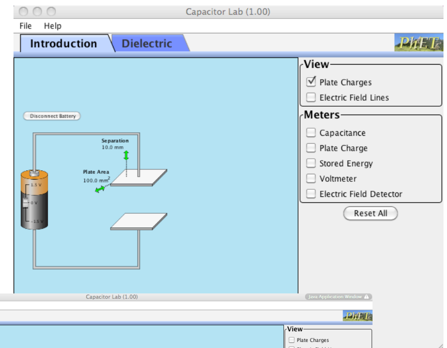
Capacitors

In this experiment, you will investigate fundamental properties of capacitors. A capacitor is a device that stores charge.

PROCEDURE

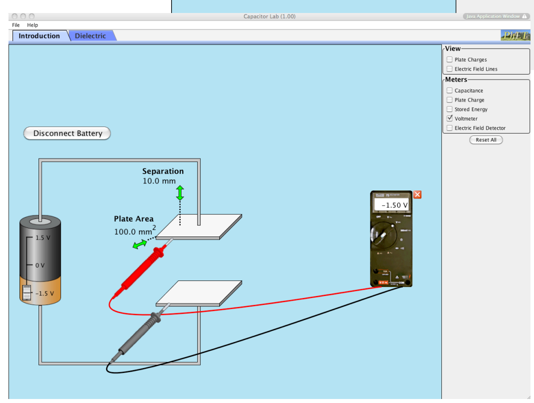
1. Properties of a capacitor. In this experiment you will use a Java simulation to investigate fundamental properties of a parallel plate capacitor.

Find the simulation on the PhET site: https://phet.colorado.edu/en/simulation/legacy/capacitor-lab . 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 enlarge the window, 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.



Check the electric field lines box. 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.

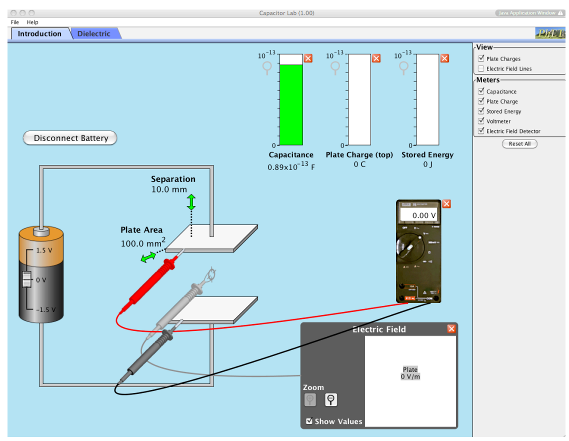
B. Changing area.

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 you think will change.

Prediction	**Actual (come back to fill this in)**
[ ] Capacitance	[ ] Capacitance
[ ] Charge on the plates	[ ] Charge on the plates
[ ] Voltage across the plates	[ ] Voltage across the plates
[ ] Net electric field between the plates	[ ] Net electric field between the plates
[ ] Energy stored in the capacitor	[ ] 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, 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 discuss any deviations from your observations with your group. 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, in addition to capacitance, which other variables (more than one) will also be halved? Explain this by referencing equations.

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 you think will change.

Prediction	**Actual (come back to fill this in)**
[ ] Capacitance	[ ] Capacitance
[ ] Charge on the plates	[ ] Charge on the plates
[ ] Voltage across the plates	[ ] Voltage across the plates
[ ] Net electric field between the plates	[ ] Net electric field between the plates
[ ] Energy stored in the capacitor	[ ] 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 discuss any deviations from your observations with your group.

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.

Prediction	**Actual (come back to fill this in)**
[ ] Capacitance	[ ] Capacitance
[ ] Charge on the plates	[ ] Charge on the plates
[ ] Voltage across the plates	[ ] Voltage across the plates
[ ] Net electric field between the plates	[ ] Net electric field between the plates
[ ] Energy stored in the capacitor	[ ] 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 discuss any deviations from your observations with your group.

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 **keep the battery connected**; 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 you think will change.

Prediction

[ ] Capacitance

[ ] Charge on the plates

[ ] Voltage across the plates

[ ] Net electric field between the plates

[ ] Energy stored in the capacitor

Actual (come back to fill this in)

[ ] 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 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).

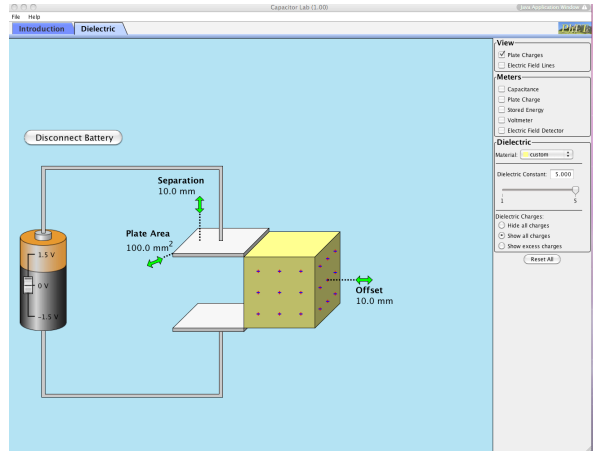
Slowly change the separation between the plates by dragging the little double arrow down (or up) and observe the changes. Fill in the table below. Check your predictions and discuss any deviations from your observations with your group.

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 you think will change.

Prediction

[ ] Capacitance

[ ] Charge on the plates

[ ] Voltage across the plates

[ ] Net electric field between the plates

[ ] Energy stored in the capacitor

Actual (come back to fill this in)

[ ] 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 as you move a dielectric into the space 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 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 discuss any deviations from your observations with your group.

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	1					
100	10	5 (filled completely)					

2. Click on Reset All (confirm “Yes” when asked); slide the battery slider all the way up, and **keep the battery connected**.

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 you think will change.

Prediction	**Actual (come back to fill this in)**
[ ] Capacitance	[ ] Capacitance
[ ] Charge on the plates	[ ] Charge on the plates
[ ] Voltage across the plates	[ ] Voltage across the plates
[ ] Net electric field between the plates	[ ] Net electric field between the plates
[ ] Energy stored in the capacitor	[ ] 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 discuss any deviations from your observations with your group.

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)					

See questions 5 and 6 on the next page.

Question 5. The capacitor is connected to a battery. When you insert a dielectric into a capacitor while the capacitor is still connected to the battery, does the energy stored in the capacitor increase or decrease? What is the main contributor to the change in energy?

Question 6. The capacitor is charged and then disconnected from the battery. When you insert a dielectric into a capacitor while the capacitor is charged but disconnected from the battery, does the energy stored in the capacitor increase or decrease? What is the main contributor to the change in energy?