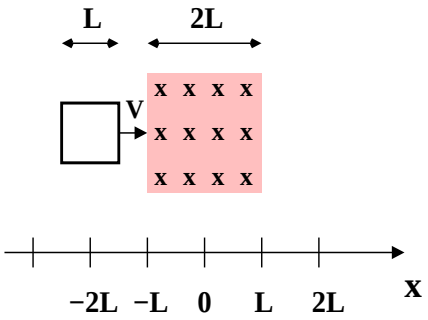
NAME:

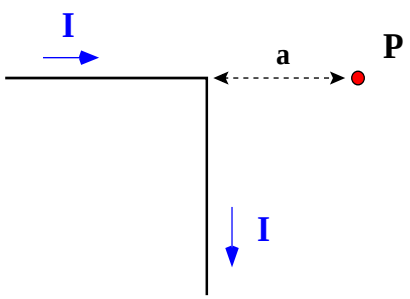
Final Exam, Physics 9C, Winter 2009

General Instructions: This exam is closed book. Please show all your work, and give units for all answers and on all graphs. Credit will only be given for complete solutions.

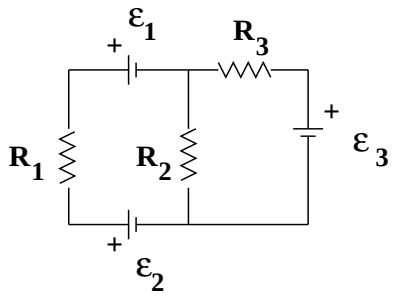
1. (20 points) A square loop of wire with side length L and resistance R is moving with constant speed v across a uniform magnetic field confined to a square region whose sides are twice the length of those of the square loop. (a) Graph the external force F needed to move the loop at constant speed as a function of the coordinate x from $x = -2L$ to $x = +2L$. (The coordinate x is measured from the center of the magnetic field region.) Take positive force to be to the right. (b) Graph the induced current in the loop as a function of x. Take counterclockwise currents to be positive.



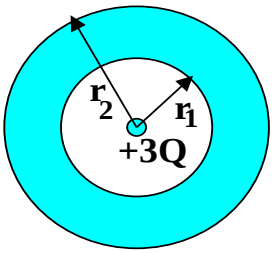
2. (10 points) A wire carrying a current I is bent to form a 90° angle, and extends out to infinity in both directions. Calculate the magnitude and direction of the magnetic field that this current produces at point P. You must explain all steps in your reasoning fully. The field produced by a *straight* infinite wire carrying current I has magnitude $B = \mu_0 I / 2\pi r$, a distance r from the wire.



[3.] (20 points) Find the current through each of the three resistors in the figure. Use the values $R_1 = 2\,\Omega$, $R_2 = 3\,\Omega$, $R_3 = 6\,\Omega$, $\mathcal{E}_1 = 16\,V$, $\mathcal{E}_2 = 6\,V$, $\mathcal{E}_3 = 12\,V$.

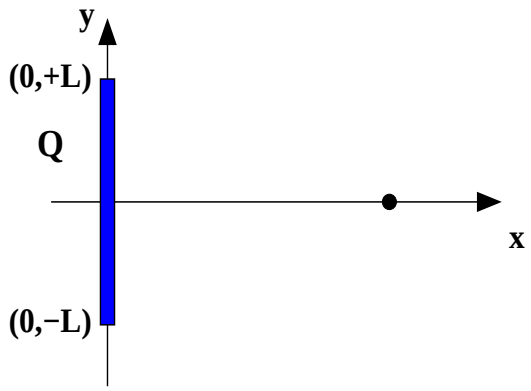


4. (20 points) A hollow, spherical conducting shell, carrying a net charge $-Q$, has inner radius r_1 and outer radius r_2 . At the center of the shell is a positive point charge $+3Q$.
Find how the charge is distributed on the surfaces of the conducting shell.
Use Gauss' law to find the magnitude of the electric field an arbitrary distance r from the center of the shell for the three regions (i) $r < r_1$, (ii) $r_1 < r < r_2$, and (iii) $r_2 < r$.

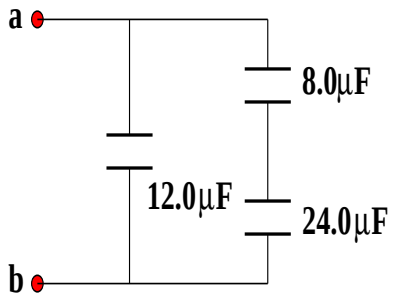


net (total) charge −Q on shell

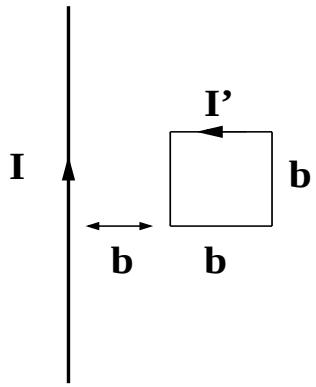
5. (20 points) Positive charge Q is distributed uniformly along a rod of length $2L$ that lies along the y-axis with its center at the origin. Find the potential at a point on the x-axis a distance x from the rod's center. (While there are two ways to proceed, trying to find the electric field first is the long way.) You will find some integrals listed on the formula sheet which might be useful.



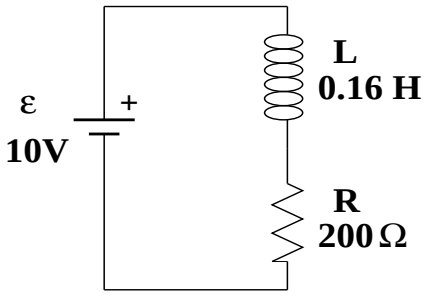
6. (20 points) A 12.0μF, an 8.0μF, and a 24.0μF capacitor are connected together as shown to a battery establishing a potential difference of 15.0V between points a and b. Find the charge on each capacitor plate.



7. (20 points) A current I flows in a long straight wire, producing the famous $\mu_0 I/2\pi r$ magnetic field. In the same plane as the straight wire is an isolated square wire loop, of side length b, and whose nearest segment is a distance b from the straight wire, as shown. A counterclockwise current I' is flowing in the square loop.
(a) Find the magnitude and direction of the net force on the square loop.
(b) The only reason the current I' is flowing in the isolated square loop at all is that the current I in the long, straight wire is changing. Is it increasing, or decreasing? Briefly explain.
(c) Without actually going through a calculation, explain how you could determine I' in terms of the quantities given and the loop's total resistance R.

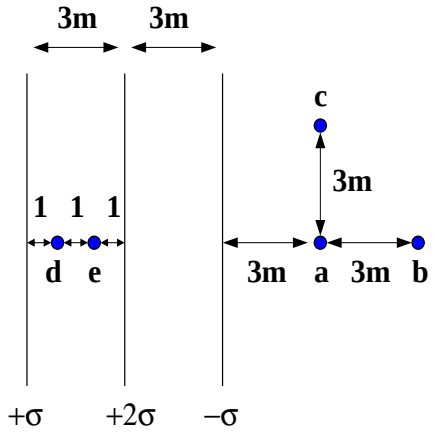


8. (20 points) An ideal battery of emf $\mathcal{E} = 10$V is connected in series to a 200Ω resistor and a solenoid of 0.16H inductance, as shown in the figure.
(a) Make a sketch showing how the current in the circuit varies as a function of time from the instant the circuit is initially connected, indicating clearly its behavior as time progresses. Give numerical values for I at $t = 0$ and $t = \infty$.
(b) What is the current in the circuit at the instant the current is changing at a rate of 50A/s?
(c) Consider the region inside the solenoid, far from the ends, at the instant referred to in part (b). The magnetic field in this region at any point in time is $\mu_0 nI$, where n is the number of turns per unit length. Given that the solenoid is 50cm long and has 3000 turns, what is the magnitude of the electric field at a point 1 cm from the solenoid's axis? Include a simple sketch to clarify your work.



[**9.**] (10 points) Explain briefly what is happening when you "tune" a radio to select a particular station.

[10.] (20 points) Three infinite planes of charge have charge densities $+\sigma$ $+2\sigma$, and $-\sigma$ as shown.
Find the electric field everywhere. Give both magnitude and direction.
Find the potential difference $V_b - V_a$.
Find the potential difference $V_c - V_a$.
Find the potential difference $V_e - V_d$.



11. (20 points) A current I flows to the right through a long conducting cylindrical shell of inner radius a and outer radius b, a section near the middle of which is shown. The current is distributed uniformly over the cross-section of the conductor. Find the magnitude of the magnetic field a distance r from the axis, for (i) $r < a$; (ii) $a < r < b$; and (iii) $b < r$.