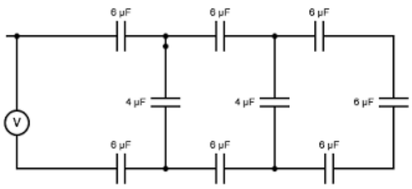
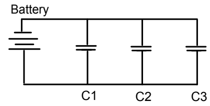
3.B.4 - Capacitor Circuits



Capacitors in Parallel (C_P)

A parallel circuit is one in which components are connected across a voltage equivalently.

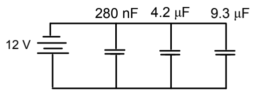


Equivalent capacitance for parallel capacitors (C_p):

$C_p = C_1 + C_2 + C_3 + \ldots$	C_1, C_2, C_3 = capacitors (units must be the same)
$C_p = \sum_i C_i$	AP Equation: i stands for individual

Parallel Example:

What is the equivalent capacitance of the following circuit?



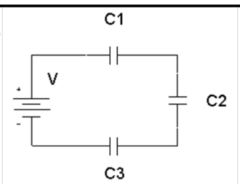
Make sure units match!
280 nF = 0.28 µF.

$$C_p = C_1 + C_2 + C_3 + \ldots$$

$$C_p = 0.28\,\mu F + 4.2\,\mu F + 9.3\,\mu F = 13.8\,\mu F$$

Capacitors in Series (C_s)

A series circuit is one in which components are connected head to tail.



Equivalent capacitance for serial capacitors (C_s):

$C_s = (C_1^{-1} + C_2^{-1} + C_3^{-1} + \ldots)^{-1}$	C_1, C_2, C_3 = capacitors (units must be same)
$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$	AP Equation: i stands for individual

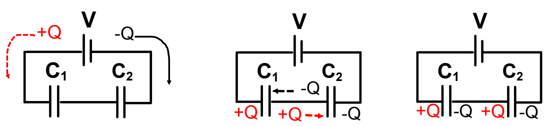
Conceptual Factoid: C_s is **ALWAYS**lower than any of the individual capacitors.

Series Circuits Explained

In a serial capacitor circuit, the effective dielectric thickness is increased with every capacitor.

Also, in series, the charge on each capacitor is the same. As negative charge flows into the negative plate of one capacitor, it's matched by positive charges on the other.

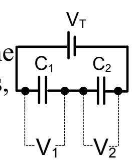
The displaced negative charges from that plate move to the next capacitor, which causes the same number of negative charges to move to the next, etc.



Charging   Charging   Charged

Series Circuits Explained

Second, since the voltage (V) provided by the battery is divvied up between the capacitors, each capacitor has a lower capacitance than if it were simply hooked up to the battery. With these facts in mind, a proof follows for a two capacitor system:



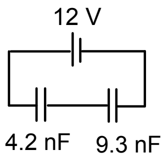
Assume: $C_{eq} = \frac{Q}{V_T}$, $Q_1 = Q_2$ and: $V_T = V_1 + V_2$

$$C_{eq} = \frac{Q}{V_T}$$

Numeric Manipulation: $\frac{1}{C_{eq}} = \frac{V_T}{Q} = \frac{V_1 + V_2}{Q} = \frac{V_1}{Q} + \frac{V_2}{Q} = \frac{1}{C_1} + \frac{1}{C_2}$

Series Capacitance Example

What is the equivalent capacitance of a series circuit in which two capacitors; 4.2 nF & 9.3 nF, are connected to a 12 V battery?

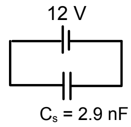


$C_1 = 4.2$ nF $C_2 = 9.3$ nF

$$C_s = (C_1^{-1} + C_2^{-1})^{-1}$$
$$= (4.2nF^{-1} + 9.3nF^{-1})^{-1}$$
$$= 2.9nF$$

Series Example: Energy

What is the total energy storage of the circuit?



Energy storage for a capacitor is:

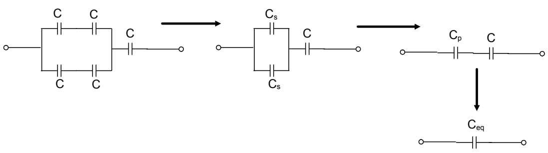
$$U_C = \frac{1}{2}CV^2$$
$$= \frac{1}{2} \bullet 2.9E-9F \bullet (12V)^2 = 2.1E-7J$$

Mixed Circuits

Some circuits combine serial & parallel components.

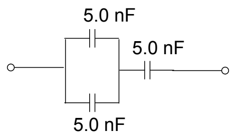
Equivalent capacitance is calculated by sequentially isolating each parallel/serial portion of the overall circuit.

Finally, the circuit boils down into one equivalent capacitor.



Mixed Circuit Example

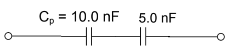
What is the equivalent capacitance of the following mixed parallel/series circuit?



Mixed Circuit Example

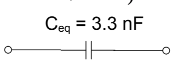
1st: reduce the parallel portion into an equivalent capacitance:

$$C_p = C_1 + C_2 = 5.0nF + 5.0nF = 10.0nF$$



2nd: find equivalent capacitance (C_{eq}), using the serial equation for the 5 nF capacitor and 10 nF equivalent capacitor:

$$C_{eq} = (10nF^{-1} + 5.0nF^{-1})^{-1} = 3.3nF$$



Homework

3.B.4 Problems.
Due: Next Class.

Finish Unit 3.B Review Problems
Due: 12/5