Course and Section_____   Names _____

Date_____   _____

CAPACITOR SIMULATION

Introduction

In class we learned how capacitors store charge and can be combined together. The charge stored on a capacitor is given as,

$$Q = C \Delta V$$

The schematic symbol of a capacitor is has two vertical (or horizontal) lines a small distance apart (representing the capacitor plates) connected to two lines representing the connecting wires or leads).
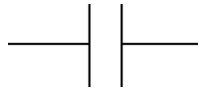
Capacitors can be connected in an electronic circuit in a series or parallel combination.

Series:
In a series connection the components are connected at a single point, end to end as shown below:
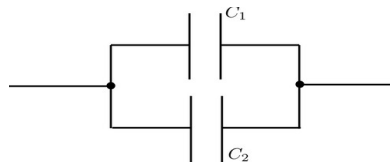

For a series connection, the charge on each capacitor will be the same while the voltage across each capacitor will add. Using this we can find the equivalent capacitance, C_{EQ}

$$\frac{1}{C_{EQ}} = \frac{1}{C_1} + \frac{1}{C_2}$$

Parallel:
In the parallel connection, the components are connected together at both ends as shown below:

For a parallel connection, the voltage across are the same, but the charges will add. Using this we can find the equivalent capacitance C_{EQ}

$$C_{EQ} = C_1 + C_2$$

Submit your answers using Blackboard.
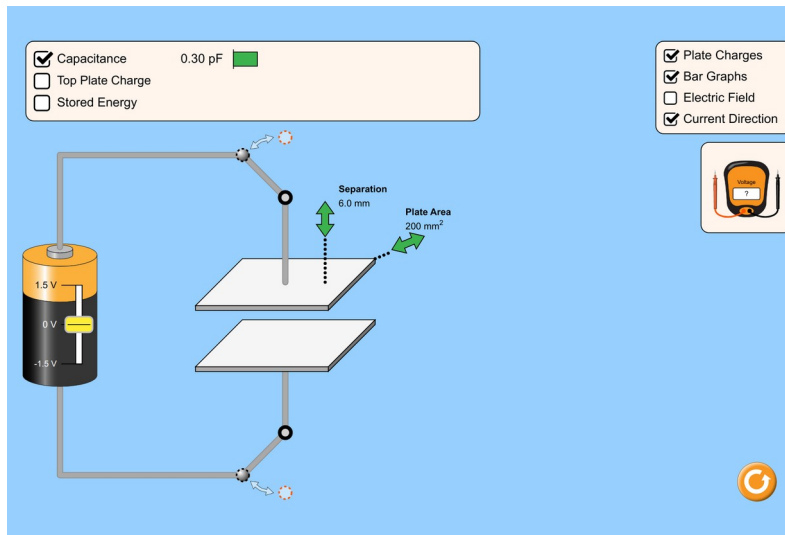
1 – Capacitor Basics

For a parallel plate capacitor the capacitance can be written as,

$$C = \frac{\epsilon_0 A}{d}$$

where A is the area of the plates and d separation between the two plates.
Open the following simulation and select capacitance.
(https://phet.colorado.edu/sims/html/capacitor-lab-basics/latest/capacitor-lab-basics_en.html)

Use the slider on the battery to set the potential difference and click the boxes to show top plate charge and stored energy. Start with 0 V
1. What is the capacitance? (pF) p-pico 10^{-12}
2. What is the charge on the top plate?
3. What is the stored energy?
4. First decrease, then increase the area of the plates. How does the capacitance change?
5. First decrease, then increase the separation of the plates. How does the capacitance change?

As you increase the voltage of the battery to 1.5 V are the following statements true?
6. As the voltage increases the capacitance grows in magnitude.
7. As the voltage increases the stored charge decreases in magnitude.
8. As the voltage increases the stored energy remains constant.

Keep the voltage at 1.5 V. If you first decrease, then increase the area of the plates:
9. How does the capacitance change?
10. How does the charge change?
11. How does the energy stored change?

Keep the voltage at 1.5 V. Open the switch to disconnect the capacitor from the battery. Is the following statement true?
12. Removing the capacitor from the applied voltage causes the capacitor to quickly drain all of its energy.

2 – Dielectric Materials

We can alter the capacitance a capacitor by placing a dielectric material between the plates. The dielectric material changes the permittivity ϵ_0 to ϵ. To see how this will effect our capacitor open the link (https://phet.colorado.edu/en/simulations/capacitor-lab) and run the java applet (you might have to download it first depending on your browser and OS). Open the applet and click on the the dielectric tab at the top. You'll see the following screen,
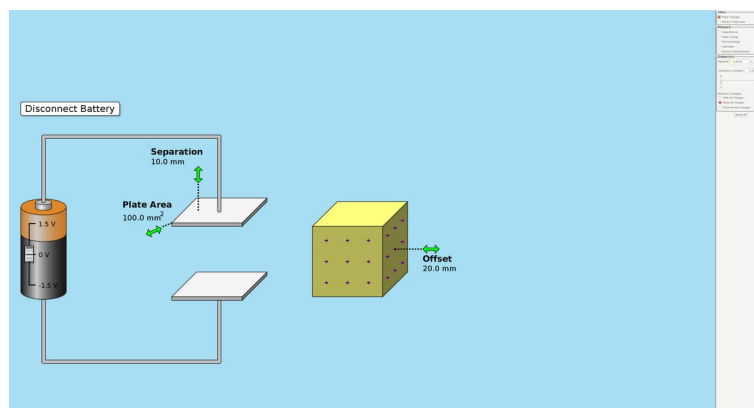
You'll see a chunk of yellow dielectric material. You can move the material in and out of the plates. On the right hand side you will see a button for total energy, total charge and capacitance click on those to display a meter. Below these buttons you will see an option to change the dielectric constant.

Set the dielectric constant to 1 and turn the battery on to 1.5V. Take note off the values of the charge, energy and capacitance. Now slide the dielectric material between the plates.

Are the following statements true?
13. Inserting the dielectric material between the plates increases the charge.
14. Inserting the dielectric material between the plates increases the stored energy.
15. Inserting the dielectric material between the plates increases the capacitance of the capacitor.

Now increase the dielectric constant to 3.5

Are the following statements true?
16. Inserting the dielectric material between the plates increases the charge.
17. Inserting the dielectric material between the plates increases the stored energy.
18. Inserting the dielectric material between the plates increases the capacitance of the capacitor.


3 – Series combinations

Open the link (https://phet.colorado.edu/en/simulation/legacy/circuit-construction-kit-ac) and run the java applet (you might have to download first it depending on your browser and OS). Select Lab. This simulation will let you construct circuits The circuit elements are displayed in bar on the left hand side and can be dragged into the blue canvas. Once you have a circuit element in the canvas it can be modified by left clicking on the object. This will let you change the

value of voltage of batteries or the capacitance of a capacitor. Click the voltmeter button. This will give you a meter to measure the voltage across elements in your circuit. To do this move the two probes (1 red 1 black) to touch each side of the wire connecting to a circuit element, the voltmeter will display the voltage across that object. In the figure below you see a capacitor connected to a batter (DC voltage).
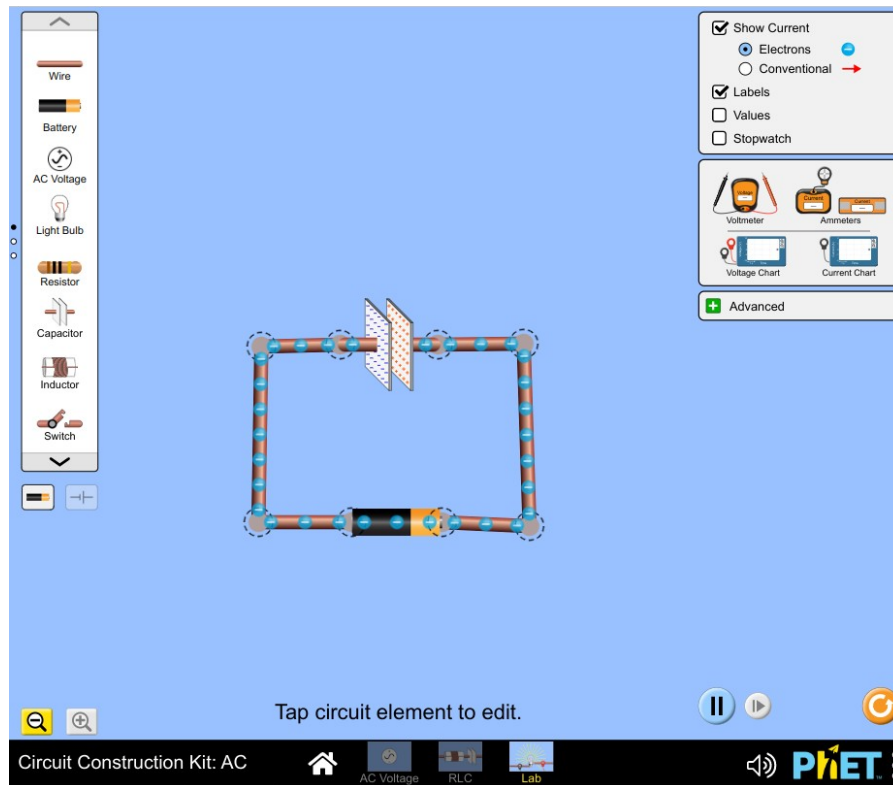
Create the circuit shown in the figure below with $C_1 = 0.05F$, $C_2 = 0.2F$, $V = 10V$
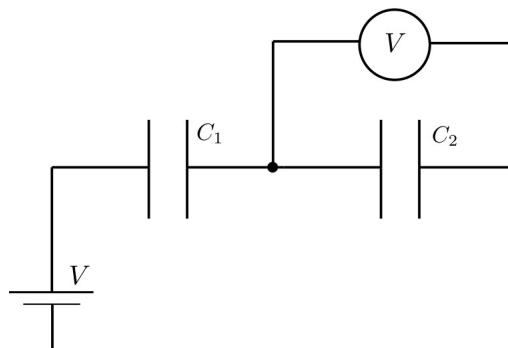
**Make sure you set the values of the capacitors before you hook them up to the battery**
If you need to disconnect the battery. Then change capacitance and then right click to discharge before you reconnect the battery.
Using the voltmeter/multimeter

19. What is the voltage measured across C_1? (V)
20. What is the voltage measured across C_2? (V)
21. What is the charge stored on C_1? (C)
22. What is the charge stored on C_2? (C)
23. What is the equivalent capacitance C_{eq} in this case? (F)
24. What is the charge stored on the equivalent capacitor? (C)

4 – Series Parallel Combination

Construct the following circuit in the circuit simulation. To do so attach a third capacitor in parallel to C_2.
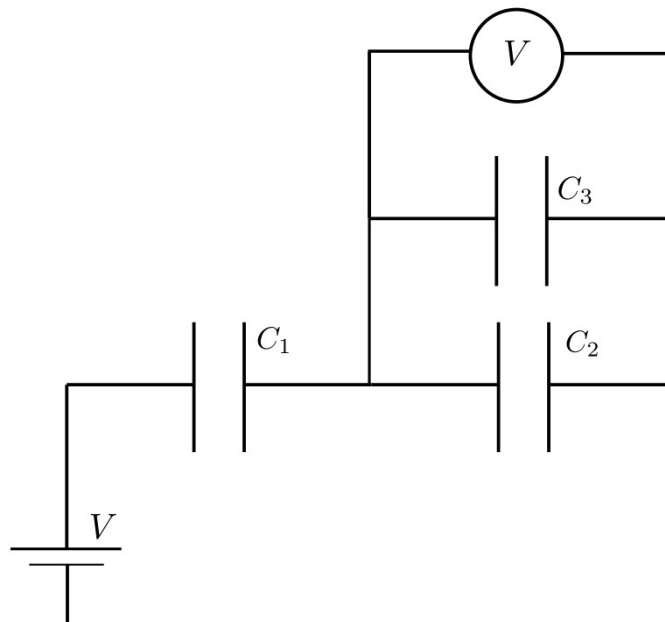
Choose the following: $C_1 = 0.1F$, $C_2 = 0.1F$, $C_3 = 0.15F$, $V = 10V$

Using the voltmeter/multimeter
25. What is the voltage measured across C_1? (V)
26. What is the voltage measured across C_2? (V)
27. What is the voltage measured across C_3? (V)
28. Calculate the charge stored on C_1? (C)
29. Calculate the charge stored on C_2? (C)
30. Calculate the charge stored on C_3? (C)
31. What is the equivalent capacitance C_{23} of the parallel combination of C_2 and C_3? (F)
32. What is the equivalent capacitance C_{eq} of the whole system? i.e. the series combination of C_1 with C_{23}? (F)
33. Calculate the charge stored on the equivalent capacitor $C_{23.}$ (C)
34. Calculate the charged stored on the equivalent capacitance C_{eq} in this case. (C) i.e. the total charge