CAPACITOR CIRCUITS LAB

Name: ______________________________

Lab Partners: ______________________

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Goals: 1) Become familiar with capacitors, voltmeters, and making circuits

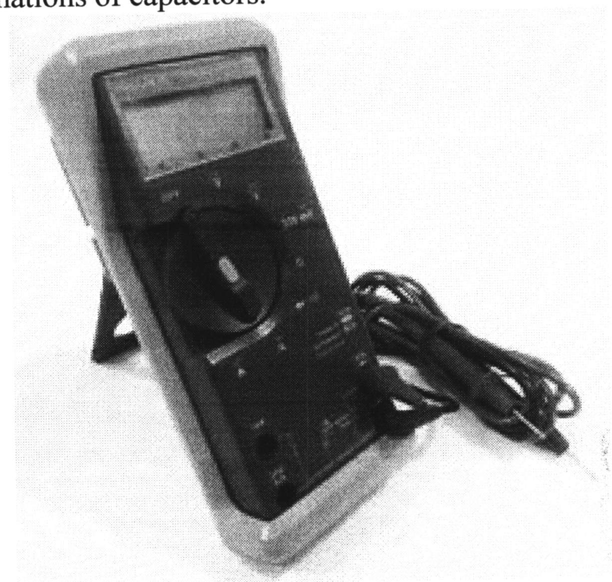
2) Understand the relationship between charge, voltage, and capacitance

3) Understand the difference between series and parallel circuits.

Note: When setting up each circuit, be sure you discharge all the capacitors first by touching both leads to the metal plate.

Part I: Using a Multimeter to Read Voltage

Multimeters are general purpose instruments used for reading voltage, current, and resistance. We will learn about current and resistance in a week or so, but today we will use a multimeter's ability to read voltage to test our understanding of combinations of capacitors.



- Set your multimeter to read steady voltages (like those produced by a battery) by turning the switch to $\overline{\overline{V}}$. The other voltage setting, $\tilde{V}$, is used to read time varying voltages and will not work for what we want to do.
- To read a voltage across a circuit element, such as a battery or a capacitor, connect the element to the multimeter voltage inputs, V and COM using the wire probes. The voltage is read with respect to the COM input. A positive reading implies that the connection V is at a higher potential than the COM input and a negative reading indicates the opposite.
- Test your understanding of the meter by reading the voltage across a battery. You should get about +1.5V if the + terminal of the battery is connected to V and the – terminal is connected to COM. Flip the battery connections and notice how the meter now reads -1.5V.
- Notation: ΔV_{ab} means the voltage between V_b and V_a, where V_a is connected to COM and V_b is connected to V. ΔV_1 means the potential across the circuit element 1.

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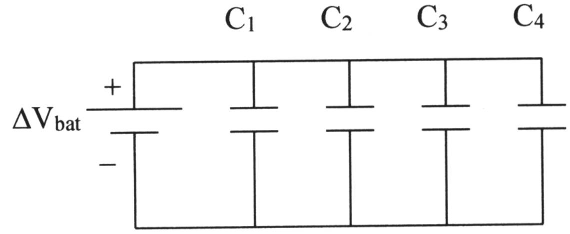
Part II: Parallel Circuit

Consider the following circuit:



In the following sections ΔV_1^{i} and Q_1^{i} represent initial values and ΔV_1^{f} and Q_1^{f} represent final values.

Knowing that capacitors in parallel have the same voltage across them, calculate or state the values listed below.

1. Take $C_1 = C_2 = 100\mu F$, $C_3 = C_4 = 330\ \mu F$, and $\Delta V_{bat} = 1.5$ V. Make sure to show your work. Your results should only make use of the values of the capacitances and the voltage of the battery.

ΔV_1^{i}	1.5 V	Q_1^{i}	150 μC
ΔV_2^{i}	1.5 V	Q_2^{i}	150 μC
ΔV_3^{i}	1.5 V	Q_3^{i}	495 μC
ΔV_4^{i}	1.5 V	Q_4^{i}	495 μC

$C = \frac{Q}{\Delta V}$

Capactors in parallel share a common ΔV.

So: $\Delta V_1^{i} = \Delta V_2^{i} = \Delta V_3^{i} = \Delta V_4^{i} = \Delta V_{bat} = 1.5V$

$Q = C\Delta V \Rightarrow Q_1^{i} = C_1 \Delta V_{bat},\ Q_2^{i} = C_2 \Delta V_{bat},\ Q_3^{i} = C_3 \Delta V_{bat},\ Q_4 = C_4 \Delta V_{bat}$

2. Do the capacitors with the larger capacitance have larger or smaller charge? Why?

Bigger C separates more charge thereby storing more energy!

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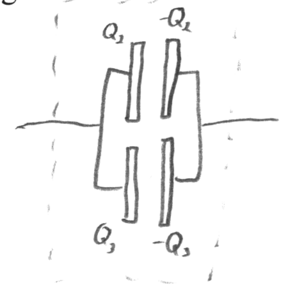
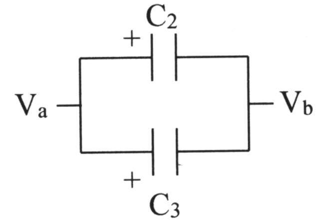
3. Now imagine you took C_2 and C_3 from the circuit and, without discharging the capacitors, created the following circuit with the positive plates oriented as shown at right. Calculate the following values:

ΔV_{ab}	1.5V
Q_2^f	150μC
Q_3^f	495μC





$C_{eff} = C_2 + C_3$, $Q_{Tot} = Q_2 + Q_3$

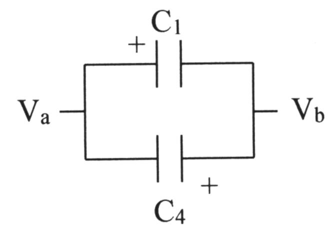
$$C_{eff} = \frac{Q_{tot}}{\Delta V_{ab}} \Rightarrow \Delta V_{ab} = \frac{Q_{tot}}{C_{eff}} = \frac{Q_2 + Q_3}{C_2 + C_3} = \frac{645\mu C}{430\mu F} = \boxed{1.5\,V}$$

4. What happens to the charges?

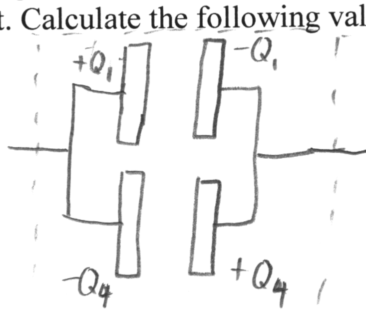
Same ΔV as before, therefore same charge.

Nothing changes.

5. Now imagine you took C_1 and C_4 from the circuit and, without discharging, created the following circuit with the positive plates oriented as shown at right. Calculate the following values:



ΔV_{ab}	0.82V
Q_1^f	82μC
Q_4^f	271μC



C_{eff}

$C_{eff} = C_1 + C_4$

$Q_{tot} = Q_4 - Q_1$

$$\Delta V_f = \frac{Q_{tot}}{C_{eff}} = \frac{Q_4 - Q_1}{C_1 + C_4}$$

$$\Delta V_f = \frac{345\mu C}{430\mu F} = 0.82\,V$$

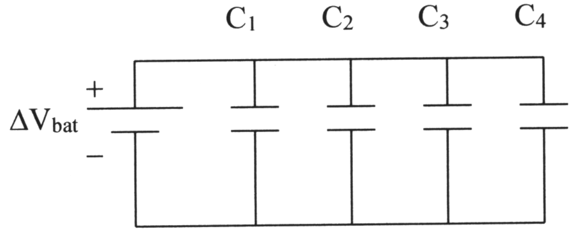
$$Q_1^f = C_1 \Delta V_1^f = (100\mu F)(0.82V) = 82\mu C$$
$$Q_2^f = C_2 \Delta V_2^f = (330\mu F)(0.82V) = 271\mu C$$

6. What happens to the charges?

They get redistributed on the plates to achieve the same potential.

7. Set up the circuit, and measure these potential differences:

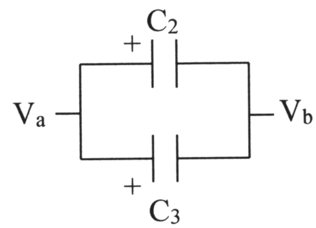
ΔV_{bat}	1.52 V
ΔV_1^i	1.52 V
ΔV_2^i	1.52 V
ΔV_3^i	1.52 V
ΔV_2^i	1.52 V



8. Did you get what you expected (from question 1)?

Yes!

9. Without discharging C_2 and C_3, create the following circuit, with the positive plates oriented as shown at right.



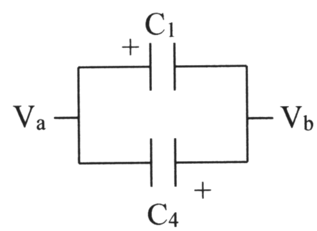
Measure ΔV_{ab}.

ΔV_{ab}	1.50

10. Did you what you expected (from question 3)? Explain.

Yes! The Voltage stayed the same because the charges did not redistribute

11. Now take C_1 and C_4 (without discharging them) and create a similar circuit, but this time with the positive plates connected as shown at right.



Measure ΔV_{ab}.

ΔV_{ab}	0.71 V

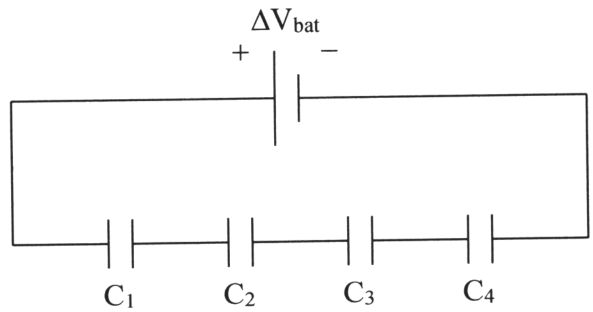
12. Did you get what you expected (from question 5)? Explain.

close... 0.1 volt difference. Capacitor precision?

Charges redistribute to achieve the same potential on the plates. New distribution yields lower ΔV.

Part III: Series Circuit

Consider the following circuit:



Knowing that capacitors in series have the same charge across them, calculate or state the values listed below.

13. Take $C_1 = C_2 = 100\mu F$, $C_3 = C_4 = 330\ \mu F$, and $\Delta V_{bat} = 1.5$ V. Your results should only make use of the values of the capacitances and the voltage of the battery.

ΔV_1^i	0.576	Q_1^i	57.6 μC
ΔV_2^i	0.576	Q_2^i	57.6 μC
ΔV_3^i	0.175	Q_3^i	57.6 μC
ΔV_4^i	0.175	Q_4^i	57.6 μC

$C_{eff} = \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_4}\right)^{-1}$

$\Delta V_{tot} = \Delta V_1^i + \Delta V_2^i + \Delta V_3^i + \Delta V_4^i = \Delta V_{bat}$

$Q = C_{eff} \cdot \Delta V_{tot} = \left(\frac{2}{100\mu F} + \frac{2}{330\mu F}\right)^{-1} \cdot (1.5V) = 57.6\mu C$ ← on all caps.

$\Delta V_1^i = \frac{Q}{C_1} = \frac{57.6\mu C}{100\mu F} = 0.576V$ → same on C_2

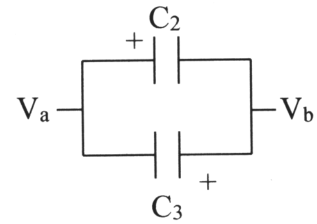
$\Delta V_3^i = \frac{Q}{C_3} = \frac{57.6\mu C}{330\mu F} = 0.175\ V$ → same on C_4

14. Do the larger capacitors have larger or smaller potential differences? Why?

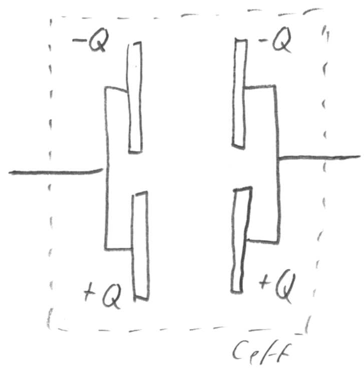
Smaller. Same charge → lower charge density

→ lower potential difference

15. Now imagine you took C_2 and C_3 from the circuit and, without discharging the capacitors, created the following circuit with the positive plates oriented as shown at right. Calculate the following values:



ΔV_{ab}	0V
Q_2^f	0V
Q_3^f	0V



$$\Delta V = \frac{Q}{C_{eff}} = 0V$$

$$Q_{tot} = Q - Q = 0$$

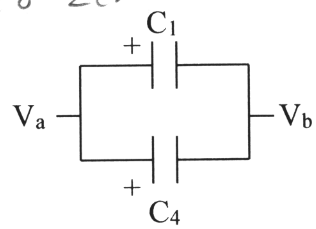
$$Q_2 = C_2 \Delta V = 0V$$

$$Q_3 = C_3 \Delta V = 0V$$

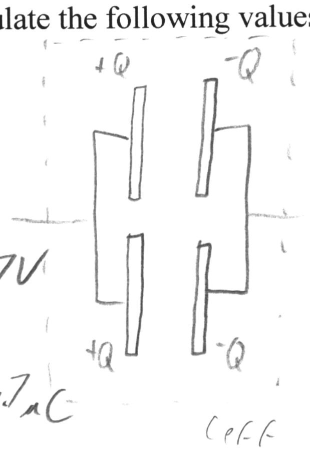
16. What happens to the charges?

They redistribute to make $\Delta V = 0$ accross connected plates. In this case, Q_{net} goes to zer

17. Now imagine you took C_1 and C_4 from the circuit and, without discharging, created the following circuit with the positive plates oriented as shown at right. Calculate the following values:



ΔV_{ab}	0.267V
Q_1^f	26.7μC
Q_4^f	88.1μC



$$Q_{tot} = 2Q$$

$$C_{eff} = C_1 + C_4$$

$$\Delta V = \frac{Q}{C_{eff}} = \frac{2(57.6\mu C)}{430\mu F} = .267V$$

$$Q_1 = C_1 \Delta V = (100\mu F)(0.267) = 26.7\mu C$$

$$Q_4 = C_4 \Delta V = (330\mu F)(0.267) = 88.1\mu C$$

18. What happens to the charges?

They redistribute to make $\Delta V = 0$ between connected plates.

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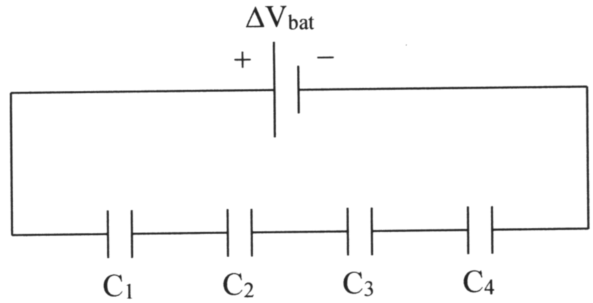
19. Set up the circuit (discharge each capacitor and connect the battery last), and measure these potential differences:

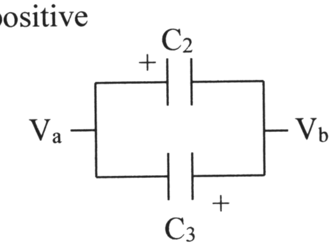
ΔV_{bat}	1.52 V
ΔV_1^i	0.6 V
ΔV_2^i	0.6 V
ΔV_3^i	0.144
ΔV_2^i	0.216



20. Did you get what you expected (from question 13)?

Close ... Capacitor precision ...

21. Without discharging C_2 and C_3, create the following circuit, with the positive plates oriented as shown at right.



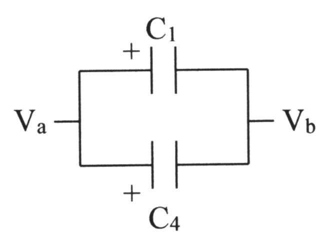
Measure ΔV_{ab}.

ΔV_{ab}	.003 V

22. Did you get what you expected (from question 15)? Explain.

almost zero!

23. Now take C_1 and C_4 (without discharging them) and create a similar circuit, but this time with the positive plates connected as shown at right.



Measure ΔV_{ab}.

ΔV_{ab}	0.313 V

24. Did you get what you expected (from question 17)? Explain.

Very close... within tolerance of shoddy capacitors.