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Lab: Equipotential Curves & Electric Fields

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Conclusions

The capacitors behaved as we expected them to in the different situations.

In Part 1, when we removed Capacitor 1 from the power supply and connected the positive terminals of the capacitors together, the capacitors shared the same voltage as we expected.

Moreover, the sum of their charges was very close to the charge of Capacitor 1 before they shared charge with a percent difference of 0.0975%, demonstrating the conservation of charge.

In Part 2, we instead charged Capacitor 2 first and got a 10.0% difference between q_{total} and Q_2

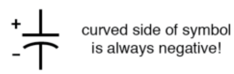
In Part 3, we also successfully confirmed conservation of charge when connecting the capacitors in series with a 0.00% difference between q_{total} and Q_{total}

In Part 4, we successfully confirmed that energy was lost when we connected the capacitors in parallel and connected their opposite poles, allowing some of the charge to recombine. This recombination caused some energy to get lost because some charge was lost. The percent difference of $U_{\text{total after}}$ from $U_{\text{total before}}$ was -189%

PHYS 42
Capacitors

The capacitors used in this experiment are *electrolytic*[1], or polarized. The high potential plate (anode) is typically made of a metal that naturally oxidizes (e.g., tantalum or aluminum). The oxide layer provides a very thin dielectric, usually much less than a micron thick. This plate is then bonded to the negative plate (cathode). The result is a device with very high capacitance and small volume. Because of the asymmetry of this arrangement, electrolytic capacitors must be connected so that the anode is always at a higher potential than the cathode.

Electrolytic ("polarized") capacitor



Procedure

Use the capacitance meter to measure the capacitance of the large and small capacitors. Call the larger capacitor C_1 and the smaller one C_2. ***Make sure to obey the polarization.***

C_1 = 3080 μ F

C_2 = 1270 μ F

You can assume these values remain fixed throughout the experiment.

Part 1 Set the table power supply to 10.0 V and verify it using the multimeter. Connect C_1 to the power supply, making sure the high potential lead is connected to the terminal on the capacitor labeled (+). Measure the voltage across the capacitor to verify it is 10.0 V. Compute the charge on it, calling that charge Q_1. Disconnect C_1 from the power supply.

Q_1 = 3.117×10^{-2} C   10.12V

Now connect C_1 to C_2 so that their (+) terminals are touching. C_1 will now act like a power supply and transfer some charge to C_2. Measure the voltage across each capacitor and compute the charge on each, calling them q_1 and q_2.

V_1 = 7.08 V

V_2 = -7.08 V

[1] https://www.allaboutcircuits.com/textbook/direct-current/chpt-13/practical-considerations-capacitors/. Accessed 02/25/2020.

$q_1 = $ 2.18×10⁻² C

$q_2 = $ 8.99×10⁻³ C

Add the charges to get the total for the system.

$q_{total} = $ 3.11×10⁻² C

Conservation of charge implies that q_{total} and Q_1 are the same. Compute their percent difference.

% diff = 0.0975 %

Use the screwdriver to discharge both capacitors.

Part 2 Now connect C_2 to the power supply (verify it is still 10.00 V) and repeat all the steps from Part 1.

$Q_2 = $ 1.29×10⁻² C V = 10.13 V

$V_1 = $ 3.27 V

$V_2 = $ 3.27 V

$q_1 = $ 1.01×10⁻² C

$q_2 = $ 4.15×10⁻³ C

$q_{total} = $ 1.42×10⁻² C

Compute the percent difference between q_{total} and Q_2.

% diff = 10.0 %

Use the screwdriver to discharge both capacitors.

Part 3 Connect C_1 and C_2 in series to the power supply. The high potential of the supply connects to the (+) terminal on C_1. The (-) terminal on C_1 then connects to the (+) terminal on C_2. Finally, the (-) terminal of C_2 connects to the low potential of the power supply. Measure V_1 and V_2 and compute the total (the total should equal that of the power supply). Now compute the charge on each capacitor (they should be the same) and then add them to get the total charge in the system.

V_1 = 3.04 V

V_2 = 7.08 V

V_{total} = 10.12 V

Q_1 9.36×10^{-3} C

Q_2 = 8.99×10^{-3} C

Q_{total} = 1.84×10^{-2} C

Remove the power supply and connect the capacitors so that their (+) terminals connect and their (-) terminals connect. Measure the voltage across each (they should be the same) and compute the charge on each and the total.

$V_1 = V_2$ = 4.23 V

q_1 = 1.30×10^{-2} C

q_2 = 5.37×10^{-3} C

q_{total} = 1.84×10^{-2} C

Compute the percent difference between q_{total} and Q_{total}.

% diff = 0.00%

Compute the total energy when the capacitors are connected to the power supply and total energy after the supply was removed. Find the percent difference. What happened to the lost energy?

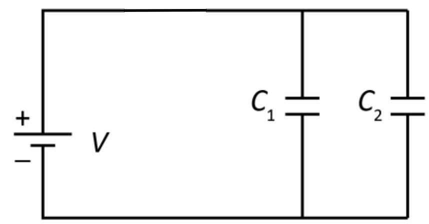
$U_{total\ before}$ = 9.31×10^{-2} J

$U_{total\ after}$ = 3.89×10^{-2} J

% diff = 82.1%

Study the following worked example before completing Part 4 of the procedure.

Example: Suppose you connect capacitors C_1 (600 μF) and C_2 (200 μF) in parallel with a 9.00 V power supply as shown. The capacitors become fully charged. Measuring the voltage and then computing the charge and energy, you complete the table shown below.



	C_1	C_2
V	10.00 V	10.00 V
Q	0.0060 C	0.0020 C
U	0.030 J	0.010 J

You remove the supply and then reconnect the capacitors, but this time (+) to (-). The capacitors exchange charge and come to equilibrium. Again, you measure the voltage and compute the charge and energy. Your results are shown in the next table.

	C_1	C_2
V	5.00 V	5.00 V
Q	0.0030 C	0.0010 C
U	0.0075 J	0.0025 J

The total charge remaining after reconnection is 0.0040 C, which is the difference between 0.0060 C and 0.0020 C in the first table. This means that 0.0020 C recombined inside the wires and is no longer present on the plates. So, how do you know the values in your second table are correct?

$$Q_{total} = Q_1 + Q_2 = 0.0040 \text{ C}$$

$$V_1 = V_2$$

$$\frac{Q_1}{C_1} = \frac{Q_2}{C_2} = \frac{0.0040 - Q_1}{C_2}$$

Solving for Q_1 and then Q_2: $Q_1 = 0.0030$ C $Q_2 = 0.0010$ C

The total energy in Table 1 is 0.040 J; the total energy in Table 2 is 0.010 J. The system has lost 75% of its initial energy due to charge recombination.

Part 4 Connect C_1 and C_2 in parallel to the power supply. Measure V_1 and V_2 (they should be the same). Compute the charge on each capacitor and the total. Compute the equivalent capacitance.

V_1 = 10.14 V

V_2 = 10.14 V

Q_1 3.12×10^{-2} C

Q_2 = 1.29×10^{-2} C

Q_{total} = 4.41×10^{-2} C

C_{eq} = 4.35×10^{-3} F

Disconnect the power supply and connect the capacitors, this time (+) to (-). Measure the voltage across each. Compute the charge on each and the total.

$V_1 = V_2$ = 4.13 V

q_1 = 1.27×10^{-2} C

q_2 = 5.25×10^{-3} C

q_{total} = 1.80×10^{-2} C

Since they're connected with opposite poles, some of the charge will recombine. Determine how much charge should remain.

$\Delta q = q_1 - q_2 =$ 7.48×10^{-3} C

Calculate the voltage across each: $\Delta q / C_{eq}$. Is this voltage the same as what you just measured?

Compute the total energy when the capacitors are connected to the power supply and total energy after the supply was removed. Find the percent difference. What happened to the lost energy?

$U_{total\ before} =$ 0.224 J

$U_{total\ after} =$ 6.43×10^{-3} J

% diff = −189%