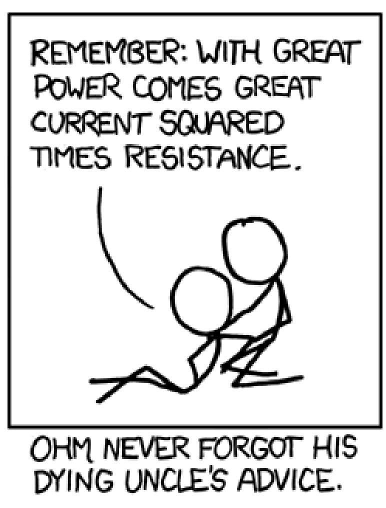
PHYS 2250 Exam II

Thursday, November 18, 2021

Instructions: *You will have at least 2 hours to complete this exam. Take a deep breath and relax! Read each question carefully, and let me know if anything is unclear. Partial credit may be awarded, so you are encouraged to clearly and legibly show your work for each problem. Write your name on every extra sheet you use, and clearly label what problem you are working on. Staple this to the back of your exam when you turn it in. You may use any information contained within this exam, as well as a calculator.*
Good luck!

Name: ______________________________



Potentially useful information

Unit analysis

Power	Prefix	Name
10^{12}	T	tera
10^{9}	G	giga
10^{6}	M	mega
10^{3}	k	kilo
10^{0}	—	—
10^{-3}	m	milli
10^{-6}	μ	micro
10^{-9}	n	nano

Constants

$$\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{C}^2/\left(\mathrm{N}\cdot\mathrm{m}^2\right)$$

$$\frac{1}{4\pi\epsilon_0} = k = 9 \times 10^{9}\ \mathrm{N}\cdot\mathrm{m}^2/\mathrm{C}^2$$

$$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{T}\cdot\ \mathrm{m/A}$$

$$e = 1.6 \times 10^{-19}\ \mathrm{C}$$

$$m_{proton} = 1.67 \times 10^{-27}\ \mathrm{kg}$$

$$m_{electron} = 9.11 \times 10^{-31}\ \mathrm{kg}$$

$$K = \frac{1}{2}mv^2 \text{ Kinetic Energy}$$

$$\Delta V = -\vec{E}\cdot\Delta\vec{r}$$

$$\Delta V = \frac{q}{4\pi\epsilon_0}\left(\frac{1}{r_f} - \frac{1}{r_i}\right) \text{ due to a point charge}$$

$$U = q\Delta V$$

$$\overline{v} = uE$$

$$i = nA\overline{v}$$

$$I = |q|i$$

$$\Delta\vec{B} = \frac{\mu_0}{4\pi}\frac{I\Delta\vec{l}\times\hat{r}}{r^2} \text{ short wire}$$

$$\left|\vec{B}_{wire}\right| = \frac{\mu_0}{4\pi}\frac{LI}{r\sqrt{r^2+(L/2)^2}} \approx \frac{\mu_0}{4\pi}\frac{2I}{r}\ (r \ll L)$$

$$\left|\vec{B}_{loop}\right| = \frac{\mu_0}{4\pi}\frac{2I\pi R^2}{(z^2+R^2)^{3/2}} \approx \frac{\mu_0}{4\pi}\frac{2I\pi R^2}{z^3}\ (z \gg R \text{ ,on axis})$$

$$\left|\vec{B}_{dipole,axis}\right| \approx \frac{\mu_0}{4\pi}\frac{2\mu}{r^3}$$

$$\mu = IA$$

$$\sigma = |q|nu \text{ elec. conductivity}$$

$$R = \frac{L}{\sigma A}$$

$$Q = C\left|\Delta V\right|$$

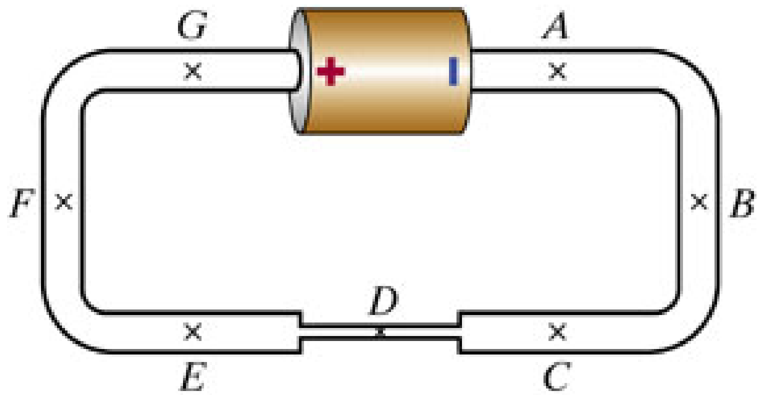
$$I = \frac{\Delta V}{R}$$

$$P = I\Delta V$$

1. (10 points) Which of the following statements about electric potential are correct? (Check all that apply)

   - ☐ If there is a constant large positive potential throughout a region, the electric field in that region is large.
   - ☐ The electric potential difference along any **closed** path is always 0.
   - ☐ The electric field “points” in the direction of increasing electric potential
   - ☐ The electric field “points” in the direction of decreasing electric potential
   - ☐ Electric potential is a vector quantity
   - ☐ The electric potential inside of a metal must always be 0
   - ☐ Negatively charged particles will feel a force in the direction of higher electric potential
   - ☐ Electric potential cannot be negative
   - ☐ A proton in a region of high electric potential has a large potential energy

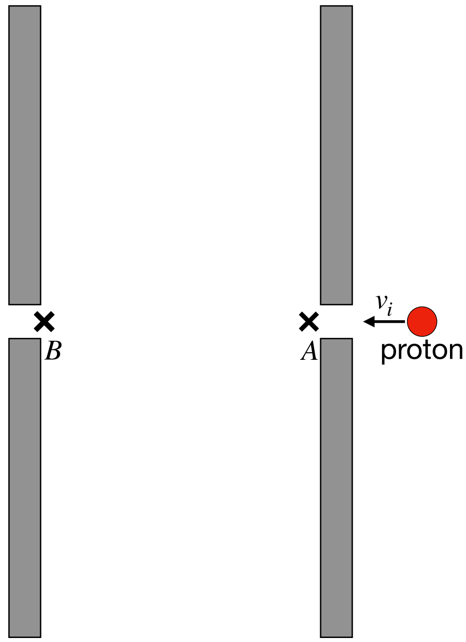
2. (10 points) In the circuit shown in the figure, all of the wires are made of Nichrome, but one wire is very thin and the others are thick.



Which of the following statements about this circuit are true? (Check all that apply)

- ☐ The magnitude of the electric field at location G is smaller in this circuit than it would be if all the wires were thick.
- ☐ Fewer electrons per second pass location E than location C.
- ☐ The electron current in this circuit is less than the electron current would be if all the wires were thick.
- ☐ The electron current is the same at every location in this circuit.
- ☐ The magnitude of the electric field at location D is larger than the magnitude of the electric field at location G.
- ☐ The magnitude of the electric field is the same at every location in this circuit.
- ☐ The battery alone creates the electric field at every point in the circuit.

3. A proton traveling in the $-\hat{x}$ direction approaches a capacitor consisting of two large, oppositely charged metal plates. The proton enters the capacitor through a small hole in one of the plates at location A with a speed of 1.6×10^4 m/s. It exits through a small hole at location B with a speed of 3.9×10^4 m/s.



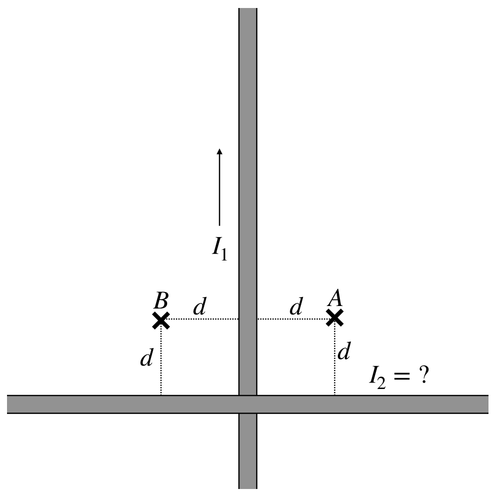
   (a) (5 points) On the diagram, draw an arrow indicating the direction of the electric field within the gap between the capacitor plates, and indicate which plate is positively charged and which is negatively charged.

   (b) (15 points) What is the potential difference $\Delta V = V_B - V_A$?

4. Two very long, thin wires run perpendicular to one another and eventually cross as shown in the figure below. The wires do not come into conductive contact when they cross. In this problem, use the standard coordinate system where $\hat{x}$ points to the right ($\rightarrow$), $\hat{y}$ points upward ($\uparrow$), and $\hat{z}$ points out of the page ($\odot$).

   A known current $I_1 = 3$ A flows upward (in the $+\hat{y}$ direction) in the vertically oriented wire. The current in the horizontal wire is unknown (you know neither direction or magnitude).

   You measure the magnetic field at two different points: point A is a distance $d = 3$ cm to the right of the vertically oriented wire and a distance d above the horizontal wire. Point B is a distance d to the *left* of the vertical wire, and a distance d above the horizontal wire.

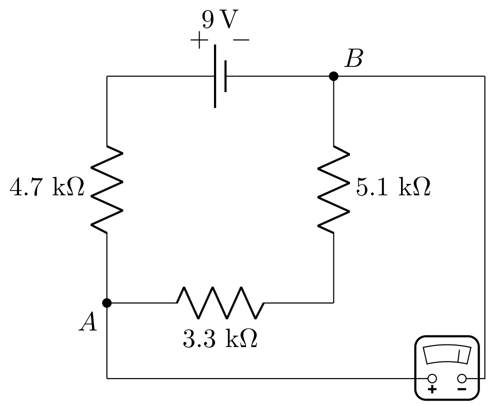


   You measure the magnetic field at point A and find that it is zero at that location.

   (a) (10 points) Based on this information, what is the current I_2? Specify both the value and the direction.

   (b) (10 points) What is the magnetic field at point B?

5. Consider the circuit shown in the diagram:



(a) (15 points) A voltmeter with an internal resistance of 100 kΩ is connected at points A and B as shown in the diagram. Note that the positive input of the meter is connected to point A, which means the meter is measuring the potential at A relative to the potential at B: $\Delta V = V_A - V_B$. What voltage will be displayed by the meter?

(b) (5 points) What voltage would be displayed by a theoretically perfect voltmeter (one with infinite resistance)? In other words, what is $V_A - V_B$ when the voltmeter is not connected?

Question	Points	Score
1	10	
2	10	
3	20	
4	20	
5	20	
Total:	80	