PHYS 122: Homework #03

January 26, 2009

Homework #03 is due in Box outside of Rock 207:
5:00 PM Sharp, Monday, February 2, 2009

Announcements:

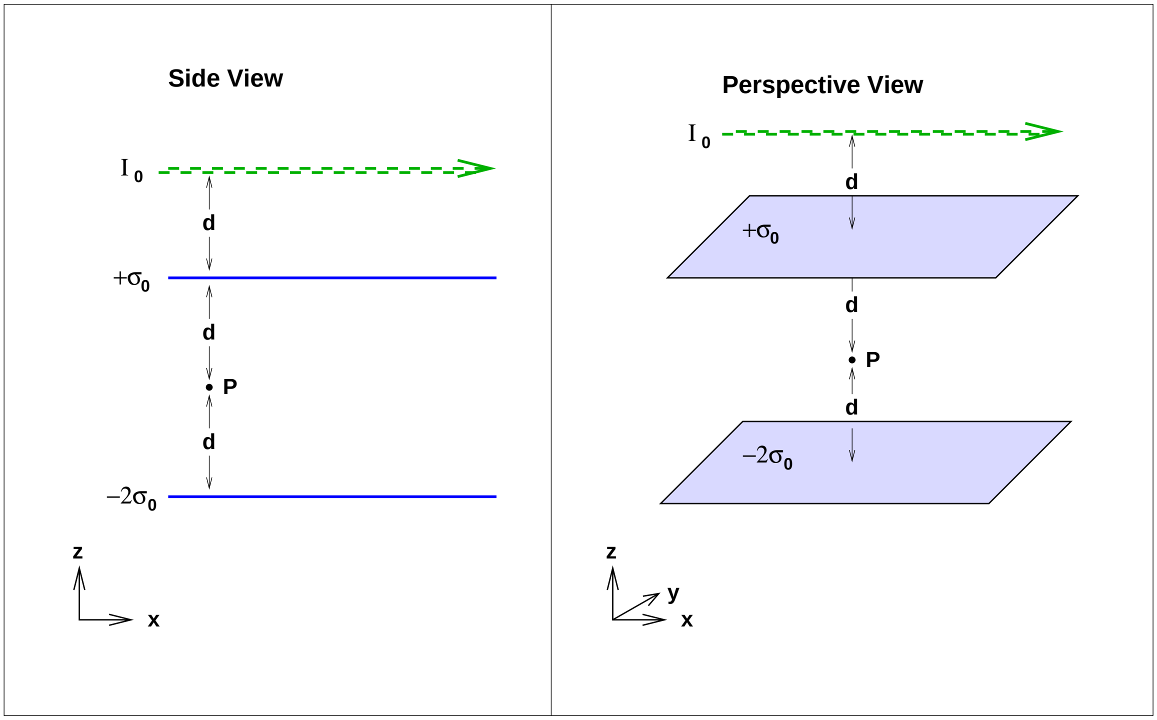
- Mr. Covault's Office Hours will generally be Mondays: 11 AM to noon and 1:30 PM to 4:00 PM, Thursdays: 1:15 PM to 2:30 PM and 3 PM to 4 PM, and Fridays: 10:45 AM to 12:15 PM.
- First Hour Exam (worth five percent of your grade) will be given Friday, February 6, **9:30 AM** in lecture. The exam is closed book, no books or notes – but you may bring one $8\frac{1}{2} \times 11$ sheet of paper (front and back) with any *hand-written* notes that you like. Simple calculators are okay – no programmable calculators, PDA's, phones, Blackberries, etc. Details will be announced in Document #08.
- Homework #01 is being graded and I expect it will be available to students sometime after Tuesday or Wednesday of this week. It usually takes about a week to get the homework graded. Solutions to Homework #01 are posted. Solutions to Homework #02 will be posted before Wednesday morning.
- Don't forget: Odd labs this week.

Homework Assignment continues next page....

This homework due in Box outside of Rock 207:
5:00 PM Sharp, Monday, February 2, 2009

Problem 1:

This from the 2007 First Hour Exam:



The above plot shows an arrangement of two infinite charged plates. The upper plate has positive surface charge density $+\sigma_0$ and the lower plate has negative surface charge density $-2\sigma_0$. The separation between the plates is $2d$. Also, at a distance d above the upper plate is an infinite wire carrying a current I_0 in the x-direction as shown.

a) Consider the point P which is located half-way between the plates. What is the electric field at point P? Write down your answer as a *vector* using the coordinate system shown: x points right, y points back (into page) and z points up. Be sure to explain how you determined your answer.

b) What is the magnetic field at point P? Write down your answer as a *vector* using the coordinate system shown. Be sure to explain your work.

c) Now particle with positive charge q_0 is placed at point P and is given an initial velocity $\vec{v} = v_0\hat{\boldsymbol{\imath}}$. What is the value of the speed v_0 that will allow the particle to move in a straight line without being deflected in any direction? *Here ignore gravity!* Write your answer in terms of the parameters given. Be sure to explain your answer.

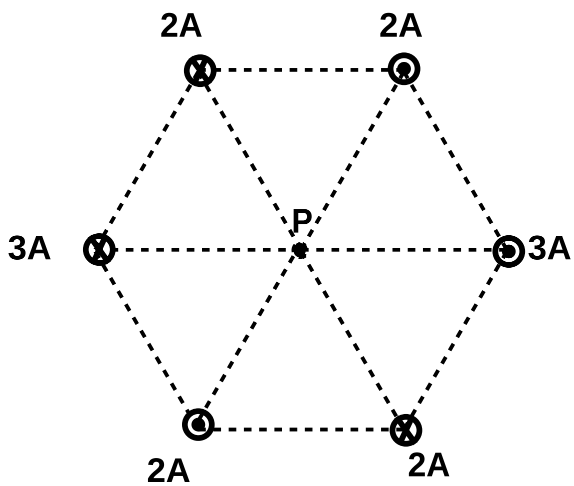
Hint: Unless you are told otherwise, assume that a wire with a non-zero electric current is nonetheless electrically neutral.

Problem 2:

Consider a set of six long straight wires arranged in a hexagon as shown. The wires run perpendicular to the page. The current in each wire is either I_2=2.00 Amps or I_3=3.00 Amps as indicated. The length of the each side of the hexagon is given by d=5.00 cm.

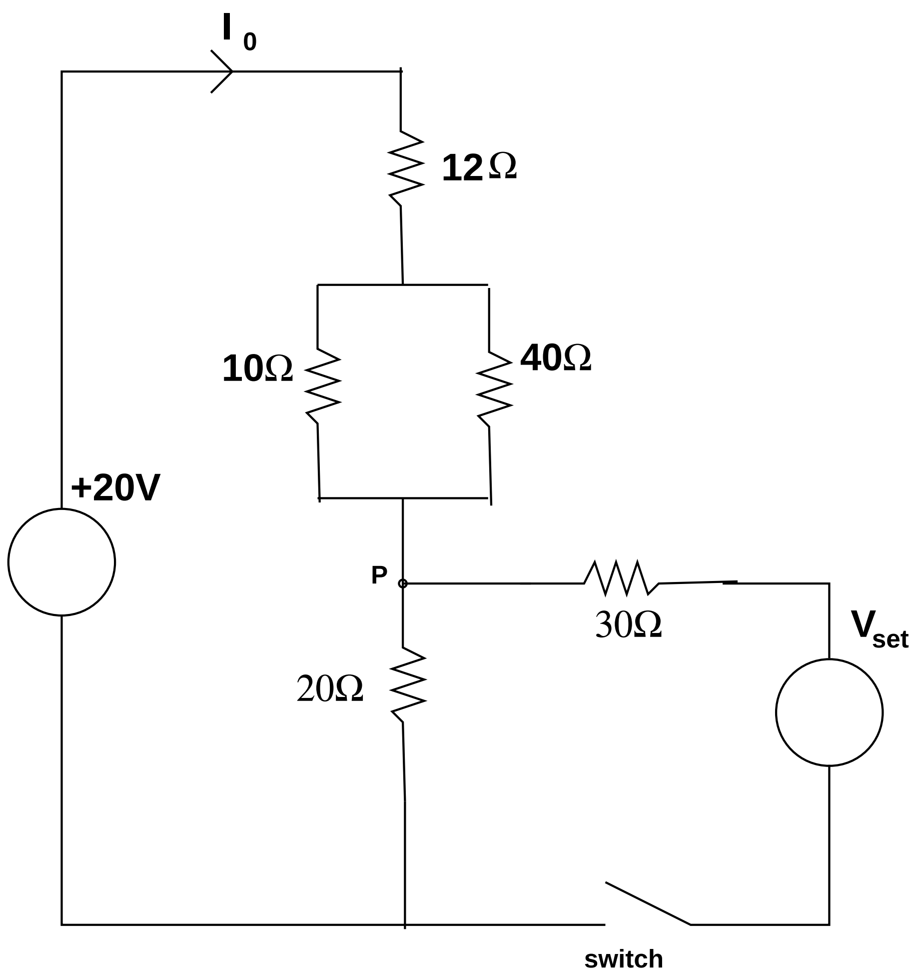
What is the *magnitude* and *direction* of the magnetic field at point P? Note: you might want to define a coordinate system here to indicate the direction as clearly as possible. Explain how you determined this. Give your answer in terms of symbolic variables and then numerically with the proper handling of units.

Note: current *into* the page is represented by an "X" on the wire, current *out of* the page is represented by a dot.



Hint: Remember that the magnetic field is applied in the **tangential** direction, according to the Right Hand Rule. So be careful with your application of symmetry here.

Problem 3: Again from an old exam:



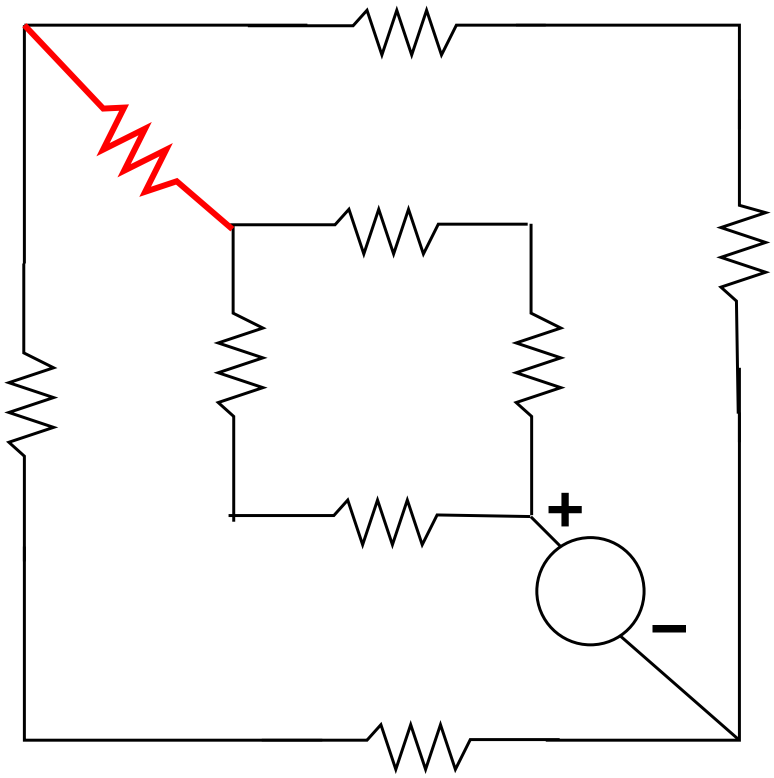
A circuit is put together as shown above. The left voltage source puts out a constant voltage of +20 volts.

Part (a) Assume that the switch is open as shown. In this case, what is the value of the current I_0 through the top of the circuit in the direction show? Give your answer in amps. Hint: You can do this from First Principles, but in this case it might be calculationally a little faster to work out the "Equivalent Resistance" of the network of resistors.

Part (b) With the switch open, what is the voltage at point P as measured with respect to the bottom of the left voltage source? Give your answer in volts.

Part (c) Suppose we close the switch. What particular value (in volts) V_{set} is required if we want the current flowing through the 30 Ohm resistor to be zero amps?

Problem 4:



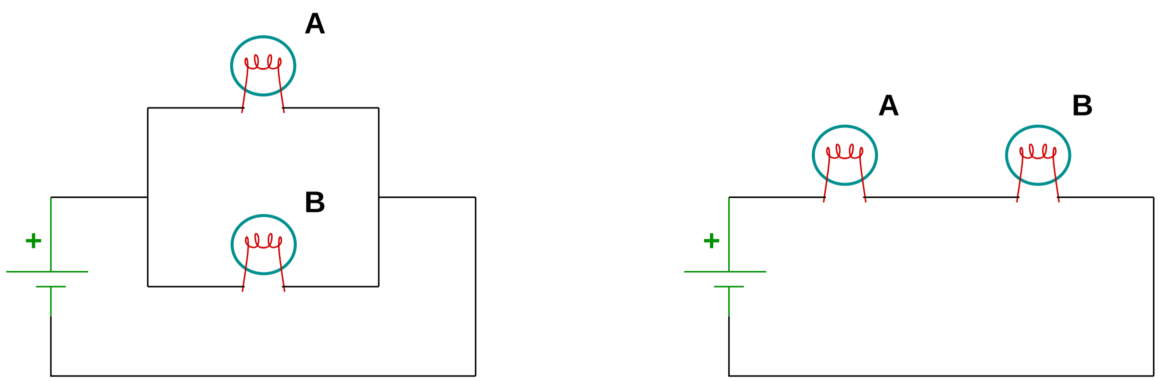
A voltage source which applies a fixed voltage $\mathcal{V}_s$ is embedded in a network of resistors as shown above. Each resistor has the same resistance R. In terms of $\mathcal{V}_s$ and R what is the current that runs through the resistor that is colored red?

Hint: This is not such a difficult problem. Consider re-drawing the circuit into a more conventional topography. I've set up the problem so that "quick equivalent resistances" are pretty easy to calculate.

Problem 5:

Hint: This one requires a little more work. Take your time and work carefully. All you really need is Ohm's Law. You also need to explicitly work out the power in each bulb:

The following figure shows two different arrangements of three electrical components (1) a voltage source which is a battery, (2) a light bulb labeled "A", and (3) a light bulb labeled "B". Light bulb A is *not* identical to light bulb "B". For the purposes of this problem assume that a light bulb is "resistor-like" and that the brightness of a given bulb depends on the total electric power dissipated.



When these components is connected as shown in the left circuit, *Bulb A is observed to be brighter than Bulb B.*

Part (a): Based on this information, which bulb has a greater resistance, Bulb A or Bulb B. Explain how you know this.

Part (b): Define $\mathcal{W}$ as the brightness power of a light bulb. Rank the follow from brightest to dimmest:

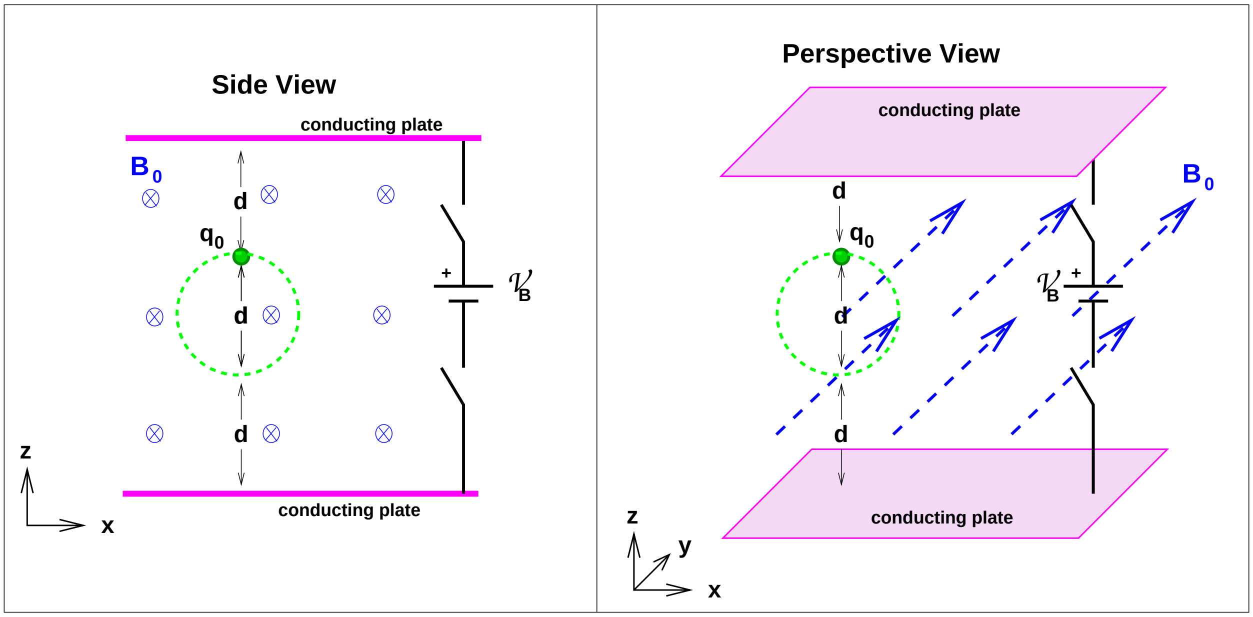
- $\mathcal{W}_{AL}$ = brightness of Bulb "A" in the left circuit.
- $\mathcal{W}_{BL}$ = brightness of Bulb "B" in the left circuit.
- $\mathcal{W}_{AR}$ = brightness of Bulb "A" in the right circuit.
- $\mathcal{W}_{BR}$ = brightness of Bulb "B" in the right circuit.

Be sure to explain in detail how you got your answer.

Note: It is relatively easy to rank the bulb brightness within each circuit. It is somewhat more technically challenging to to rank the brightness between the two circuits.

Problem 6:

From 2008 First Hour Exam:



A positively charged particle with given charge q_0 and mass m_0 is moving within a region of uniform magnetic field given by $\vec{B} = +B_0\hat{\boldsymbol{\jmath}}$ as shown. As a result of the force on the particle due to the magnetic field, the particle moves with *uniform circular motion* on a circle of given diameter d as shown. **For this problem ignore gravity.**

Part (a) – Is the particle traveling clockwise or counter-clockwise as show? Explain how you know this.

Part (b) – In terms of the given parameters, what is the value of the speed of the particle as it travels on the circular path? For this part, assume that the plates above and below are *electrically neutral*. Explain your work.

Part (c) – Assume that at the *instant* that the particle is at the position shown in the figure above, both switches are closed so that a battery with voltage $\mathcal{V}_B$ is connected to the upper and lower conducting plates as shown. What is the electric field between the plates? Be sure to give your answer as a *vector expression*. Explain how you know this.

Part (d) – Assume that as a result of the application of the electric field as described in part (c), the path of the particle is *deflected* so that it then hits the lower plate. Determine the *speed* of the particle when it hits the lower plate in terms of the given parameters. Explain your work.

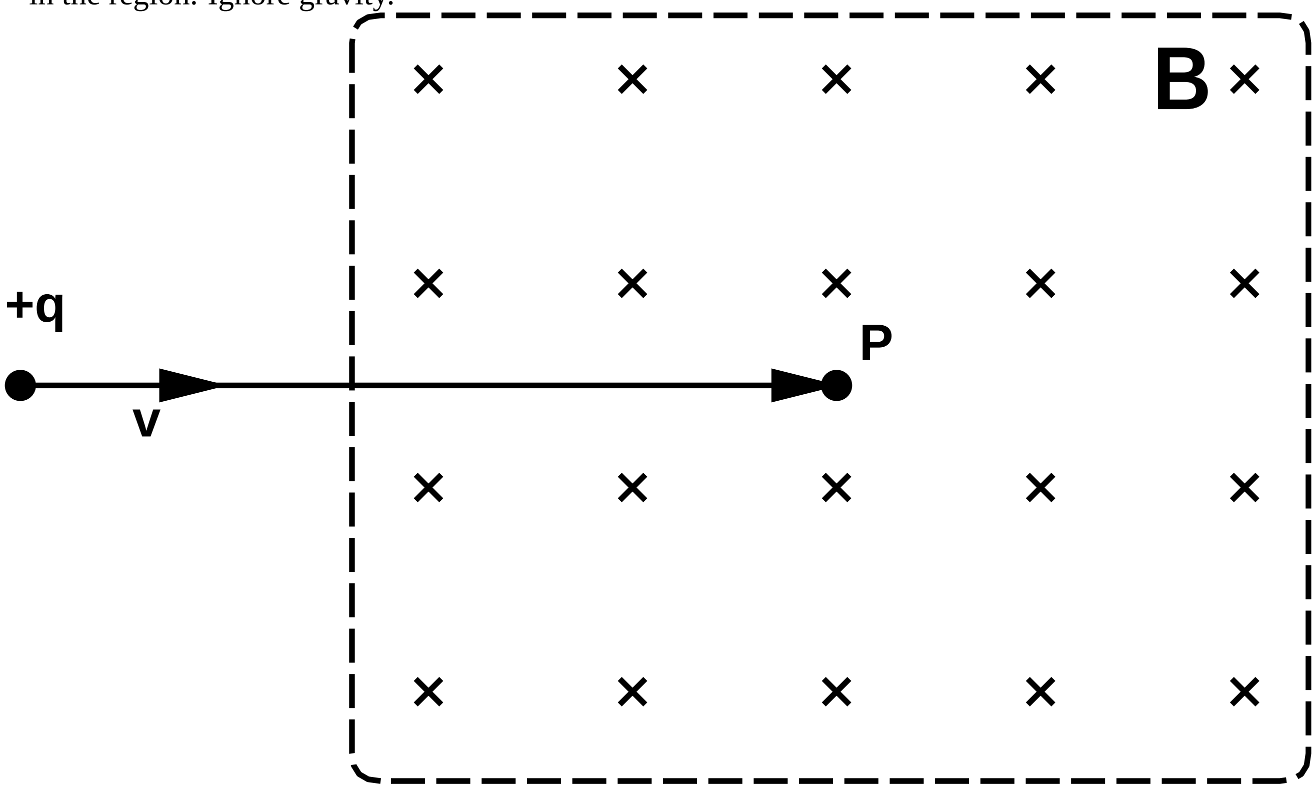
Problem 7:

Force on a charged particle due to B-field:

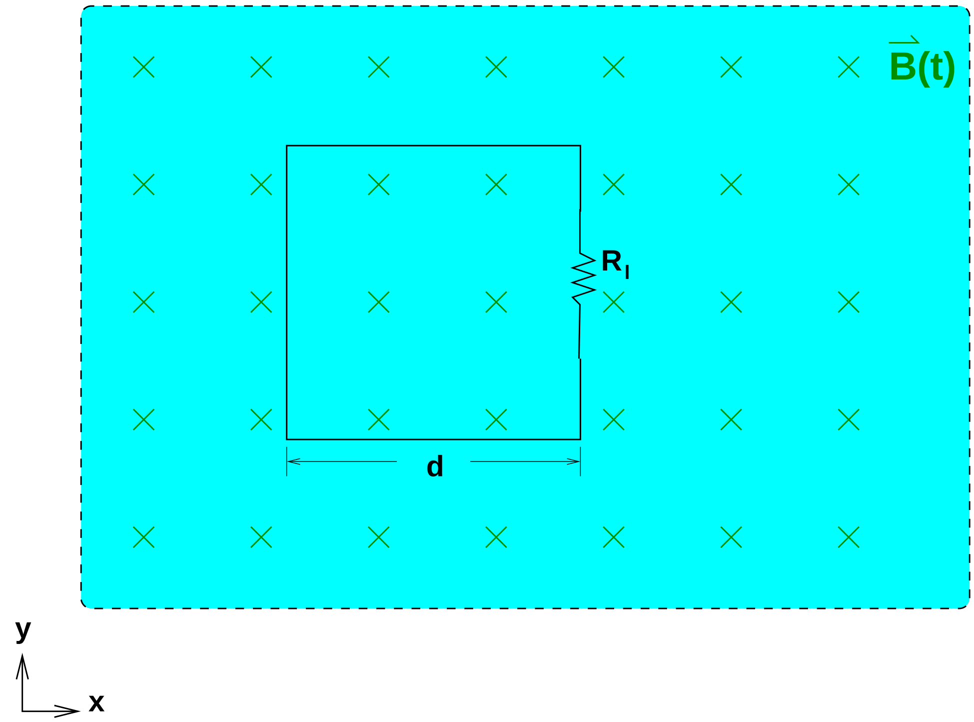
An experiment is conducted in a laboratory as follows: A particle with a charge $+q$ and mass m enters a rectangular region of space as show in the figure. Within this region there is an magnetic field $\vec{B}$ applied *into* the page as shown. However B varies with time as follows:

- For times $t < t_1$, $B = 0$
- For times $t_1 < t < t_2$, $B = B_1$
- For times $t > t_2$, $B = 2B_1$

Assume that the time t_1 corresponds to the position of the particle at point P as seen in this figure. Assume that time t_2 is a fairly long time after t_1. Sketch the path of this particle for all times $t > t_1$ directly on the figure. Assume that B_1 is strong enough to keep the particle trapped in the region. Ignore gravity.



Problem 8: Faraday's Law and Ohm's Law in one problem!



A uniform magnetic field is oriented into the page as shown above. The field is time-varying for all times $t = 0$ according to the following prescription:

$$\vec{B}(t) = -B_0 e^{-t/\tau} \hat{\boldsymbol{k}}$$

where $B_0 = 10.0$ Tesla and $\tau = 2.00$ seconds.

A square hoops of conducting wire is embedded in the B-field as shown. The side of each square $d = 0.50$ meters. The loops includes a (physically small) resistor $R_l = 20$ Ohms.

Part (a) At time $t = 2.0$ seconds, calculate the current through the resistor. If the current is not zero, which way is it flowing?

Part (b) At time $t = 2.0$ seconds, calculate the magnitude and direction of any force that is applied to the bottom-most straight segment of the square loop due the magnetic field.