Section	Group	Name	Signature
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Grade			
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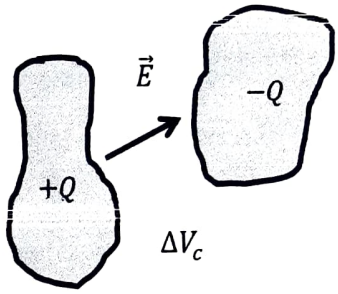
Materials: *"PhET Circuit Construction Kit (AC+DC)" https://phet.colorado.edu/en/simulation/circuit-construction-kit-ac. The simulation requires that Java is installed on your Windows machine: https://www.java.com/en/download/* Java is not supported by Apple IOS.

After this activity you should know: • *Know the role of a emf in a circuit* • *Know Kirchhoff's loop rule* • *Know the definition of capacitance and how an emf charges a capacitor.*

1. A capacitor consists of two conductors (called plates) separated by an insulating gap. The plates are given opposite charges $+Q$ and $-Q$. This generates an electric field in the gap and a voltage difference between the plates. The capacitance of a capacitor is the charge per voltage difference:

$$C = \frac{Q}{\Delta V_c}.$$

In this definition both Q and ΔV_c is taken as positive. The SI units of capacitance is the Farad. It is named after the British experimental physicist/chemist Michael Faraday (1791-1867).



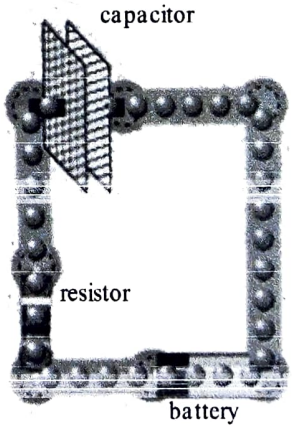
a. Rewrite the Farad in terms of Joules and Coulombs. Show work.

$$F = \frac{C}{V} = \frac{C}{\frac{J}{C}} = \frac{C^2}{J}$$

b. The voltage across a 2 nF capacitor ("n"=nano=10^{-9}) is 15 Volts. What is the charge on the capacitor? *"Charge on capacitor" means the charge on the positive plate.*

$$2 \cdot 10^{-9} = \frac{Q}{15} \qquad Q = 3 \cdot 10^{-8}$$

2. Open the PhET simulation and build the circuit consisting of a capacitor, resistor and battery as shown. Click on each circuit element and set the capacitance to 0.1 F, the resistance to 10 Ω and the battery to 9V. *Note the blue dots represent the motion of the conduction electrons. The current is defined as the direction positive charges move and so the direction of the current is opposite the direction the electrons move.*



a. Right click on the capacitor and discharge it, then watch the capacitor charge. Where do the unbalanced charges on the plates come from? Choose one!

- Electrons initially stored in the battery are delivered to the negative plate of the capacitor. Similarly, protons stored in the battery are delivered to the positive plate of the capacitor.
- The battery moves electrons from the positive plate to the negative plate leaving the plates with charge of opposite sign but same magnitude.
- Electrons moves across the gap between the plates leading to plates with charge of opposite sign but same magnitude.

b. The voltmeter measures the voltage difference between the red and black leads: $V_{voltmeter} = V_{red} - V_{black}$. Therefore the voltmeter reading is positive if the voltage at the red lead is higher than that at the black lead.

Click on the voltmeter button. Place the black lead at the negative terminal of the battery and the red lead at the positive terminal of the battery. What is meant when we say the emf of the battery is 9 Volts?

- The voltage of the positive terminal is 9 Volts and the voltage of the negative terminal is −9 Volts.
- The voltage of the positive terminal is 9 Volts above the voltage of the negative terminal.
- The voltage of the positive terminal is always 9 Volts and the voltage of the negative terminal is always zero.

c. What is the change in electric potential energy of an electron when the electron is moved from the positive terminal of the 9 Volt battery to the negative terminal? *The voltage across the battery terminals when there is no current is called the EMF. Originally the term "EMF" stood for "electromotive force" but this is an outdated term since the EMF is work per charge (not force)! The SI units of emf are therefore just Volts.*

$\Delta U = -\Delta V \cdot q$

$= -9(-e) = 9e$

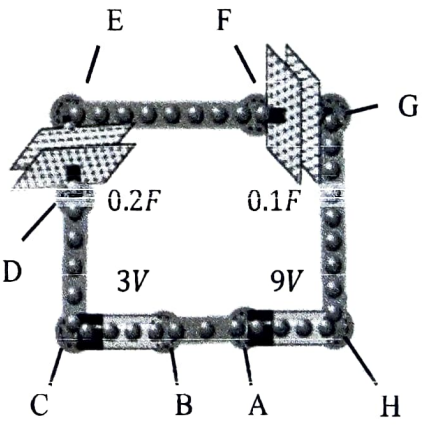
d. What is the role of the battery in this circuit? Power supplies are sometimes called *"the source of EMF"*.

- The battery stores conduction electrons. The electrons are then released to the capacitors.
- The battery does work on the conduction electrons using chemical energy in the battery to increase the electrical potential energy of the electrons.
- The battery does work on the conduction electrons converting the chemical energy in the battery to decrease the electrical potential energy of the electrons.

e. Move the voltmeter to measure the voltage across the capacitor. Change the resistance to 1Ω. Discharge the capacitor and watch the capacitor charge. Measure the voltage across the charged capacitor. What changes when you decrease the resistance?

9 V The speed at which it is charged.

3. Build the circuit shown with two capacitors $C_1 = 0.2\,F$ and $C_2 = 0.1\,F$ and two batteries $\mathcal{E}_1 = 9V$ and $\mathcal{E}_2 = 3V$. To discharge both capacitors simultaneously you must first hit the "pause" button at the bottom of the simulation. Click on each capacitor and discharge them. Then hit "play" to recharge the capacitors.

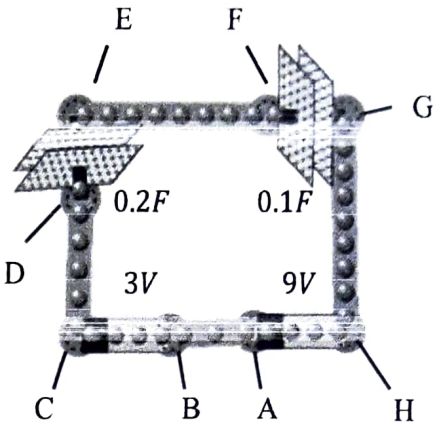


a. Only voltage differences matter. As a reference point we choose point H as zero volts.. Keep the black lead at point H and move the red lead to measure the voltages at the different points. Include units in all measurements.

V_A	V_B	V_C	V_D	V_E	V_F	V_G
9V	9V	12V	12V	8V	8V	0V

b. What is the voltage difference between two points (such as A and B or C amd D) connected directly by conducting wires?

$V_f - V_i$



c. Move the black and red leads to measure the voltage difference across each battery and each capacitor. *The voltage across the battery terminals when there is no current is called the emf.*

$V_A - V_H$	$V_C - V_B$	$V_E - V_D$	$V_G - V_F$
9V	3V	-4V	-8V

Make sure your table for voltage differences agree with your table in part (a).

d. Based on the table above, what is true of the sum of voltage changes around a closed loop?

$= 0$

This result is general and called Kirchoff's Loop Rule.

e. Calculate the charge on each capacitor in the circuit shown.

$Q_1 = 0.8C$ $\qquad$ $Q_2 = 0.8C$

$Q_1 = \quad 0.2F = \frac{Q}{4V}$ $\qquad$ $Q_2 = \quad .1F = \frac{Q}{8V}$

f. Two capacitors are connected in series if they are connected one after another without a branch point in between.[1] Based on your results for (e), what can you say about the charge on capacitors in series?

$Q_1 = Q_2$

[1] A branch point is a place where a single wire splits into two or more wires.