Name ~~SOLUTION~~ Student ID ______________

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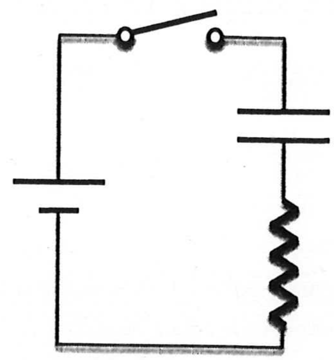
Part I: Multiple choice: 9 questions for 5 points each

Questions 1 - 3 concern the circuit shown at right, which contains a resistor (R = 200 Ω), a capacitor (C = 240 nF) and an ideal 12 V battery.



1. **Immediately after** the switch is closed, what is the potential difference across the capacitor?

A. $V_C = 0$ V.

B. $V_C = 2.40 \times 10^{-9}$ V.

C. $V_C = 6$ V.

D. $V_C = 12$ V.

no charge on capacitor yet so $V = \frac{Q}{C} = 0$

2. **Immediately after** the switch is closed, what is the current through the resistor?

A. $i_R = 0$ A.

B. $i_R = 27$ mA.

C. $i_R = 60$ mA.

D. $i_R = 200$ mA.

no charge on capacitor yet so $\Delta V_{Res} = \Delta V_{batt}$

$iR = \Delta V_{batt}$

$i = \frac{12\,V}{200\,\Omega}$

3. **A long time after** the switch has been closed, what is the charge on the capacitor?

A. $Q_C = 2.88 \times 10^{-6}$ C.

B. $Q_C = 2.40 \times 10^{-7}$ C.

C. $Q_C = 2.00 \times 10^{-8}$ C.

D. $Q_C = 0$.

no current flows so

$\Delta V_{cap} = \Delta V_{batt}$

$Q = CV = 240\,nF \times 12\,V$

$=$

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4. A positively charged particle has an initial velocity of unknown magnitude and direction when it enters a region in which there is a uniform electric field E = 2000 V/m in the -z direction and a uniform magnetic field B = 0.2 T in the -y direction. The particle's velocity is **not affected** by the fields. What is its velocity?

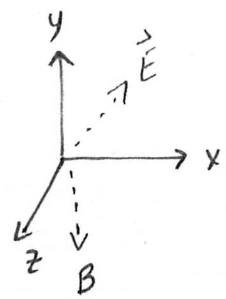
A. 1.0×10^{4} m/s in the +y direction

B. 1.0×10^{4} m/s in the –x direction

C. 1.0×10^{-4} m/s in the +x direction

D. 1.0×10^{-4} m/s in the –x direction

E. 1.0×10^{-4} m/s in the +z direction



velocity not affected

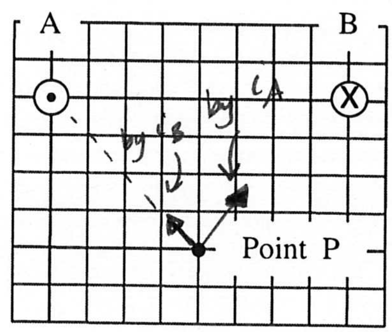
$\Rightarrow F_{net} = 0$

$\Rightarrow \cancel{q}E = \cancel{q}vB$

$v = \frac{E}{B}$

force on ptcle by E field along -z
∴ force by B-field must be along +z ∴ $\vec{v}$ along -x

Questions 5 and 6 concern the current-carrying wires shown at right. Wire A carries current I_A out of the page; wire B carries current I_B into the page. $I_A = 2I_B$.



5. Which arrow below best represents the direction of the magnetic field at point P?

↗	↙	⊗	⊙	other
A	B	C	D	E

6. Which arrow below best represents the direction of the force exerted **on** wire B **by** wire A?

→	←	↓	↑	other
A	B	C	D	E

at location of wire B, field due to A is ↑

by RHR $i \times B$ →

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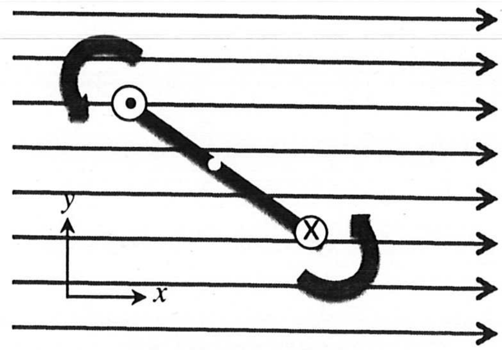
Questions 7 - 9 concern a conducting loop in a uniform magnetic field directed along the $+x$-axis, as shown in the **side-view** diagram at right. **At the instant shown** an external force is causing the loop to rotate with a constant angular velocity ω about an axis along the z-axis through the loop's center.

For question 7, the loop is carrying a current (produced by a battery) in the direction indicated (out of the page at the top of the loop). For questions 8 and 9, the loop is not carrying a current produced by a battery.



Side-view diagram

7. (**With** current from a battery.) Which of the following best describes the potential energy U at the instant shown?

   A. U is **increasing** (*i.e.*, it is negative and tending towards zero OR it is positive and tending toward larger absolute values).

   B. U is **decreasing** (*i.e.*, it is negative and tending toward larger absolute values OR it is positive and tending towards zero).

   C. U is **zero**.

   D. It is impossible to tell.

U_{min} is when $\vec{\mu}$ & $\vec{B}$ are aligned
loop is rotating toward $\vec{\mu}$ & $\vec{B}$ being anti-aligned

8. (**Without** current from a battery.) Which of the following best describes the **absolute value** of the magnetic flux $|\Phi|$ through the loop at the instant shown?

   A. $|\Phi|$ is increasing.

   B. $|\Phi|$ is decreasing.

   C. $|\Phi|$ is zero, and remaining constant.

   D. $|\Phi|$ is not zero, but remaining constant.

fewer field lines through loop ~~aft~~ as time passes

9. (**Without** current from a battery.) Assuming the loop has a single turn, area A and total resistance R, the B-field has magnitude B_0 and at the instant shown the angle between the loop and the B-field is 45°, what is the magnitude of the induced current i?

   A. $\frac{BA\omega}{\sqrt{2}R}$

   B. $\frac{BA}{\sqrt{2}R}$

   C. $\frac{BA\omega}{\sqrt{2}}$

   D. There is no induced current.

~~[illegible]~~ $i =$

$$|\mathcal{E}| = \left|\frac{d\Phi}{dt}\right| = \left|\frac{d}{dt}(AB\cos\omega t)\right|$$

$$= AB\omega \sin\omega t$$

$$i = \frac{\mathcal{E}}{R}$$

ωt here is 45°

$$= \frac{AB\omega}{\sqrt{2}}$$

P.3

Name ____ Student ID ________________ Score________
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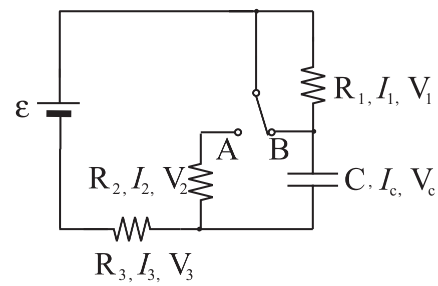
II. [10 pts total] The following questions are based on your experience in the lab.

10. [3 pts.] Consider Circuit 1 at right. Assume the battery and capacitor are ideal and the resistors are identical.

The switch is at position B for a long time. Which of the following is a true statement?

a. $I_1 > I_2$.
b. $I_1 > I_3$.
c. $|V_c| = |\varepsilon|$.
d. $|V_1| + |V_c| < |\varepsilon|$.



Circuit 1

In this configuration the capacitor is completely charged therefore there is no current flowing through the system. This eliminates (a) and (b). If there is no current in the system, then there is no potential difference across the resistors. The only potential difference is across the capacitor, which equals the magnitude of the potential difference across the battery. The answer is (c).

11. [3 pts] Consider Circuit 1 above and to the right.

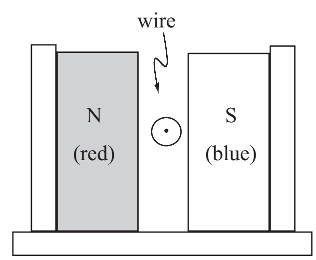
The switch is then flipped to position A and left there for a long time. Which of the following statements is true?

a. $I_1 = I_2$.
b. $I_1 > I_2$.
c. $I_2 = I_3$.
d. $|V_1| = |V_2|$

Similar to the previous question, the capacitor is charged therefore no current is flowing down the branch that contains the capacitor and resistor 1 and current only flows down the branch that contains resistor 2. This eliminates (a) and (b). Resistor 2 and 3 can be thought to be connected in series therefore they must have the same current making (c) a true statement. There is no current flowing through resistor 1 therefore there is no potential difference across resistor 1 eliminating (d). The answer is (c).

12. [4 pts] Consider the figure at right.

The magnets and wire in the diagram are similar to those used in lab. Which of the following statements is true?



Wire is carrying current out of the page

a. When an electron is placed at rest in between the two magnets, it experiences a force in the same direction as the force felt on the wire.
b. When a proton is placed at rest in between the two magnets, it experiences a force in the same direction as the force felt on the wire.
c. When an electron moves through the region between the two magnets with a velocity vector out of the page, the electron experiences a force in the same direction as the force felt by the wire.
d. When a proton moves through the region between the two magnets with a velocity vector out of the page, the proton experiences a force in the same direction as the force felt by the wire.

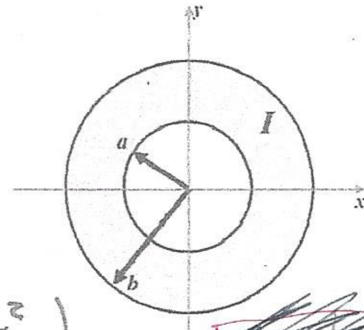
The force on the current carrying wire is vertically up ($\mathbf{F} = I\mathbf{l}x\mathbf{B}$ which can also be derived by $\mathbf{F}=q\mathbf{v}x\mathbf{B}$). A charge at rest in a magnetic field experiences no force ($\mathbf{F}=q\mathbf{v}x\mathbf{B}$) eliminating (a) and (b). An electron moving out of the page in the magnetic field produced by the magnets experiences a vertically downward force eliminating (c). A proton moving out of the page in the magnetic field produced by the magnetic field experiences a vertical force up which is similar to the force felt on the wire. The answer is (d).

Name The Key
last first **Student ID** ______________

III. [25 pts] Parts A and B are independent.

PART A: An infinitely long cylindrical shell with inner radius **a** and outer radius **b** carries a uniformly distributed current **I** out of the page.

Determine **B** in the three regions listed below and explain or support your reasoning with words or calculation.



17pts

1. **r < a**

(4) I enclosed $= 0$
$B = 0$

2. **a < r < b** $B = \frac{\mu_0 I_{enc}}{2\pi r}$; $I_{enc} = I\left(\frac{r^2 - a^2}{b^2 - a^2}\right)$

(5)

$\therefore\; B = \frac{\mu_0 I}{2\pi r}\left(\frac{r^2-a^2}{b^2-a^2}\right)$

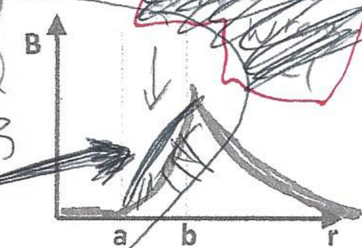
3. **r > b** I enclosed $= I$

(4) $B = \mu_0 I / 2\pi r$

4. Sketch |**B**| as a function of **r**.

(4)

Updated 3/14/13



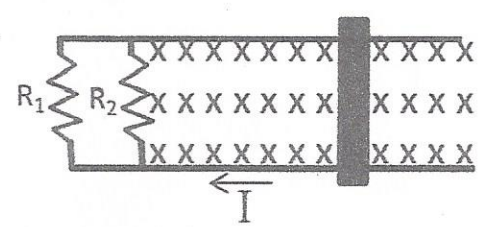
1 overall

2 for correct sketch, wrong answer

(8) pts

PART B: A wire bar rolls with a speed of 8.0 m/s on two metallic rails, 30 cm apart, that form a closed loop. A uniform magnetic field of magnitude 1.20 T is into the page. Resistors R_1 and R_2 each have resistance 7 kΩ. The current direction is as shown.

What is the direction of the moving bar (left or right) and what is the current induced in the circuit?



For I to go CW, flux goes into page ⊗, Induced I, opposes existing, so if bar moves LEFT, I goes CW to restore flux

1pt. 2 if no units at all

$\frac{1}{R_{eff}} = \frac{1}{7k\Omega} + \frac{1}{7k\Omega} \Rightarrow R = 3.5\,k\Omega$

I = 8.2 × 10^{-4} A	(5)
Bar moves (circle one): Left Right	(3)

$I = \frac{\mathcal{E}}{R} = \frac{\left(\frac{d\phi}{dt}\right)}{R} = \frac{w v B}{R} = \frac{(.3)(8)(1.2)}{3.5\,k\Omega} = 8.2\times 10^{-4}\,A$

2pt. resistance adding

Name ______________________________________ **Student ID** _______________ **Score**________

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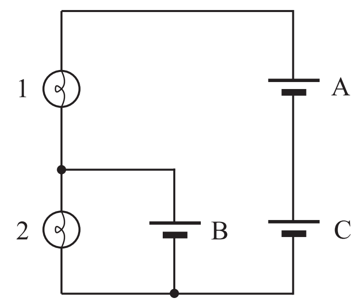
IV. [20 points total] This question consists of two independent parts, A and B.

A. In the circuit at right, assume all bulbs are identical, and all batteries are identical and ideal.



i. [5 pts] Is the brightness of bulb 1 *greater than, less than,* or ***equal to*** that of bulb 2? If either bulb will not light, state so explicitly. Explain.

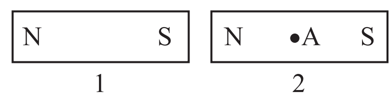
*Kirchhoff's loop rule on the inner loop shows that the voltage across bulb 2 is equal to that of a battery. In the outer loop, the voltage across 1 and 2 is equal to two batteries, so therefore the voltage across bulb 1 is also equal to that of one battery. Thus the voltage across both bulbs is the same, so they are **equally bright**.*

ii. [5 pts] Is the current through battery A ***greater than***, *less than,* or *equal to* the current through battery B? If the current through either battery is zero, state so explicitly. Explain.

*Since both bulbs are equally bright, they have the same current through them. Thus no current splits at the junction to go through B, and battery B has no current through it. Thus the current through battery A is **greater than** through B.*

B. A student performs 3 experiments with identical magnets. Point A is at the center of magnet 2.

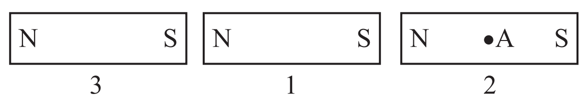
i. [3 pts] Experiment 1: two magnets labeled 1 and 2 are placed next to each other. On the diagram, indicate the direction of the net force on magnet 2 from magnet 1. Explain.



Experiment 1

*The two magnets are oriented in the same direction, so the south pole of magnet 1 is next to the north pole of magnet 2, and the two magnets attract each other. Thus the net force on magnet 2 is **to the left.***

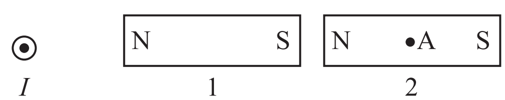
ii. [3 pts] Experiment 2: a third magnet is added to the left of magnet 1. Is the magnitude of the net force on magnet 2 ***greater than***, *less than,* or *the same as* that in experiment 1? Explain.



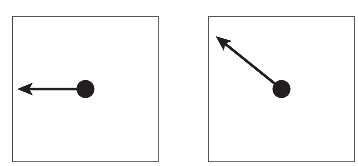
Experiment 2

*Magnet 3 is oriented in the same way as magnet 1, so both magnets will attract magnet 2. In experiment 1 only one magnet was exerting a leftward force on magnet 2, and now two magnets are both exerting a force to the left on magnet 2, so the net force has **increased** compared to experiment 1.*

iii. [4 pts] Experiment 3: the third magnet is replaced with a wire carrying a current I out of the page. In the spaces provided, draw qualitatively correct vectors showing the magnetic field at point A in experiments 1 and 3. Explain your reasoning.



Experiment 3



Experiment 1 Experiment 3

Point A is inside magnet 2, and the magnetic field there points left (from S to N inside a magnet). At point A the magnetic field from magnet 1 also points left, so the net field due to the two magnets points left. In experiment 3 the magnetic field circles counter-clockwise around the current, so at point A the magnetic field from the wire points upward. Thus the net field points left in experiment 1, and up and to the left in experiment 3.