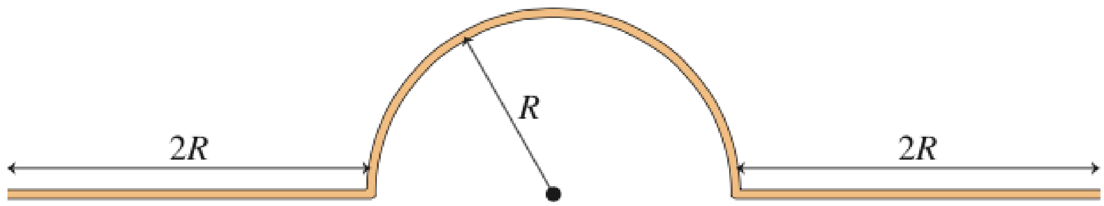
Name: ____

1. **Calculating Potential by Direct Integration (10 points).** The wire in the figure has linear charge density λ. What is the electric potential at the center of the semicircle? SHOW YOUR WORK.



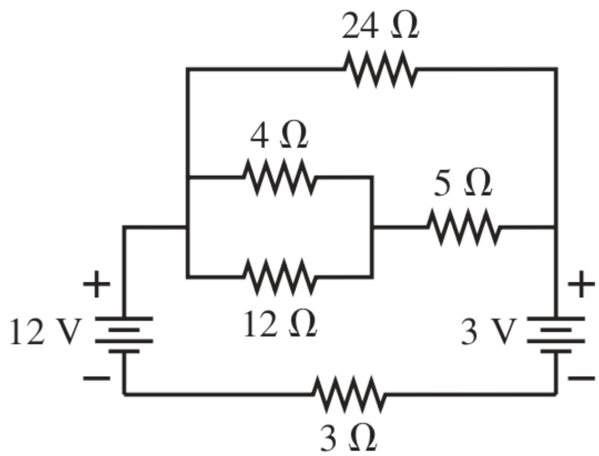
Name: ____

2. Capacitance and Energy (10 points). A capacitor has square metal plates that are 3.0 cm on a side, with a separation of about 5.0 mm. The potential difference between the plates is 25.0 V. The plates are close enough that we can ignore fringing at the ends. Under these conditions:

(a) how much charge is on each plate, and
(b) how strong is the electric field between the plates?
(c) what is the electric potential at 3.0 mm from the negative plate?
(d) If an electron is ejected at rest from the negative plate, how fast is it moving when it has travelled 3.0 mm?
(e) how fast is it moving when it reaches the positive plate?
(f) what is the energy stored in this capacitor (at 25V)?

Name: ____________________________________

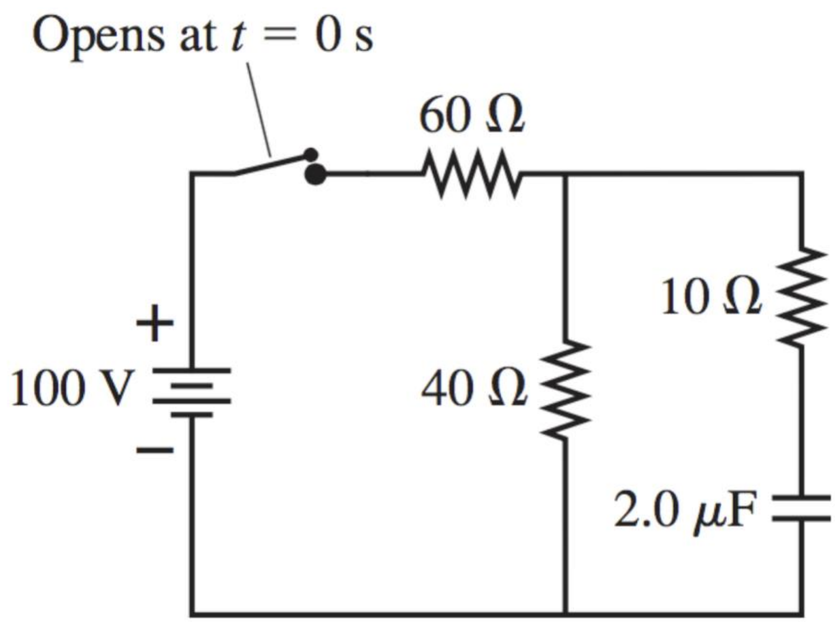
3. DC Circuits (10 points). For the circuit, find the current through and the potential difference ΔV across each resistor. Place your results in a table for ease of reading, and show – in a sequence of organized and clear diagrams – how you are calculating equivalent resistances throughout this circuit.



Name: ____

4. RC Circuits (10 points). The switch in the figure has been closed for a very long time.

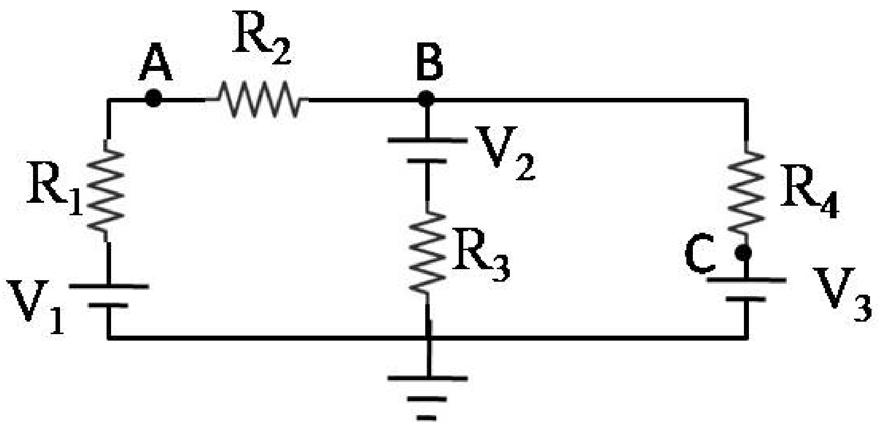
a. What is the charge on the capacitor?
b. The switch is opened at $t = 0$ s. At what time has the charge on the capacitor decreased to 10% of its initial value?
c. What is the current though the 10Ω resistor at the time you found in part (b)?



Name: ____

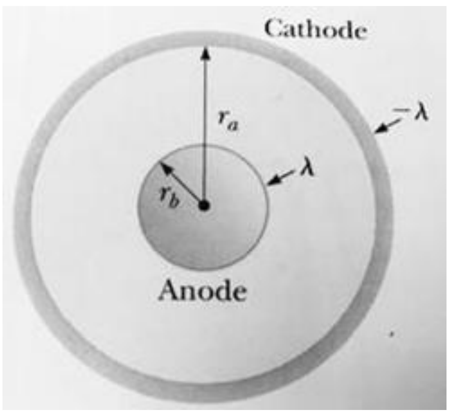
5. DC Circuits (10 points). What is the electric potential at the points A, B, and C in the circuit below? V1 = 20.0 volts. V2 = 10.0 volts. V3 = 5.00 volts. R1 = 1.00 Ω. R2 = 2.00 Ω. R3 = 3.00 Ω. R4 = 4.00 Ω.

Note that the circuit is grounded where indicated, and SHOW YOUR WORK!



Name: ____

6. Getting V from $\vec{E}$ (10 points). A Geiger-Mueller tube is a radiation detector that consists of a *very long*, hollow metal cylinder (the cathode) of inner radius r_a and a concentric thin metal rod of radius r_b (the anode), as shown in the figure. The charge per unit length on the anode is λ and the cathode is -λ, and a gas fills the space between the electrodes. When a high-energy elementary particle passes through this space, it can ionize a molecule of the gas, and the strong electric field makes the resulting ion and electron accelerate in opposite directions. They strike and ionize other molecules of gas, causing an avalanche of electrical discharge which is counted by an external circuit.



(a) Show that (in the middle of the cylinder far away from either end) the magnitude of the electric potential difference between the wire and the cylinder, ΔV, is:

$$|\Delta V| = 2k_e\lambda\ ln\left(\frac{r_a}{r_b}\right)$$

(b) The absolute value sign on ΔV is because the negative sign in the definition of ΔV, etc., can be confusing (e.g., you must define the positive direction correctly for the integral, etc.). But, given the direction of the **E** field and the charge distribution, is the inner cylinder at a higher or lower voltage than the outer cylinder? EXPLAIN YOUR ANSWER IN BULLETPOINT FORM.

Name: ____

7. Electric Potential by Direct Integration & Getting $\vec{E}$ from V (10 points). As shown in the figure below, a disc of radius R has a nonuniform surface charge density of σ = C*r*, where C is a constant and *r* is the distance from the center of the disc to a spot on the disc.

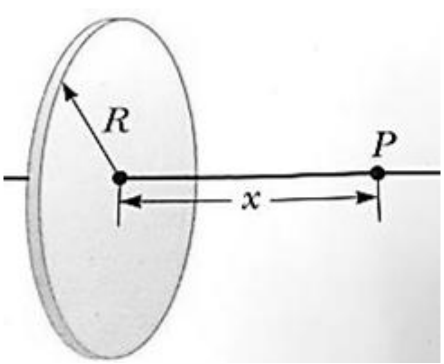
(a) What is the total charge on the disc Q_{disc}? SHOW YOUR WORK!

(b) Find, by direct integration, the electric potential at an observation point *P* located a distance *x* from the disc along its axis.

(c) Find the electric field $\boldsymbol{E}$ along the axis of the disc (Hint: $\boldsymbol{E} = -\frac{\partial V}{\partial x}\hat{\boldsymbol{\imath}}$). Your expression will be complicated, but demonstrate to me that it has the proper units for electric field.

-- OR --

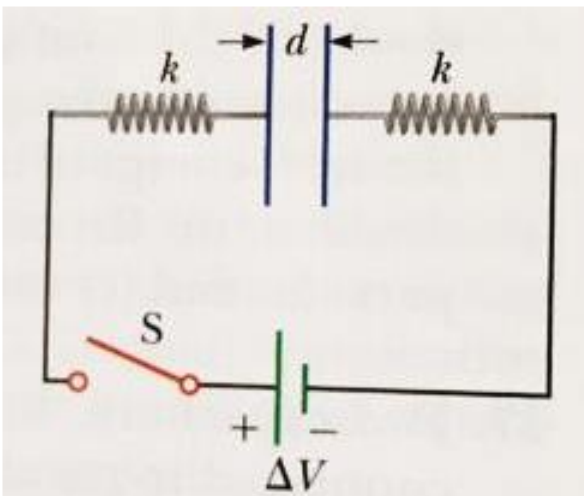
(d) Show that your expression for V from part (b) can be made to look like the V of a point charge with the Q_{disc} when x/R >>> 1. In taking this limit, you will have to "massage" your expression from part (b) in just right ways…show those steps and justify them.



Name: ____

8. Capacitance and Energy (10 points). The circuit in the figure consists of two identical parallel metal plates connected to two identical metal springs , a switch, and a 100V battery. *With the switch open*, the plates are uncharged and separated by a distance d = 8.00 mm, and have a capacitance C = 2.00 μf. When the switch is closed, the distance between the plates decreases by a factor of 0.5.

(a) How much charge collects on each of plate?
(b) What is the spring constant k for each spring?
(c) What is the force that one plate exerts on the other? SHOW YOUR WORK!!



Name: ____

9. BONUS PROBLEM (*20 points*). ***NOT DUE UNTIL 04/19 !!!***

Reconsider the capacitor and spring circuit/system of Problem #8. Let the capacitor fully charge as in problem 8(a) so that the springs are stretched and at equilibrium as in 8(a) and 8(b).

Now open the switch so that no current can flow, and replace the 100 V battery with a resistor R = 1 MΩ (1,000,000 Ω), and then close the switch at $t = 0$. As the capacitor discharges, the plates of the capacitor will "relax" back towards their initial separation of 8.00 mm.

Derive an expression for (i) the charge on the capacitor as a function of time and (ii) the separation between the plates as a function of time. Work symbolically (i.e., nevermind the numerical values given), and you will have to solve a differential equation.

This is not a simple RC circuit problem…the capacitance is changing as a function of time because the plate separation is changing. *This is a hard problem*, and it might not even have an analytical solution. In that case – to get full credit – numerically/graphically solve it using the values listed.