Capacitors

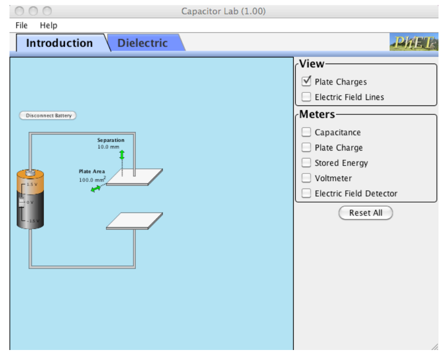
In this experiment you will investigate fundamental properties of capacitors and circuits involving capacitors.

PROCEDURE

1. Properties of a capacitor.

In this experiment you will use a Java simulation to investigate fundamental properties of a parallel plate capacitor.

Open Intro I folder and double click on applab_capacitor1.jar file. After the applet starts you should see the following window (you have seen this window when doing your pre-lab).



Using the right-bottom corner of the window you can stretch it up for better visibility.

A. Charging a capacitor.

Disconnect Battery (by clicking on the control).

Uncheck Plate Charges.

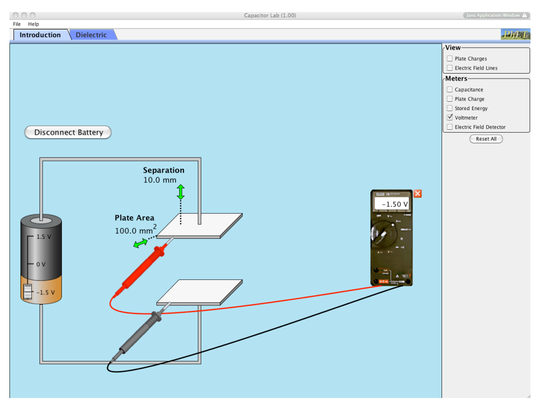
Check Voltmeter.

Attach the red probe to the top plate and the black one to the bottom plate.

Slide the slider on the battery all the way *down*.

Connect the battery.

Now you should see the following picture.



In the space below, draw the capacitor and show some electric field lines inside it.

Question 1. What is the polarity of the charges on the top plate of the capacitor?

Check in the View on Plate Charges and check your answer.

B. Changing area.

1) Predict: which of the physical variables listed below will change when you change the area of the capacitor plates (while keeping the battery connected). Mark all that will change.

[ ] Capacitance

[ ] Charge on the plates

[ ] Voltage across the plates

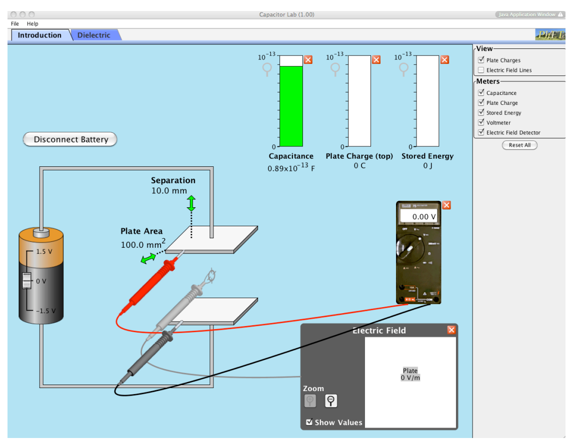
[ ] Electric field between the plates

[ ] Energy stored in the capacitor

Predict: in which direction will the *electrons* be traveling when you will be increasing the area of the plates? Check your prediction below.

[ ] clockwise [ ] counterclockwise [ ] there will be no moving electrons

Check all the meters on, like in the picture on the right (your battery should have the slider all the way down).



Slowly increase the area of the plates by dragging the little double arrow away from the plates and observe the changes. Fill in the table below. Check your predictions and explain any deviations from your observations. If your meter bars are overfilled, click on  to scale them back.

Pay attention to units in the table!

A (mm^2)	d (mm)	κ	C (pF)	|V| (V)	|Q| (pC)	|E| (V/m)	U (pJ)
100	10						
400	10						

Question 2. When a capacitor is connected to a battery and you halve its area, which other variable will also halve?

2) Click on Reset All (confirm "Yes" when asked); slide the battery slider all the way up, and disconnect the battery.

Predict: which of the physical variables listed below will change when you change the area of the capacitor plates (while keeping the battery disconnected)? Mark all that will change.

[ ] Capacitance

[ ] Charge on the plates

[ ] Voltage across the plates

[ ] Electric field between the plates

[ ] Energy stored in the capacitor

Predict: in which direction will the *electrons* be traveling while you increase the area of the plates? Check your prediction below.

[ ] clockwise [ ] counterclockwise [ ] there will be no moving electrons

Check all the meters on (do not forget to connect the voltage probes to the plates; make sure the field probe is between the plates).

Slowly increase the area of the plates by dragging the little double arrow away from the plates and observe the changes. Fill in the table below. Check your predictions and explain any deviations from your observations.

Pay attention to units in the table!

A (mm^2)	d (mm)	κ	C (pF)	$\lvert V \rvert$ (V)	$\lvert Q \rvert$ (pC)	$\lvert E \rvert$ (V/m)	U (pJ)
100	10						
400	10						

Question 3. When a charged capacitor is *disconnected* from a battery and the area of the plates is *decreasing*; describe what is happening to the electric field in the capacitor and explain why.

C. Changing separation.

1. Click on Reset All (confirm "Yes" when asked); slide the battery slider all the way up, and disconnect the battery; maximize the area of the plates.

Predict: which of the physical variables listed below will change when you change the separation between the capacitor plates (while keeping the battery disconnected)? Mark all that will change.

[ ] Capacitance

[ ] Charge on the plates

[ ] Voltage across the plates

[ ] Electric field between the plates

[ ] Energy stored in the capacitor

Predict: in which direction will the *electrons* be traveling when you will be increasing the separation between the capacitor plates? Check your prediction below.

[ ] clockwise [ ] counterclockwise [ ] there will be no moving electrons

Check all the meters on (do not forget to connect the voltage probes to the plates; make sure the field probe is between the plates).

Slowly change the separation between the plates by dragging the little double arrow down (or up) and observe the changes. Fill in the table below. Check your predictions and explain any deviations from your observations.

Pay attention to units in the table!

A (mm^2)	d (mm)	κ	C (pF)	|V| (V)	|Q| (pC)	|E| (V/m)	U (pJ)
400	10						
400	5						

2. Click on Reset All (confirm "Yes" when asked); slide the battery slider all the way up, and do not disconnect the battery; maximize the area of the plates.

Predict: which of the physical variables listed below will change when you change the separation between the capacitor plates (while keeping the battery connected)? Mark all that will change.

[ ] Capacitance [ ] Charge on the plates

[ ] Voltage across the plates [ ] Electric field between the plates

[ ] Energy stored in the capacitor

Predict: in which direction will the *electrons* be traveling while you increase the separation between the capacitor plates? Check your prediction below.

[ ] clockwise [ ] counterclockwise [ ] there will be no moving electrons

Check all the meters on (do not forget to connect the voltage probes to the plates; make sure the field probe is between the plates).

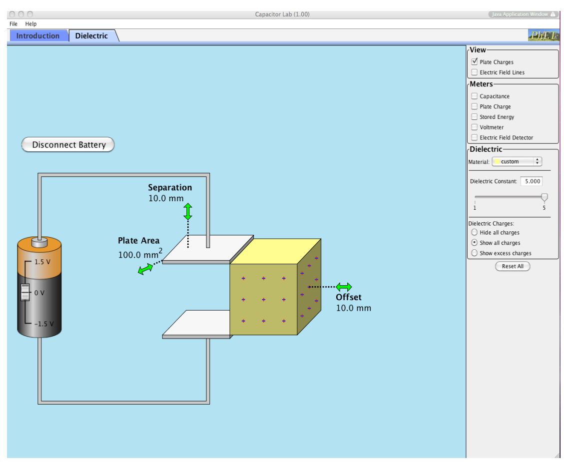
Slowly change the separation between the plates by dragging the little double arrow down (or up) and observe the changes. Fill in the table below. Check your predictions and explain any deviations from your observations.

Pay attention to units in the table!

A (mm^2)	d (mm)	κ	C (pF)	|V| (V)	|Q| (pC)	|E| (V/m)	U (pJ)
400	10						
400	5						

Question 4. When a capacitor is *connected* to a battery and the separation between the plates is *increasing*; describe what is happening to the electric field in the capacitor and explain why.

D. Changing dielectric



Click on the Dielectric tab to switch to another window.

1. Slide the battery slider all the way up, and disconnect the battery.

Predict: which of the physical variables listed below will change when you fill the capacitor with a dielectric (while keeping the battery disconnected)? Mark all that will change.

[ ] Capacitance

[ ] Charge on the plates

[ ] Voltage across the plates

[ ] Net electric field between the plates

[ ] Energy stored in the capacitor

Predict: in which direction will the *electrons* be traveling when you fill the capacitor with a dielectric? Check your prediction below.

[ ] clockwise [ ] counterclockwise [ ] there will be no moving electrons

Check all the meters on (do not forget to connect the voltage probes to the plates; make sure the field probe is between the plates and within a dielectric; the field you are interested in is the *net* field!).

Slowly insert the dielectric between the plates by dragging the little double arrow to the left and observe the changes. Fill in the table below. Check your predictions and explain any deviations from your observations.

Pay attention to units in the table!

A (mm^2)	d (mm)	κ	C (pF)	|V| (V)	|Q| (pC)	|E| (V/m)	U (pJ)
100	10	1					
100	10	5 (filled completely)					

2. Click on Reset All (confirm "Yes" when asked); slide the battery slider all the way up, and do not disconnect the battery.

Predict: which of the physical variables listed below will change when you fill the capacitor with a dielectric (while keeping the battery connected)? Mark all that will change.

[ ] Capacitance

[ ] Charge on the plates

[ ] Voltage across the plates

[ ] Net electric field between the plates

[ ] Energy stored in the capacitor

Predict: in which direction will the *electrons* be traveling when you fill the capacitor with a dielectric? Check your prediction below.

[ ] clockwise [ ] counterclockwise [ ] there will be no moving electrons

Check all the meters on (do not forget to connect the voltage probes to the plates; make sure the field probe is between the plates and within a dielectric; the field you are interested in is the *net* field!).

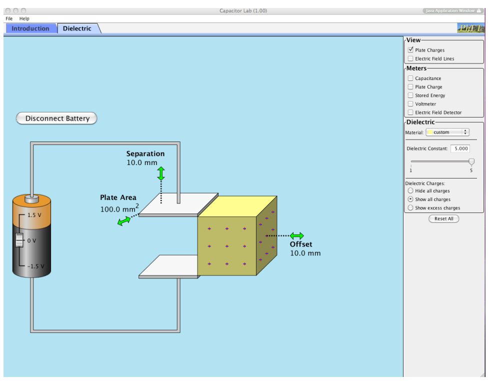
Slowly insert the dielectric between the plates by dragging the little double arrow to the left and observe the changes. Fill in the table below. Check your predictions and explain any deviations from your observations.

Pay attention to units in the table!

A (mm^2)	d (mm)	κ	C (pF)	|V| (V)	|Q| (pC)	|E| (V/m)	U (pJ)
100	10	1					
100	10	5 (filled completely)					

Question 5. When you insert a dielectric into a capacitor, in which case do you do *positive* work; when the capacitor is connected to a battery or when it is disconnected from a battery (or in both cases or neither)? Provide your reasoning to support your answer.

E. Combining the changes.



Reset All the data (see the picture on the left).

Slide the battery slider all the way up. Insert the dielectric completely in the capacitor.

This is your *initial* situation.

Question 6. Predict: what is the ratio of the final energy to the initial energy, $\frac{U_f}{U_i}$, if the final state has been achieved by the following sequence of steps (starting from the initial situation)?

1. the battery is disconnected,
2. the area is quadrupled,
3. the dielectric is taken out of the capacitor,
4. the separation is halved.

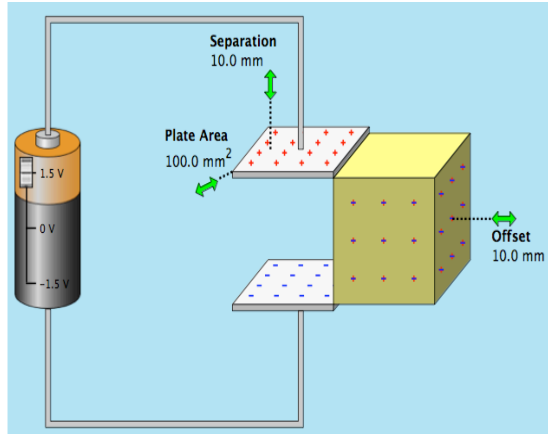
Use the table below to help conducting your calculations.

Step	**area**	**separation**	κ	**capacitance**	**voltage**	**charge**	**field**	**energy**
initial	**A**	**d**		**C**	**|V|**	**|Q|**	**|E|**	**U**
1								
2								
3								
4								

Perform the steps in the simulation and check your prediction.

Reset All.

Start from the initial situation shown in the picture on the right.



Question 7. Your goal is to achieve a final state with energy ≈ 1600 times the energy in the initial state. You can play with the applet, but in the end you have to provide algebraic proof for your solution. Try to find the shortest sequence of the steps list all your steps and give the proof that it works.