Physics 196 VirtuLab 5: Capacitance

Name:____

Lab Day:______________________________________

Overview

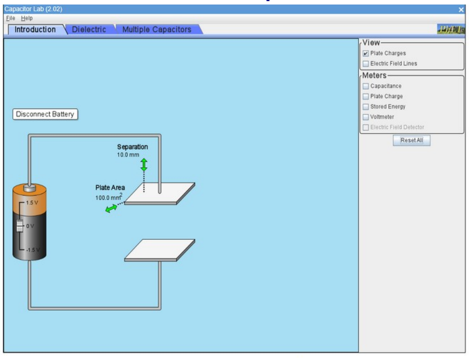
Examine the behavior of capacitors in series and parallel arrangements. See how charge, electric field and energy storage are related.

Mathematical Models and Assumptions

Charge can be related to an electric field and the change in potential can be related to an electric field. So, potential and charge can be related. The proportionality constant between electric charge and electric potential in a system is capacitance. It depends solely on system geometry and materials. The capacitance of a parallel plate system is given by $C=\frac{\epsilon_0 A}{d}$, where A is the surface area of the parallel plates and d is the separation distance.

Data Collection

Visit this URL: https://phet.colorado.edu/sims/cheerpj/capacitor-lab/latest/capacitor-lab.html?simulation=capacitor-lab



There are three tabs at the top of the simulation page. Begin by selecting the 'Introduction' tab. Then under the 'View' menu: Deselect 'Plate Charges'. Under the 'Meters' menu: Select 'Capacitance'. Click on the 'Disconnect Battery' button.

Part I. Capacitance and Plate Characteristics

Use the slider to increase the plate area. Record the value in Data Table One. Do not change this value. Verify the value of the plate separation is 10 mm and record the corresponding value on the capacitance meter in the data table. Next, change the plate separation by about 1 mm or slightly less. Record the new separation distance and the new capacitance value in the data table. Repeat this process until the data table is complete. Note that the scale of the capacitance meter can be changed using the 'zoom in/out' buttons next to the meter.

Data Table One

Plate Area (mm^2)	Separation (mm)	Capacitance (F)
	10	0.89e-13
[redacted]		

Physics 196 VirtuLab 5: Capacitance

Use a Cartesian coordinate system to construct a graph of reciprocal capacitance as a function of plate separation distance, i.e. $\frac{1}{C}(d)$. Use the slope of the graph to obtain the value for ϵ_0 . Show your work, with units in the space below.

Calculate the percent difference (or error, as appropriate) between the value obtained from your graph and the standard accepted value. Show all work, with units, in the space below.

Part II. Capacitance and Dielectrics

Select the 'Dielectric' tab at the top of the simulation screen. Use the slider on the battery to set a value of +1.5 V. Under the 'Meters' menu, select 'Capacitance', 'Plate Charge' and 'Stored Energy'. Record the initial values in Data Table Two. Leave capacitor separation and plate area set to the default values.

Drag the dielectric between the capacitor plates until the offset distance is 8 mm. Record the meter readings. Change the offset distance to the values indicated and complete the data table.

Data Table Two

Offset (mm)	Capacitance (F)	Charge (C)	Energy (J)
10	0.89e-13	0.13e-12	1.00e-13
8	1.58e-13	0.24e-12	1.78e-13
6	2.31e-13	0.35e-12	2.60e-13
4	3.00e-13	0.45e-12	3.38e-13
2	3.73e-13	0.56e-12	4.20e-13
0	4.43e-13	0.66e-12	4.98e-13

Physics 196 VirtuLab 5: Capacitance

You will notice that the charge density on the top plate increases as the dielectric is inserted. Using complete sentences in the space below, explain why this is a consequence of the battery's constant potential.

As the charge increases while the dielectric is inserted between the plates. This is because the battery is connected between the plates. When the dielectric is inserted then E between the two plates decreases because of the induced charges on the dielectric. This decreased E will tend to decrease potential between the plates but since the purpose of the battery is to maintain a constant potential difference between the pates. Moreover, to maintain the potential difference the battery supplies move charge to the plates to keep the same E as before the dielectric was inserted.

Click on the 'Reset All' button. Use the slider on the battery to set a value of +1.5 V. Under the 'Meters' menu, select 'Capacitance', 'Plate Charge' and 'Stored Energy'. Record the initial values in Data Table Two. Leave capacitor separation and plate area set to the default values. Now click 'Disconnect Battery'.

Drag the dielectric between the capacitor plates until the offset distance is 8 mm. Record the meter readings. Change the offset distance to the values indicated and complete the data table.

Data Table Two

Offset (mm)	Capacitance (F)	Charge (C)	Energy (J)
10	0.89e-13	0.13e-12	1.00e-13
8	1.58e-13	0.13e-12	0.56e-13
6	2.31e-13	0.13e-12	0.38e-13
4	3.00e-13	0.13e-12	0.29e-13
2	3.73e-13	0.13e-12	0.24e-13
0	4.43e-13	0.13e-12	0.20e-13

You will note that the stored energy decreases as the dielectric is inserted. Using complete sentences in the space below, explain why this allows us to predict that the dielectric will experience a force that pulls it into the capacitor.

We know that force is given by F = - dU/dx. Now in this case, since energy stored in the capacitor (which resembles the potential energy of the formula) decreases as the offset decreases (which can be resembled as the x in the formula), we can predict that the dielectric experiences a net force which will be negative. The negative sign indicates that the force is attractive in nature.