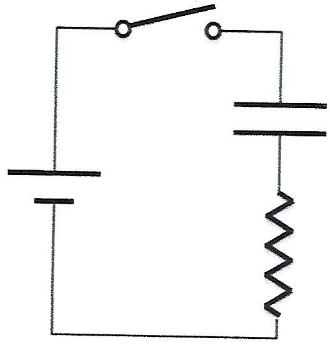
Name ______________________________ Student ID ______________

last *first*

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



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. ✗

   $V_C = 12 - iR \Rightarrow 0$, $i = 12/R$

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.

   $12/R = \frac{12.0}{200} = 6 \times 10^{-2} = 60$ mA

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 $V_C = V_{batt}$

   $Q = 12 \times 240 \times 10^{-9} = 2.88\ 10^{-6}$ C

---

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?

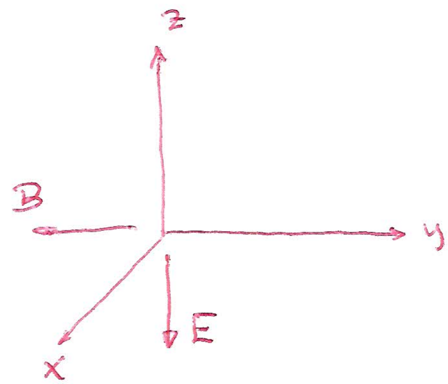
   A. 1.0×10^4 m/s in the +y direction

   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



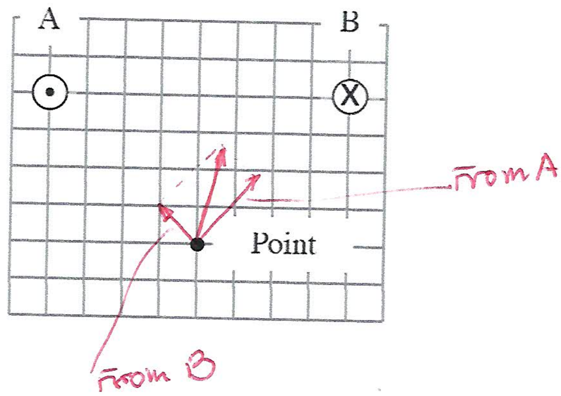
$\vec{F}_E$ has to equal $-\vec{F}_B$

$q\vec{E} = -q\,\vec{v} \times \vec{B} \Rightarrow \vec{v}$ has to be along $-\hat{x}$

$E = vB \Rightarrow v = \frac{2 \times 10^3}{0.2} = 10^4$ m/s

Name ______________________________ **Student ID** ______________
last *first*

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. $I_A = 2I_B$.

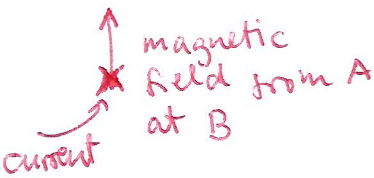


5. Which arrow below best represents the direction of the magnetic field at point X?

↗	↙	⊗	⊙	other
A	B	C	D	E

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

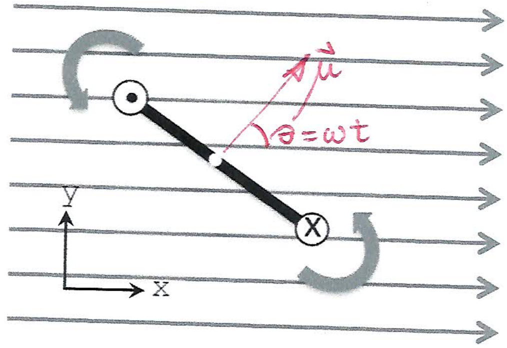
→	←	↓	↑	other
A	B	C	D	E



Name ______________________________ **Student ID** ______________
last *first*

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** the loop is rotating 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.) **At the instant shown** is potential energy *U* increasing, decreasing or remaining constant?

   A. *U* is increasing.
   B. *U* is decreasing.
   C. *U* is not zero, and remaining constant.
   D. *U* is zero, and remaining constant.

U minimal when $\vec{\mu}$ aligned with $\vec{B}$ ⇒ increasing

8. (**Without** current from a battery.) **At the instant shown**, is the absolute value of the rate of change of the magnetic flux through the loop $\left|\frac{d\phi}{dt}\right|$ increasing, decreasing, or constant?

   A. |! ! / ! "| is increasing.
   B. |! ! / ! "| is decreasing.
   C. |! ! / ! "| is not zero, and remaining constant.
   D. |! ! / ! "| is zero, and remaining constant.

$\frac{d\phi}{dt}$ is

$\phi = BA \cos \omega t$

$\left|\frac{d\phi}{dt}\right| = BA\omega \sin \omega t$

at time shown $\sin \omega t$ is increasing ⇒ $\left|\frac{d\phi}{dt}\right|$ increasing

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.

$i = \frac{d\phi/dt}{R} = \frac{\omega BA}{R} \cdot \sin 45$ ($\frac{1}{\sqrt{2}}$.)

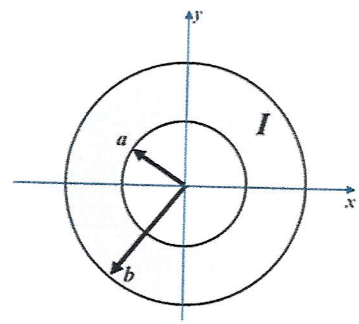
$i = \frac{\omega BA}{\sqrt{2}R}$.

Name ______________________________ Student ID ______________
last first

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.



1. r < a $\oint \vec{B}\cdot d\vec{\ell} = 0$ symmetry $\Rightarrow B = 0$

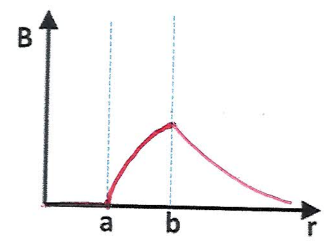
2. a < r < b

$$2\pi r B = \mu_0 \frac{I\pi(r^2-a^2)}{\pi(b^2-a^2)} \Rightarrow B = \frac{\mu_0 I}{2\pi}\cdot\frac{(r^2-a^2)}{r(b^2-a^2)}$$

3. r > b

$$2\pi r B = \mu I \Rightarrow B = \frac{\mu_0 I}{2\pi}\frac{1}{r}$$

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



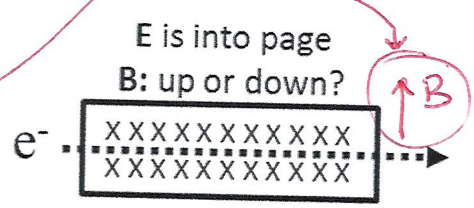
PART B: See sketch. A beam of electrons passes undeflected through the a region which contains a uniform electric field of 10 N/C into the page and a uniform magnetic field of 2×10^{-4} T perpendicular to its path and to the electric field orientation.

What is the speed of the electrons through this region and which way does the B field point?

Since electrons undeflected

$$\vec{E} + \vec{v}\times\vec{B} = 0 \Rightarrow \vec{v}\times\vec{B} = -\vec{E}$$

with $\vec{B}$ in the direction $\vec{v}\times\vec{B}$ is out of the page $= -\vec{E}$



magnitude

$$v = \frac{E}{B} = \frac{10}{2\times10^{-4}} = 5\times10^{4}$$

v_e = 5×10^4 m/s
B is (circle one): **UP** (circled) DOWN