The Two-Plate Special

This tech lab is an in-depth virtual exploration of capacitors. Part A is an investigation of the capacitance of parallel plates. Part B is an investigation of the energy-storing abilities of capacitors.

The Physics Education Technology Group (PhET) at the University of Colorado at Boulder has developed dozens of excellent, interactive physics computer simulations. You can find them at **http://phet.colorado.edu.** You can download all the PhET simulators from their web site, free of charge.

The PhET simulator used in this tech lab is "Capacitor Lab." Download and run it before class to make sure your computers can run it. This tech lab and corresponding key were written using "Capacitor Lab" version 1.00.

Answers to the Procedure Questions

PART A: CAPACITANCE

Step 3: The battery must do ***work*** on the charge, and the amount of ***work*** a battery can do depends—in part—on its voltage.

Step 4: a. Top.
b. Positive is red. Negative is blue. (Coulombs are sweet, and so are joules.)

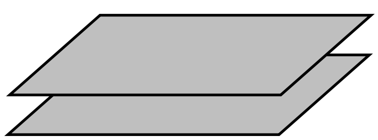
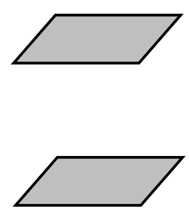
Step 5: $Q \sim V$

Step 6: $C \sim Q$ or $Q \sim C$. The capacitance is proportional to the plate charge.

Step 7: a. Disconnect the battery. Keep the plate constant. Vary the plate separation.
b. $C \sim 1/V$. Capacitance is inversely proportional to voltage.

Step 8: a. $C \sim Q/V$
b. coulombs per volt; C/V

Step 9:

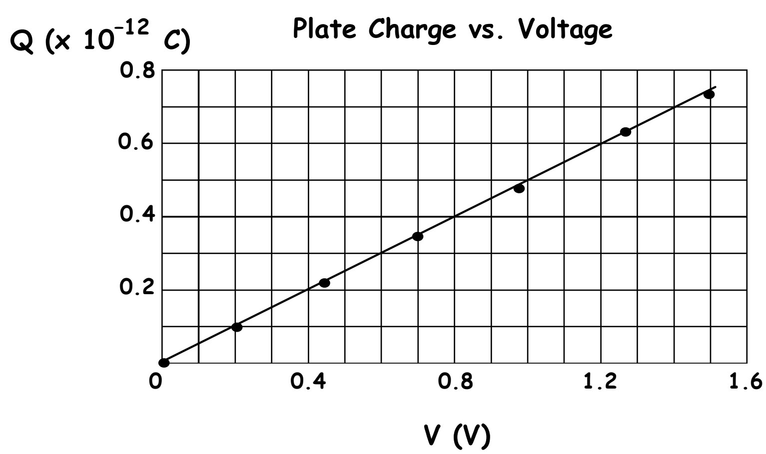
	
High C: large area, small separation	Low C: small area, large separation

Step 10: C ~ A/d

PART B: ENERGY

Step 4/5: Data table and graph

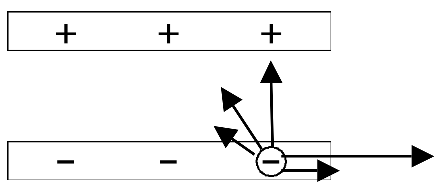
Voltage V (V)	Plate Charge Q ($\times 10^{-12}$ C)
0.00	0
0.20	0.10
0.44	0.22
0.70	0.35
0.96	0.48
1.34	0.67
1.50	0.75



Step 6: a. $\Delta Q / \Delta V$ = 0.75E–12 / 1.50 V = 0.5E–12 C/V = 0.5 pF
b. Capacitance
Step 7: a. ½ $\Delta Q \Delta V$ = 0.5 · 0.75E–12 · 1.50 V =4.5E–13 C·V = 0.45 pJ
b. Energy Stored
Step 8: Energy stored is equal to the area under the curve
Step 9: $W \sim QV/2$
Step 10: a. 8.0E–13 J = 0.8 pJ
b. Area is maximum, separation is minimum, capacitance is maximum
c. 1.0E–13 J = 0.1 pJ
d. Area is minimum, separation is maximum, capacitance is minimum
Step 11: a. 1.6E–10 J = 0.16 nJ = 160 pJ
b. Area is minimum, separation is maximum, voltage is maximum, capacitance is minimum
c. 2.0E–11 J = 20 pJ
d. Area is maximum, separation is minimum, voltage is minimum, capacitance is maximum

Answers to the Summing Up Questions

1. Parallel plates with high capacitance can hold a large charge at low voltage
2. a.



b. The attracting forces vary with separation distance.
c. A battery can hold more charge on parallel plates when the plates are close together.
3. A battery can hold more charge on parallel plates when the plates are larger.
4. a. $C = Q/V$
b. $W = QV/2$
c. $W = CV^2/2 = Q^2/2C$
5. Since Q is squared, energy depends more on charge than on capacitance. Doubling both quadruples the charge factor, so energy is increased.
6. Since V is squared, energy depends more on voltage than capacitance. Doubling both quadruples the voltage factor, so energy is increased.
7. a. $C = Q/V$ = 0.25 F = 250 mF
b. $W = QV/2$ = 12.5 J
8. a. $Q = CV$ = 3600E–6 F · 12 V = 0.043 C = 43 mC
b. $W = CV^2/2$ = 3600E–6 F · (12 V)^2 / 2 = 0.26 J = 260 mJ
9. high power