Capacitors Circuits

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Circuits containing capacitors are easy to understand, take a closer look at them.

Capacitors Circuits

When a capacitor is placed in a circuit, current does not actually travel across it. Rather, equal and opposite charge begins to build up on opposite sides of the capacitor --- mimicking a current --- until the electric field in the capacitor creates a potential difference across it that balances the voltage drop across any parallel resistors or the voltage source itself (if there are no resistors in parallel with the capacitor). The ratio of charge on a capacitor to potential difference across it is called capacitance.

It is important to break down a complicated circuit into the equivalent capacitance using the rules for capacitors in series and capacitors in parallel. Also remember that capacitors in parallel have the same voltage while capacitors in series have the same charge.

Key Equations

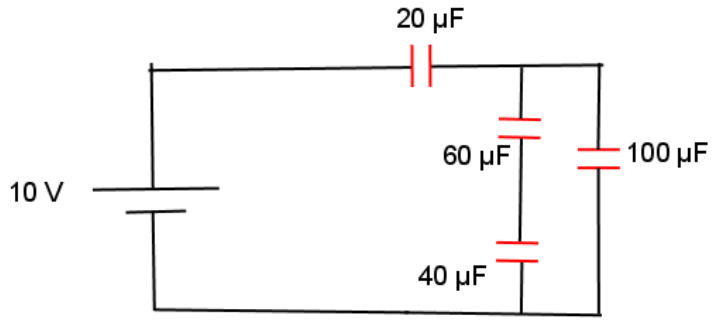
$$C = \frac{Q}{V} \qquad \text{Definition of Capacitance}$$

$$C_{\text{parallel}} = C_1 + C_2 + C_3 + \ldots \qquad \text{Capacitors in parallel add like resistors in series}$$

$$\frac{1}{C_{\text{series}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots \qquad \text{Capacitors in series add like resistors in parallel}$$

Example

In the circuit shown below, determine (a) the total capacitance and (b) the total charge stored.



[Figure1]

(a): In solving this problem, we'll call the $20\ \mu\text{F}$ capacitor C_1, the $60\ \mu\text{F}$ capacitor C_2, the $40\ \mu\text{F}$ capacitor C_3, and the $100\ \mu\text{F}$ capacitor C_4.

Our first step will be to find the equivalent capacitance of C_2 and C_3.

$$\begin{aligned}\frac{1}{C_{2,3}} &= \frac{1}{C_2} + \frac{1}{C_3} \\ \frac{1}{C_{2,3}} &= \frac{1}{60\ \mu\text{F}} + \frac{1}{40\ \mu\text{F}} \\ \frac{1}{C_{2,3}} &= \frac{5}{120\ \mu\text{F}} \\ C_{2,3} &= 24\ \text{F}\end{aligned}$$

Next, we'll combine the capacitance of $C_{2,3}$ and C_4.

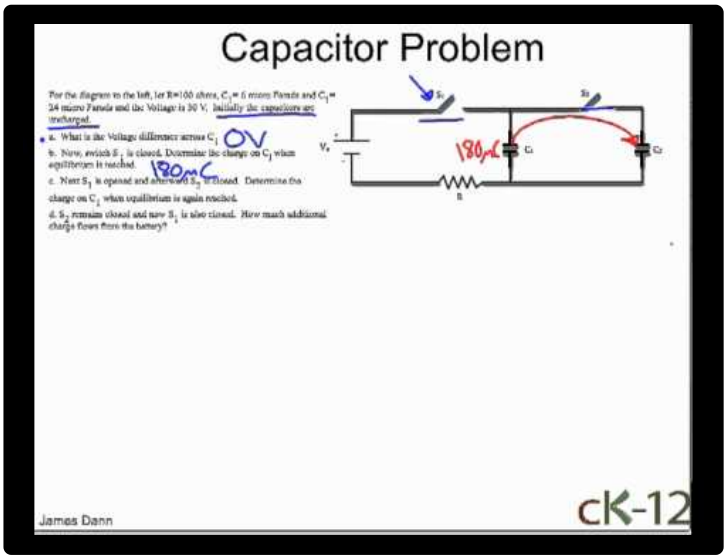
$$\begin{aligned}C_{2,3,4} &= C_{2,3} + C_4 \\ C_{2,3,4} &= 24\ \mu\text{F} + 100\ \mu\text{F} \\ C_{2,3,4} &= 124\ \mu\text{F}\end{aligned}$$

Finally, we can combine $C_{2,3,4}$ with C_1 to find the total capacitance.

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_{2,3,4}}$$
$$\frac{1}{C_{eq}} = \frac{1}{20\ \mu\text{F}} + \frac{1}{124\ \mu\text{F}}$$
$$\frac{1}{C_{eq}} = .058\ \mu\text{F}^{-1}$$
$$C_{eq} = 17.22\ \mu\text{F}$$

(b): Now we can use this value to find the total charge stored on all the capacitors by also using the voltage provided on the diagram.

$$Q = CV$$
$$Q = 17.22\ \mu\text{F} * 10\ \text{V}$$
$$Q = 172.2\mu\text{C}$$



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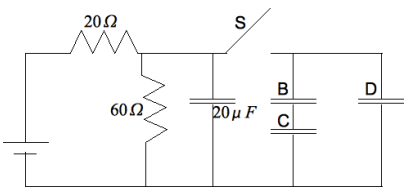
Review



[Figure2]

1. Consider the figure above with switch, S, initially open and the power supply set to 24 V:

   a. What is the voltage drop across the 20Ω resistor?

   b. What current flows thru the 60Ω resistor?

   c. What is the voltage drop across the 20 microfarad capacitor?

   d. What is the charge on the capacitor?

   e. How much energy is stored in that capacitor?

   f. Find the capacitance of capacitors B, C, and D if compared to the $20\mu\text{F}$ capacitor where...

      i. B has twice the plate area and half the plate separation

      ii. C has twice the plate area and the same plate separation

      iii. D has three times the plate area and half the plate separation

2. Now the switch in the previous problem is closed.

   a. What is the total capacitance of branch with B and C?

   b. What is the total capacitance of the circuit?

   c. What is the voltage drop across capacitor B?

Review (Answers)

1. a. 6V b. 0.3A c. 18V d. $3.6\times10^{-4}\text{C}$ e. $3.2\times10^{-3}\text{J}$ f. i) $80\mu\text{F}$ ii) $40\mu\text{F}$ iii) $120\mu\text{F}$

2. a. $26.7\mu\text{F}$ b. $166.7\mu\text{F}$

1.0 REFERENCES

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