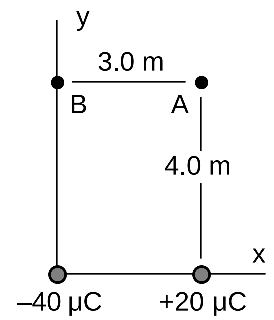
Exam #2

Name ________________________________

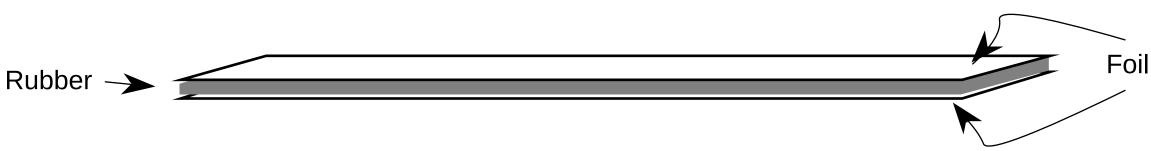
Please work the problems on separate sheets of paper and staple this sheet to the front. Read each problem carefully. Show your work and/or give explanations for *all* answers. Make sure that your answers are given with a reasonable number of sig figs and that you have included appropriate units. Check your answers for physical *reasonableness* whenever possible. I do give partial credit, but *only* if I can follow your work, so be as clear as possible about what you are doing.

1. [25 pts] *Two* charges are placed as shown in the figure at right.

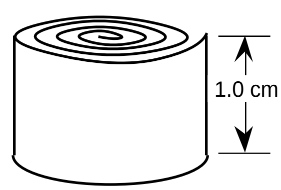


   a) [10] Find the *electric field*—magnitude and direction—*at* A.
   b) [5] Find the *potential difference* $V_B – V_A$.
   c) [5] *Now* I put a –2.0 μC charge at point A. What *force* —magnitude and direction—would be exerted on this charge?
   d) [5] How much *work* would it take to move the –2.0 μC charge from point A to point B?

2. [25 pts, 5 pts each part] Let's build a capacitor. We'll use two sheets of aluminum foil that are both 0.10 mm thick, 1.0 cm wide, and 100 cm long. Between them we'll place a layer of rubber (dielectric constant = 6.7, dielectric strength = 1.2 x 10^7 V/m, and resistivity = 2.0 x 10^{13} Ω m) that is 0.30 mm thick.



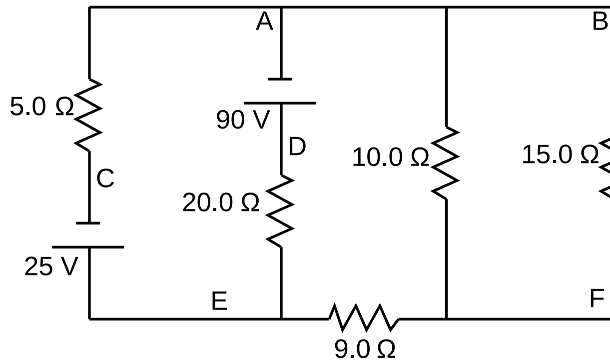
   a) What is the *capacitance* of our capacitor?
   b) The rubber dielectric is not a perfect insulator and is capable of conducting charge from one plate to the other. What is the *resistance* of the rubber to current flow from one plate to the other?
   c) If we put *too large* a voltage across the capacitor, the rubber will "break down" and discharge the capacitor plates. What is the *maximum voltage* we can apply to this capacitor?
   d) Even if we don't *overly* charge the capacitor, it will still discharge itself eventually because of the finite resistance of the rubber dielectric. What is the *time constant* for this "self-discharge" process? (Express your answer in *meaningful* units of time.)
   e) To make our capacitor less bulky we roll it into a cylinder as shown at right. What is the *diameter* of this cylinder? [Hint: The volume must still be the same as it was before we rolled it up!]



   f) (For an *extra* 5 pts) Show that the time constant for "self-discharge" is completely independent of the area or separation of the foil "plates."

Score ________/100

3. [25 pts total] Our goal in this problem is to fill out the two tables with the currents through all five resistors and the potentials of points B through F (given that the potential of point A is 0 V.) You will receive full credit for doing so as long as I can follow your method. I *suggest* that you do the following:
   a) [5 pts] Simplify the circuit as much as possible by combining parallel and series resistors.
   b) [10 pts] Use Kirchhoff's rules to analyze the simplified circuit (which should consist of only two loops) and find the currents in each of its *three* legs.
   c) [5 pts] Expand the portion of the simplified circuit that was collapsed to a single resistor during step a to find the currents through each of its resistors.
   d) [5 pts] Determine the potentials of the five points, fill out the tables, and check your results for internal consistency.



R (Ω)	I (A)
5.0	
9.0	
10.0	
15.0	
20.0	

Point	Potential (V)
A	0
B	
C	
D	
E	
F	

Short Answer

4. [10 pts] In the Earth's radiation belts, a 1 MeV electron (mass = 9.1×10^{-31} kg, charge = 1.6×10^{-19} C) moves perpendicularly to a weak 5×10^{-7} T magnetic field. What is the *radius* of its circular path? [Hint: The magnetic force (qvB) on the electron is equal to its mass times its acceleration, v^2/r. What is its speed?]

5. [10 pts] The electron in a hydrogen atom is about 5×10^{-11} m away from the proton. How much work would it take to double this separation? Express your answer in eV.

6. [10 pts] What is the *charge* on the capacitor at the instant shown in the figure at right? [Hint: What is the voltage drop across its plates at this instant?]