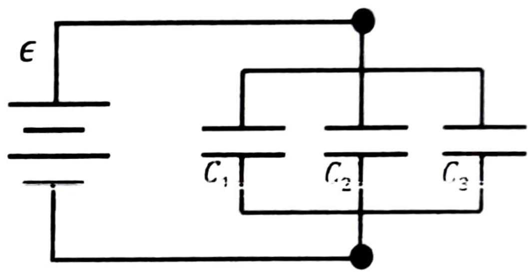
| Section | Group | Name | Signature |
|---|---|---|---|
| | | | |
| | | | |
| Grade | | Jacob Hawkins | Jacob Hawkins |

**After this activity you should know:** • *recognize when capacitors are connected in series and in parallel* • *know the relation for the voltage drops across parallel capacitors and series capacitors.* • *know the relation for the charge on parallel capacitors and for series capacitors.* • *know the effective capacitance for parallel and series capacors.* • *Be able to solve for the charge and voltage drops for parallel and series capacitor circuits.*

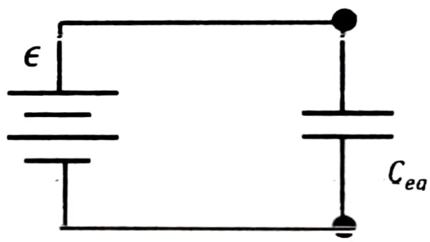
1. **Parallel Capacitors:** Capacitors are connected in parallel if their high voltage ends are connected together and their low voltage ends are connected together. For example, the three capacitors shown are connected in parallel.[1]

The three capacitors $C_1$, $C_2$ and $C_3$ can be replaced by a single equivalent capacitor $C_{eq}$. Here we determine the properties of the capacitors connected in parallel and the equivalent capacitance.




a. What is the relation between the voltage drops across the individual capacitors connected in parallel and the voltage drop across the equivalent capacitor? Choose one.

- The voltage drops across each individual capacitor is the same as the voltage drop across the equivalent capacitor: $\Delta V_1 = \Delta V_2 = \Delta V_3 = \Delta V_{eq}$.
- The sum of the voltage drops of the individual capacitors is the same as the voltage drops across the equivalent capacitor: $\Delta V_{eq} = \Delta V_1 + \Delta V_2 + \Delta V_3$.




b. What is the relation between the charge on the individual capacitors connected in parallel and the charge on the equivalent capacitor? Choose one.

- The charge on the each individual capacitors is the same as the charge on the equivalent capacitor: $Q_1 = Q_2 = Q_3 = Q_{eq}$.
- The sum of the charges on the individual capacitors is the same as the charge on the equivalent capacitor: $Q_{eq} = Q_1 + Q_2 + Q_3$.

c. What is true of the equivalent capacitance for capacitors connected in parallel? Choose one.

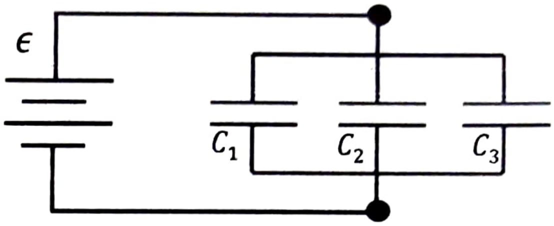
- $C_{ea} = C_1 + C_2 + C_3$
- $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

d. What is true of the equivalent capacitance of capacitors in parallel?

- The equivalent capacitance is larger than the largest individual capacitor.
- The equivalent capacitance is smaller than the smallest individual capacitor.
- The equivalent capacitance is equal to the average capacitance of the individual capacitors.

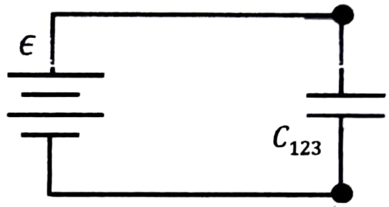
[1] Note that the terms "parallel capacitors" and "parallel plate capacitors" do not describe the same thing.

e. Let $C_1 = 2\ \mu F$, $C_2 = 6\ \mu F$ and $C_3 = 12\ \mu F$ and the EMF be 30 Volts. *Reminder: the EMF is the voltage of the power supply.*




I. Determine the equivalent capacitance of the circuit.

$C_{eq} = 2 + 6 + 12 = 20\ \mu F$




II. Use your knowledge of capacitors connected in parallel to determine the charge and voltage drops across each capacitor and for the equivalent capacitor. Complete the table below. Show work.

*Check that the basic capacitance relation $Q = c\Delta V$ is obeyed for each column and that the charge on the equivalent capacitor is equal to the sum of charges on the individual capacitors connected in parallel.*

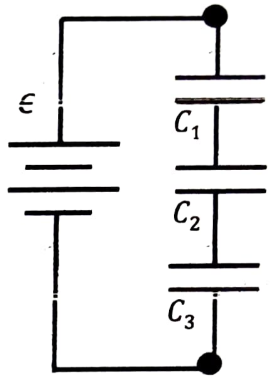
| | $C_1$ | $C_2$ | $C_3$ | $C_{123}$ |
|---|---|---|---|---|
| *capacitance* $\mu F$ | $2 \cdot 10^{-6}$ | $6 \cdot 10^{-6}$ | $12 \cdot 10^{-6}$ | $20 \cdot 10^{-6}$ |
| *voltage across* V | 30 | 30 | 30 | 30 |
| *charge on* $\mu C$ | $60 \cdot 10^{-6}$ | $180 \cdot 10^{-6}$ | $360 \cdot 10^{-6}$ | $600 \cdot 10^{-6}$ |

f. What is the total electric potential energy stored in the capacitors? *Hint: there's an easy way and a hard way to do this.*

$\Delta U = q \Delta V$

$U = 600 \cdot 30 \cdot 10^{-6} = 1800\cancel{0} \cdot 10^{-6}$ J

2. **Series Capacitors:** Capacitors are connected in series if they are joined end to end with the low voltage end of one capacitor connected to the high voltage end of the next capacitor. Capacitors are connected in series only if there are no junction point between one capacitor and the next. (A junction point is a point where the circuit splits or recombines.) Series capacitors can also be replaced by a single equivalent capacitor.

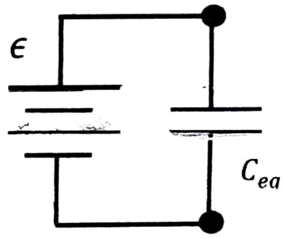



a. What is the relation between the voltage drops across the individual capacitors connected in series and the voltage drop across the equivalent capacitor?

- The voltage drops across each individual capacitor is the same as the voltage drop across the equivalent capacitor: $\Delta V_1 = \Delta V_2 = \Delta V_3 = \Delta V_{eq}$.
- The sum of the voltage drops across the individual capacitors is the same as the voltage drop across the equivalent capacitor: $\Delta V_{eq} = \Delta V_1 + \Delta V_2 + \Delta V_3$.

b. What is the relation between the charge on the individual capacitors connected in series and the charge on the equivalent capacitor?

- The charge on the each individual capacitors is the same as the charge on the equivalent capacitor: $Q_1 = Q_2 = Q_3 = Q_{eq}$.
- The sum of the charges on the individual capacitors is the same as the charge on the equivalent capacitor: $Q_{eq} = Q_1 + Q_2 + Q_3$.



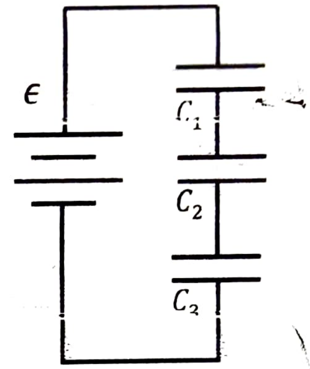

c. What is true of the equivalent capacitance for capacitors connected in series?

- $C_{eq} = C_1 + C_2 + C_3$
- $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

d. What is true of the equivalent capacitance of capacitors in series?

- The equivalent capacitance is larger than the largest individual capacitor.
- The equivalent capacitance is smaller than the smallest individual capacitor.
- The equivalent capacitance is equal to the average capacitance of the individual capacitors.

e. Let $C_1 = 2\ \mu F$, $C_2 = 6\ \mu F$ and $C_3 = 12\ \mu F$ and the emf be 30 Volts.

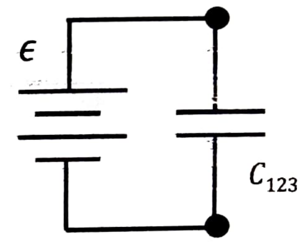



i. Determine the equivalent capacitance for this circuit.

$$C_{eq} = \left(\frac{1}{2} + \frac{1}{6} + \frac{1}{12}\right)^{-1}$$

$$= \frac{4}{3}\ \mu F$$

ii. Use your knowledge of capacitors connected in series to determine the charge and voltage drops across each capacitor and for the equivalent capacitor. Complete the table below. Show work.

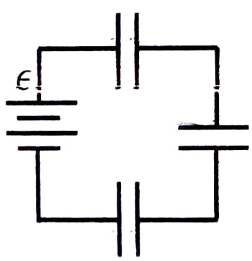



$\cancel{\frac{Q}{V} = C}$ $Q = cV$ $V = \frac{q}{c}$

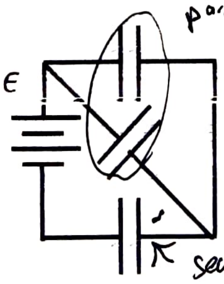
*Check that the basic relation $Q = c\Delta V$ is obeyed for each column and that the voltage drop across the equivalent capacitor is equal to the sum of voltage drops across the individual capacitors connected in series.*

| | $C_1$ | $C_2$ | $C_3$ | $C_{123}$ |
|---|---|---|---|---|
| *capacitance* F | $2 \cdot 10^{-6}$ | $6 \cdot 10^{-6}$ | $12 \cdot 10^{-6}$ | $\frac{4}{3} \cdot 10^{-6}$ |
| *voltage across* V | 20 | $\frac{20}{3}$ | $\frac{10}{3}$ | 30 |
| *charge on* C | $40 \cdot 10^{-6}$ | $40 \cdot 10^{-6}$ | $40 \cdot 10^{-6}$ | $40 \cdot 10^{-6}$ |

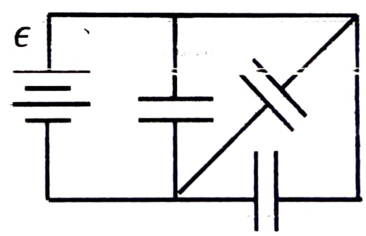
3. Capacitors in parallel do not need to be drawn in parallel nor do capacitors in series need to be drawn on a line. Three capacitors are connected in the different ways shown in the diagrams. State whether all three capacitors are in (1) series, (2) parallel or (3) neither.




parallel




series




Series

neither

parallel

~~parallel~~