**The Capacitance of a parallel Plate Capacitor**

**PURPOSE**: In this lab, you will explore how

* The capacitance varies with the separation between the plates
* The capacitance varies with the area of the plates
* The dielectric affects the stored charge, energy, and voltage between the plates of the capacitor, when it is connected or disconnected from the battery

This lab is based on ***Capacitor Lab*** simulator that can be accessed at

<https://phet.colorado.edu/en/simulation/legacy/capacitor-lab>

Click on the picture to download the simulator file. You will be prompted to download Java in to open it. In this lab, you will be using the middle tab: ***Dielectric***.

**PART I: Capacitance**

**DISCUSSION**: When a capacitor is connected to an EMF (*E*), the plates attain charge from the terminals of the battery. The amount of charge is governed by the geometry of the capacitor. For a parallel plate capacitor, the capacitance is given by



where *A* is the effective plate area (the area effectively overlapping, *d* is separation of the plates,  is electric permittivity of free space, and *K* is the dielectric constant for the insulating material in the inner plate region.

In this lab, you will investigate this relation. First you will keep the separation constant and vary the area. In this case, a plot of C against A should be a straight line with the slope given by



Then, you will keep the area contact and vary the separation. Here a plot of C against  should be a straight line with the slope given by



**PROCEDURE:**

1. Select “paper” from the choice of dielectrics in the menu on the right-hand side. Insert the dielectric completely inside the capacitor. Check the “Capacitance” to see the capacitance meter. The battery could be either connected or disconnected for this part.
2. Record the values of the plates’ area *A*0 (initially, it should be the smallest possible), distance between the plates *d*0 (initially, it should be the largest possible), and corresponding capacitance.
3. Slowly increase the plates’ area and measure the corresponding capacitance 4 more times. Record your results in the table. It is recommended to use SI units for all measurements.

|  |  |  |
| --- | --- | --- |
|  | *A* | *C* |
| 0 |  |  |
| 1 |  |  |
| 2 |  |  |
| 3 |  |  |
| 4 |  |  |

1. Use Excel or other software of your choice to plot capacitance as dependent variable against the area. Then, use linear regression to draw the best-fit line (also called trendline) to approximate the data with the linear model. Insert the screenshot of your graph below. It should contain:
* Labeled axes and units
* Data points and best-fit line (remember that the best-fit line does not necessarily go through all the points, but approximates the trend)
* Equation of the best-fit line
1. Restore the area to initial. Slowly decrease the separation between the plates and measure the corresponding capacitance 4 more times. Record your results in the table below, along with the reciprocal of the separation.

|  |  |  |  |
| --- | --- | --- | --- |
|  | *d* | $$\frac{1}{d}$$ | *C* |
| 0 |  |  |  |
| 1 |  |  |  |
| 2 |  |  |  |
| 3 |  |  |  |
| 4 |  |  |  |

1. Use Excel or other software of your choice to plot capacitance as dependent variable against the *reciprocal* of the separation between the plates. Then, use linear regression to draw the best-fit line (also called trendline) to approximate the data with the linear model. Insert the screenshot of your graph below. It should contain:
* Labeled axes and units
* Data points and best-fit line (remember that the best-fit line does not necessarily go through all the points, but approximates the trend)
* Equation of the best-fit line

**CONCLUSIONS:**

* Summarize, based on your graphs, how the capacitance of a parallel-plate capacitor depends on area of the plates and the separation between the plates.
* Use the slope of the one of the graphs to calculate *K*, the dielectric constant of paper. Show your calculations below. Compare it with the value given by the simulator and find the percent error.

**Part 2: Effect of the dielectric on the capacitor**

1. Revert the values of the plates’ area and the plate separation to the original and remove the dielectric entirely from the capacitor. Show the capacitance, charge, voltage, and energy meters by checking off approximate boxes on the right side of the simulator. (You will have to “connect” the voltmeter – place the red electrode on the plate with the positive charge, and the black electrode on the plate with the negative charge.)
2. Connect the battery and turn on the battery voltage to about 1 V. You might have to zoom in or out the scale of some of the meters to measure the values effectively.
3. Slowly insert the dielectric inside the capacitor. As the dielectric fills more space in the capacitor, observe and record the changes in
* Capacitance
* Charge
* Voltage between the plates
* Energy stored by the capacitor
1. Remove the dielectric entirely and disconnect the battery. Repeat step 3 and record the changes in
* Capacitance
* Charge
* Voltage between the plates
* Energy stored by the capacitor

**Conclusion:** Describe and explain your observations using the law of conservation of charge and the properties of the conductors.

**Questions:**

1. If the battery is connected, is the energy of capacitor-battery system conserved throughout the process of inserting the dielectric? Explain the changes of energy, if any.
2. If the battery is disconnected, does the energy stored in the capacitor remain constant as the dielectric is inserted? Explain the changes of energy, if any.