PHYS 2250 Final Exam

Tuesday, December 14, 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: _____

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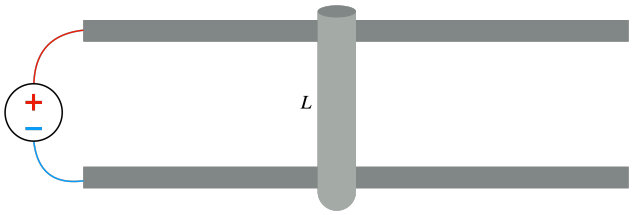
1. (30 points) In this problem, we will demonstrate the basic physics of a railgun. Two very long conducting rails are held in place while a conducting rod is free to slide atop them with negligible friction but good electrical contact. The two long rails are connected to a high-voltage power supply as shown in the figure.



(a) Assume that the conducting rails and voltage supply have negligible resistance, and that the movable rod has a resistance of $R = 1\ \Omega$. If the voltage source creates a potential difference of $\varepsilon = 100,000$ V, what is the current through the circuit?

(b) This current will create a magnetic field. Make the assumption that the two conducting rails are extremely long, and that they are the only wires which contribute to the magnetic field. The two conducting rails are a distance $L = 0.5$ m apart. What is the magnetic field due to the two long conducting rails at the midpoint between them? Be sure to specify both magnitude and direction.

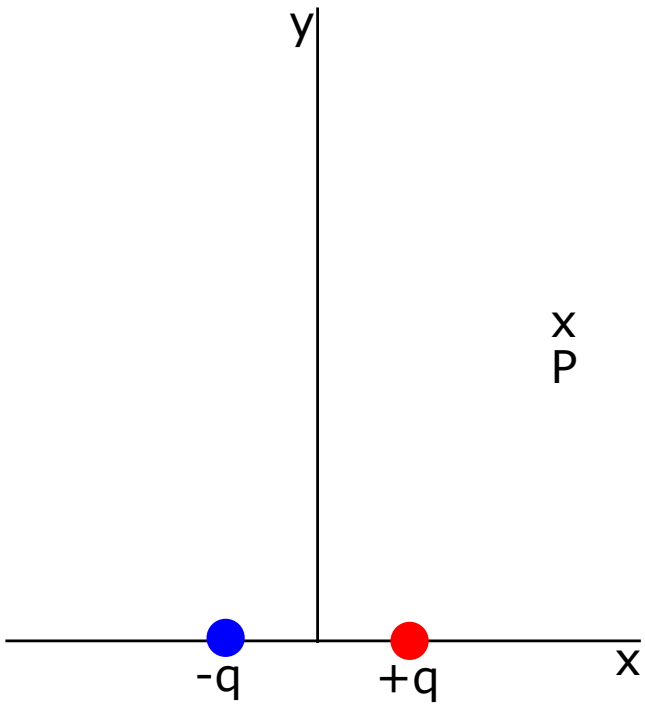
(c) Now, make the assumption that the magnetic field you found in the previous part is uniform and fills the entire region (this is not actually true, but will help give us a *basic* idea of how the railgun works).

This magnetic field exerts a force on the current-carrying movable rod which causes it to accelerate. What is the initial acceleration of the rod if it has a mass of 10 kg? (The length of the rod is $L = 0.5$ m).

(d) As the sliding rod picks up speed v, an induced motional emf is generated. What is the direction of the induced motional emf (does it tend to drive current clockwise or counter-clockwise)?

(e) Assuming that the magnetic field remains constant, at what speed v will the motional emf equal the voltage of the voltage supply (100,000 V)?

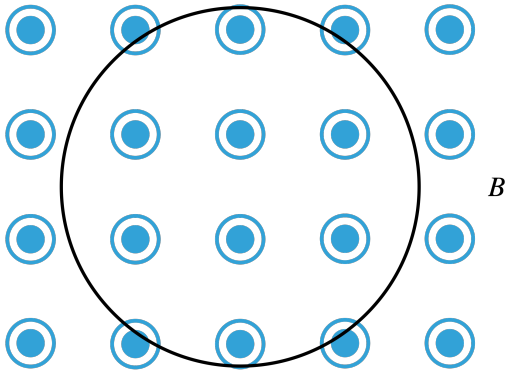
2. (20 points) A dipole with dipole moment $p = qs = 6.0 \times 10^{-30}$ C $\cdot$ m is centered at the origin. The two charges are separated by a distance $s = 4.0 \times 10^{-12}$ m, with the positive charge lying on the positive side of the x axis. What is the electric field $\vec{E}$ at the point $\vec{P} =< 8.0 \times 10^{-12}, 5.0 \times 10^{-12}, 0 >$ m, which is neither on the dipole's parallel nor perpendicular axis? Be sure to express your answer as a vector with proper units.



3. (20 points) A loop of wire with radius $R = 15$ cm lies as shown in a region where there is a uniform magnetic field coming out of the page. The magnetic field is changing with time:

$$B(t) = B_0 e^{-\frac{t}{\tau}}$$

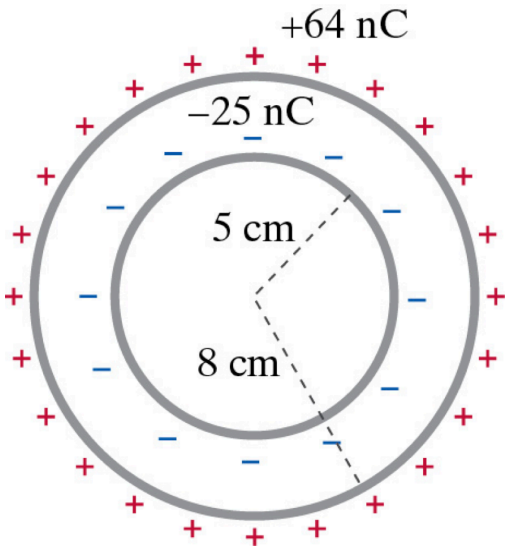
Where $B_0 = 0.5$ T and $\tau = 0.02$ s.



(a) Initially (at time $t = 0$) what is the magnitude of the induced emf in the loop?

(b) What direction is the induced emf (what direction will induced current flow?)

4. (20 points) Two insulating spherical shells with different radii share a common center. The inner shell has a radius $R_1 = 5$ cm and carries a charge of -25 nC distributed uniformly around its surface. The outer shell has a radius $R_2 = 8$ cm and carries a charge of $+64$ nC distributed uniformly around its surface.



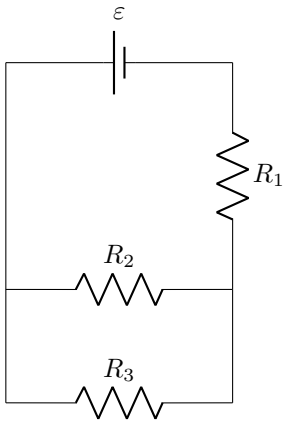
You measure the magnetic field at point A and find that it is zero at that location.

(a) What is the electric field (both magnitude and direction) at a distance of 3 cm away from the center?

(b) What is the electric field (both magnitude and direction) at a distance of 7 cm away from the center?

(c) What is the electric field (both magnitude and direction) at a distance of 10 cm away from the center?

5. (20 points) Consider the circuit shown in the diagram where $\varepsilon = 9$ V, $R_1 = 330\ \Omega$, $R_2 = 100\ \Omega$, and $R_3 = 220\ \Omega$.



(a) What is the current through resistor R_1?

(b) What is the current through resistor R_2?

(c) What is the current through resistor R_3?

6. (20 points) Answer the following questions:
   (a) List all of the possible ways to produce an electric field

   (b) List all of the possible ways to produce a magnetic field

   (c) How does the phenomenon of "light" relate to the electric and magnetic fields?

   (d) We have seen on several occasions that electrons in circuits travel very slowly. Why do lights turn on almost instantly?

   (e) You rub a neutrally charged PVC rod with a neutrally charged fur cloth, and find that the PVC rod becomes negatively charged. Give a qualitative explanation of what has happened. Where did the charge come from? Does the fur cloth now have excess charge?

Question	Points	Score
1	30	
2	20	
3	20	
4	20	
5	20	
6	20	
Total:	130	