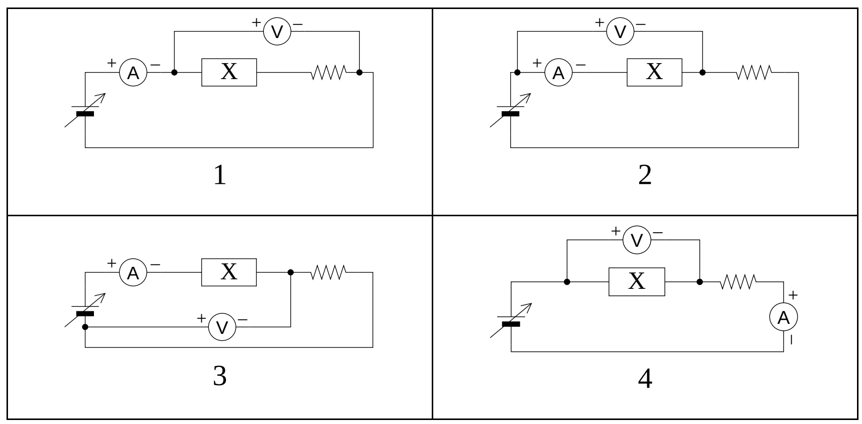
11. [4 pts] In the circuit at right, all resistors are identical. What is the value of the unknown voltage, labeled "**??**"

(A) 1 V (B) 2 V (C) 3 V (D) 4 V (E) 11 V

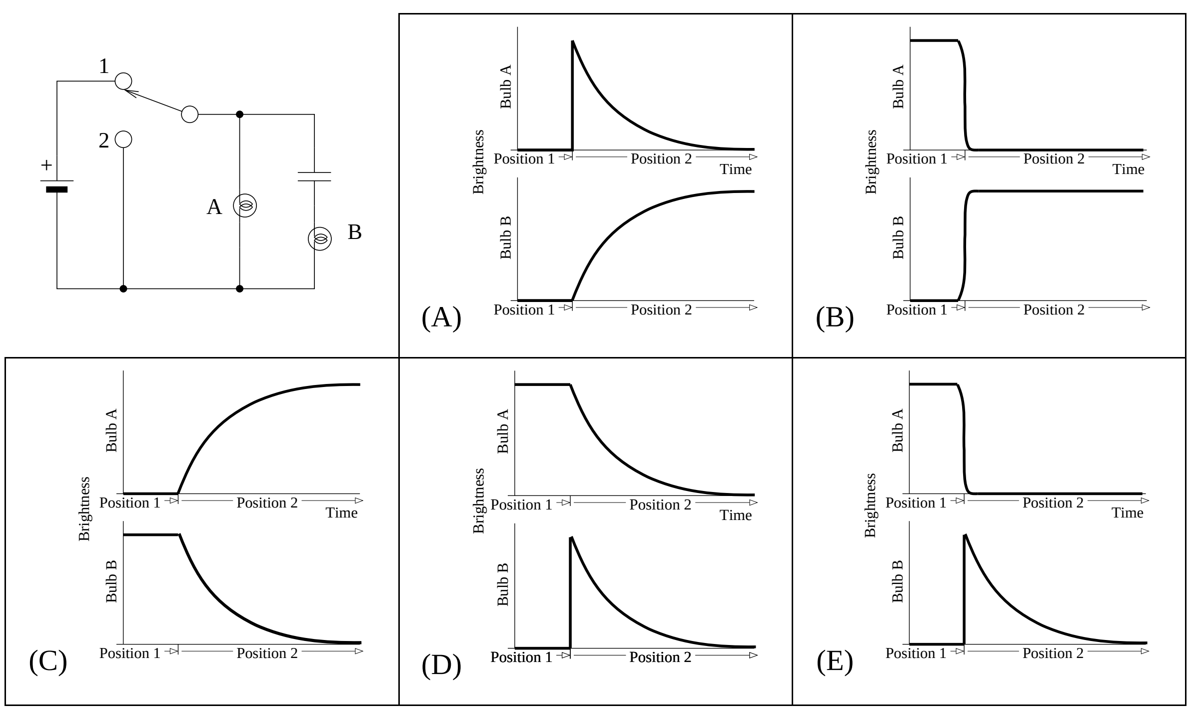


12. [4 pts] Assume you have an ***ideal ammeter and an ideal voltmeter***. You <u>do not know</u> the value of the resistor or the voltage produced by the variable voltage source (the battery symbol with an arrow). Which circuits shown below would allow you to measure the *I*-*V* curve of the unknown element X?

(A) 1
(B) 1 or 2
(C) 1 or 3
(D) 2 or 4
(E) 2, 3 or 4



13. [4 pts] Initially, the switch in the circuit below left has been in position 1 a long time. Then it is flipped to position 2. The graphs show the brightness of bulbs A and B before and after the switch is flipped. Which one is correct?



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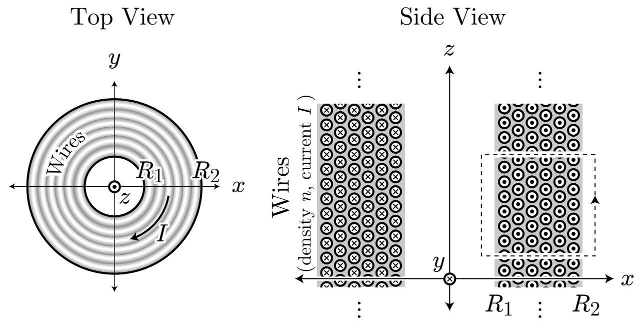
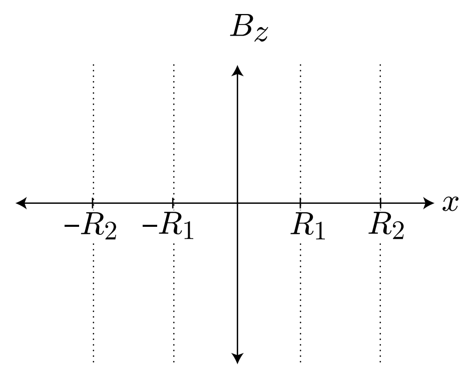
The next two problems are related. An infinitely long solenoid is oriented along the z-axis as shown. The solenoid is wrapped with multiple concentric layers of wire with a density of n **wires per unit cross-sectional area**. The inner radius of the solenoid is R_1 and the outer radius is R_2. The direction of the current I is shown in the figure.



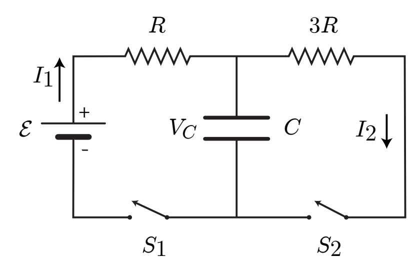
X. (8 pts) Use the **Ampère's Law** to **derive** an expression for the magnetic field vector as a function of the displacement r from the z-axis as a function of r, R_1, R_2, n, I, and μ_0. (Hint: Consider the Ampèrian Loop drawn in the side view.)



$\vec{B}$ for $r < R_1$	
$\vec{B}$ for $R_1 < r < R_2$	
$\vec{B}$ for $R_2 < r$	

X. (5 pts) **Sketch** the z component of the B field in the figure to the right.

The next four problems are related. Consider the RC circuit shown to the right. Before time zero, both switches are open and the capacitor is uncharged. At $t = 0$ switch S_1 is closed. Switch S_1 is opened at $t = RC$. Switch S_2 is then closed at $t = 2RC$.



X. (3 pts) **Sketch** the voltage across the capacitor V_C.

X. (3 pts) **Label max value** and **asymptotic value** ($t \to \infty$).

X. (3 pts) **Sketch** current I_1.

X. (3 pts) **Label max value** and **asymptotic value** ($t \to \infty$).