

Capacitors in Series and Parallel

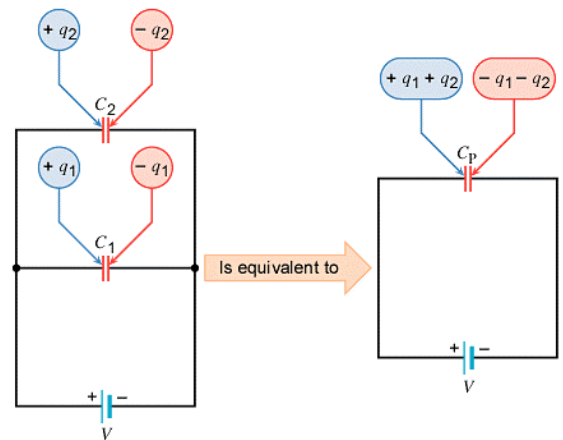
In a parallel combination of capacitances C_1 and C_2 , the voltage V across each capacitor is the same, but the charges q_1 and q_2 on each capacitor are different.

Even though two capacitors are connected in parallel across it, the seat of emf “sees” a single equivalent capacitance C_P :

$$C_P = \frac{q_1 + q_2}{V} \quad \text{or}$$

$$C_P = \frac{q_1}{V} + \frac{q_2}{V} \quad \text{or}$$

$$\boxed{C_P = C_1 + C_2}$$



Example

A $3.0 \mu\text{F}$ and a $5.0 \mu\text{F}$ capacitor are connected in parallel across a 12 V battery.

- a. Find the charge on each capacitor.

$$\begin{aligned} q_1 &= C_1 V_1; \quad q_1 = (3.0 \mu\text{F})(12 \text{ V}); & \boxed{q_1 = 36 \mu\text{C}} \\ q_2 &= C_2 V_2; \quad q_2 = (5.0 \mu\text{F})(12 \text{ V}); & \boxed{q_2 = 60 \mu\text{C}} \end{aligned}$$

- b. Find the equivalent capacitance.

$$C_P = C_1 + C_2; \quad C_P = 3.0 \mu\text{F} + 5.0 \mu\text{F}; \quad \boxed{C_P = 8.0 \mu\text{F}}$$

In a series combination of capacitances C_1 and C_2 , the same amount of charge q is on the plates of each capacitor, but the voltages V_1 and V_2 across each capacitor are different.

Even though two capacitors are connected in series with it, the seat of emf “sees” a single equivalent capacitance C_P , which may be determined as follows.

$$V = V_1 + V_2$$

$$\frac{q}{C_S} = \frac{q}{C_1} + \frac{q}{C_2}; \quad \boxed{\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2}}$$

An example follows on the next page.

Example

A $3.0\ \mu\text{F}$ and a $5.0\ \mu\text{F}$ capacitor are connected in series with a $12\ \text{V}$ battery.

- a. Find the equivalent capacitance.

$$\frac{1}{C_s} = \frac{1}{3.0\ \mu\text{F}} + \frac{1}{5.0\ \mu\text{F}}; \quad \frac{1}{C_s} = \frac{5+3}{15\ \mu\text{F}}; \quad C_s = \frac{15\ \mu\text{F}}{8}; \quad \boxed{C_s = 1.9\ \mu\text{F}}$$

- b. Find the charge on each capacitor.

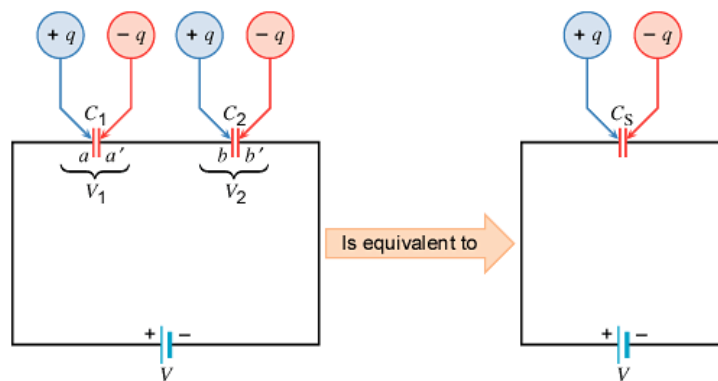
$$q = C_s V: \quad q = (1.9\ \mu\text{F})(12\ \text{V}); \quad \boxed{q = 23\ \mu\text{C}}$$

- c. Find the potential drop (or voltage) across each capacitor.

$$\begin{aligned} V_1 &= \frac{q}{C_1}: \quad V_1 = \frac{23\ \mu\text{C}}{3.0\ \mu\text{F}}; & \boxed{V_1 = 7.7\ \text{V}} \\ V_2 &= \frac{q}{C_2}: \quad V_2 = \frac{23\ \mu\text{C}}{5.0\ \mu\text{F}}; & \boxed{V_2 = 4.6\ \text{V}} \end{aligned}$$

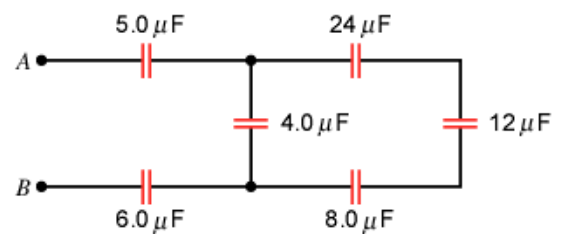
Capacitance Networks

It is possible to use the formulas for capacitors connected in series and parallel to find the equivalent capacitance of more elaborate capacitance networks.



group of capacitors in the drawing.

Example
(Chapter
20 problem
87)



Determine
the equivalent capacitance between A and B for the

87. **REASONING** Our approach to this problem is to deal with the arrangement in parts. We will combine separately those parts that involve a series connection and those that involve a parallel connection.

SOLUTION The 24, 12, and 8.0- μF capacitors are in series. Using Equation 20.19, we can find the equivalent capacitance for the three capacitors:

$$\frac{1}{C_s} = \frac{1}{24\ \mu\text{F}} + \frac{1}{12\ \mu\text{F}} + \frac{1}{8.0\ \mu\text{F}} \quad \text{or} \quad C_s = 4.0\ \mu\text{F}$$

This 4.0- μF capacitance is in parallel with the 4.0- μF capacitance already shown in the text diagram. Using Equation 20.18, we find that the equivalent capacitance for the parallel group is

$$C_p = 4.0\ \mu\text{F} + 4.0\ \mu\text{F} = 8.0\ \mu\text{F}$$

This 8.0- μF capacitance is between the 5.0 and the 6.0- μF capacitances and in series with them. Equation 20.19 can be used, then, to determine the equivalent capacitance between *A* and *B* in the text diagram:

$$\frac{1}{C_s} = \frac{1}{5.0\ \mu\text{F}} + \frac{1}{8.0\ \mu\text{F}} + \frac{1}{6.0\ \mu\text{F}} \quad \text{or} \quad C_s = \boxed{2.0\ \mu\text{F}}$$