Exam 3

Your Name:

Instructions

Solve each of the following problems to the best of your abilities. The exam is worth 100 points total and is calibrated for 90 minutes. You must show all your work to receive full credit.

Once you have completed the exam, hand it to me, and you can take a break before the second part of class. Class resumes at 10:00AM.

Good luck!

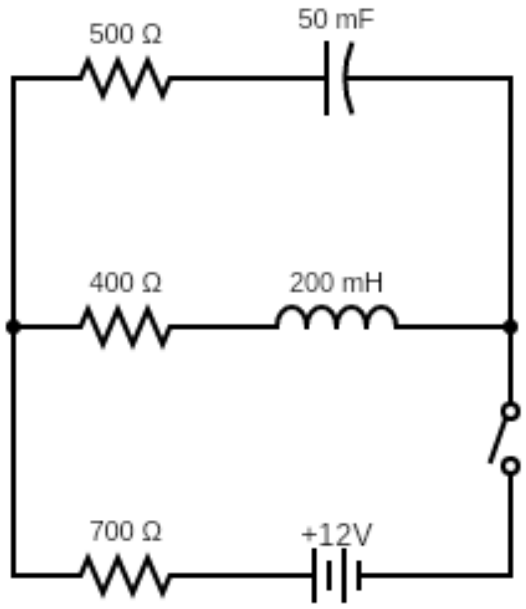
Problem 1

(20 points) A very long wire carrying a current of 2.00 A is placed along the x-axis and carries the current in the -x direction. Another very long wire carrying a current of 4.22 A is placed along the y-axis and carries the current in the –y direction. You can assume that the wires are locked into place and cannot move.

a) (5 points) What is the magnitude and direction of the net magnetic field at the point (3.00 m, 2.00 m)?
b) (5 points) Suppose a positive point charge with a charge of Q = +2.5 mC is placed at the point (3.00 m, 2.00 m) and is at rest. What is the net magnetic force on the point charge (magnitude and direction)?
c) (5 points) Suppose a positive point charge with a charge of Q = +2.5 mC moves past the point (3.00 m, 2.00 m) with a velocity of 30 m/s in the +y direction. What is the net magnetic force on the point charge (magnitude and direction)?
d) (5 points) Suppose I center a small ring of wire in the xy-plane at the point (3.00 m, 2.00 m). I then move the ring with a velocity in the +x and +y direction (i.e. away from the wires). What is the direction of the current in the small ring? Sketch a diagram of the system including the wires, the ring, and the direction of the current.

Problem 2

(30 points) Three resistors, a 50 mF capacitor, a 200 mH inductor, and a 12 V battery are connected in the configuration shown below. The switch is closed at time t = 0 seconds, and the circuit is allowed to come to equilibrium.



a) (5 points) What is the current in the 400 ohm resistor at time t = 0 seconds?
b) (5 points) What is the current in the 500 ohm resistor at time t = 0 seconds?
c) (5 points) What is the current in the 700 ohm resistor after a very long time?
d) (5 points) What is the energy stored in the 200 mH inductor after a long time?
e) (5 points) Suppose I double the strength of the battery to 24 volts. Would the current at time t = 0 seconds in the 700 ohm resistor increase, decrease, or stay the same? Why?
f) (5 points) Suppose I double the strength of the inductor to 400 mH. Would the current at time t = 0 seconds in the 700 ohm resistor increase, decrease, or stay the same? Why?

Problem 3

(30 points) A square loop of wire with side length l = 0.25 m is immersed in a uniform magnetic field that changes with time. The area vector of the loop makes an angle of 30 degrees with respect to the magnetic field lines, and the strength of the magnetic field evolves with time according to $B(t) = 2(t + 1)$ Teslas for all times $t \geq 0$ seconds.

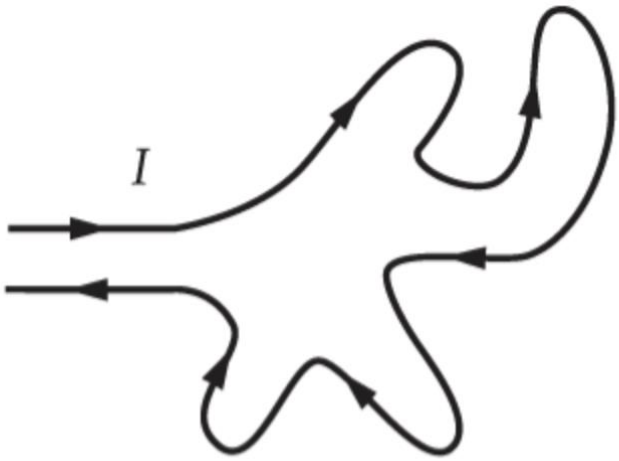
a) (5 points) Sketch a diagram of the system. Be sure to label the magnetic field lines and the square loop.
b) (5 points) What is the net magnetic flux through the loop at time t = 1.5 seconds?
c) (5 points) What is the induced EMF through the loop at time t = 0.0 seconds?
d) (5 points) What is the induced EMF through the loop at time t = 5.0 seconds?
e) (5 points) Suppose I double the strength of the magnetic field so that $B(t) = 4(t + 1)$ Teslas for all times $t \geq 0$ seconds. Would the induced EMF in the loop increase, decrease, or stay the same at time t = 0 seconds? Why?
f) (5 points) Suppose I reverse the direction of the magnetic field but keep everything else the same. Would the induced current in the loop reverse direction or stay in the same direction? Why?

Problem 4

(10 points) Suppose that magnetic monopoles existed in nature. In other words, you could isolate the north or south pole of a magnet as if it were a single magnetic "charge". How might Gauss' Law for Magnetism change in this universe?

Problem 5

(10 points) Suppose I run a current through the wire shown below. What will happen to the shape of the wire?



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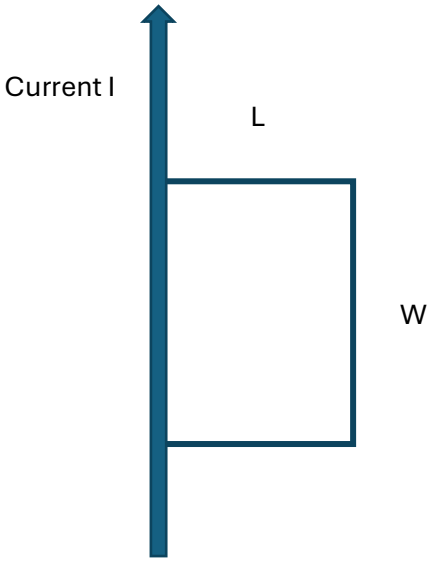
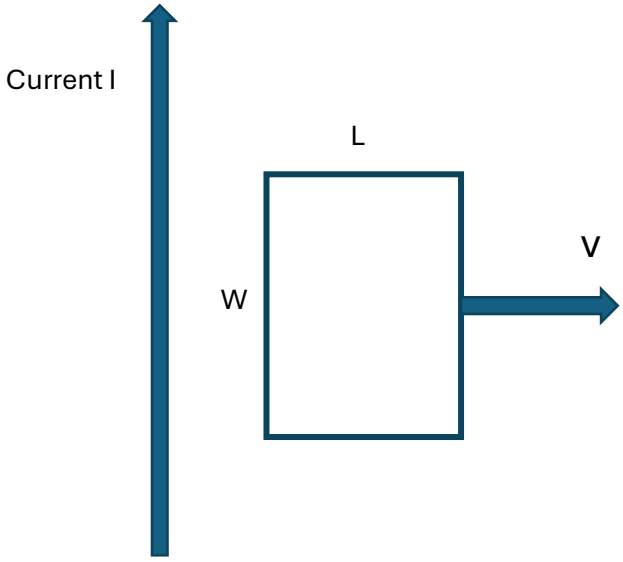
Challenge Problem! Extra Credit!

(10 points) A very long wire carries a current I along the y-axis in the positive y-direction. A loop of wire with a net resistance of R is located in the xy-plane with its left edge overlapping the long wire. The loop has a length of L and a width of W. I move the loop of wire in the positive x-direction with a constant velocity v. Derive an expression for the current in the loop as a function of time.



Initial Configuration



Time t > 0