Key Concepts

Chapter 8

Capacitors in series:

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

Capacitors in parallel:

$$C_{eq} = C_1 + C_2 + C_3 + \ldots$$

$$Q = CV$$

Takeaways

There is a standard process for solving capacitor network problems:

1) Find the equivalent capacitance of the circuit through a number of equivalent capacitance steps.

2) Find the total charge in the circuit.

3) Expand the circuit back out until you have reached the desired capacitor.

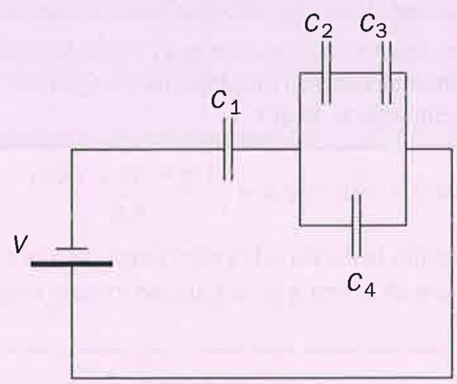
Remember that capacitors in series must have the same charge—just like resistors in series must have the same current. If there are branches in the circuit, the charge splits between the branches.

Things to Watch Out For

Many test takers confuse the rules for adding capacitors with those for adding resistors.

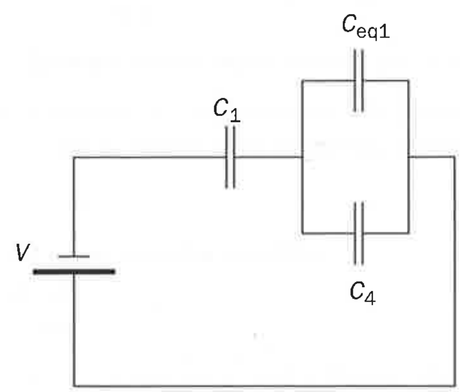
Capacitor Networks

In the capacitor network shown below, $C_1 = 30\ \mu F$, $C_2 = 20\ \mu F$, $C_3 = 5\ \mu F$, $C_4 = 6\ \mu F$, and $V = 4$ volts. What is the charge stored in C_2?



1) Find the equivalent capacitance of the network.

The first step is to combine capacitors 2 and 3. These capacitors are in series. The equivalent capacitance of two capacitors in series is given by $\frac{1}{C_{eq}} = \frac{1}{C_A} + \frac{1}{C_B}$



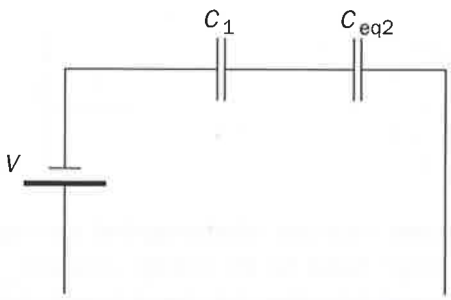
$$\frac{1}{C_{eq1}} = \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{20} + \frac{1}{5} = \frac{1}{20} + \frac{4}{20} = \frac{5}{20} = \frac{1}{4}$$

$$C_{eq1} = 4\ \mu F$$

Remember: *Capacitors add simply in parallel but in a complicated way in series. This is the opposite of resistors.*

2) Find the equivalent capacitance of the network.

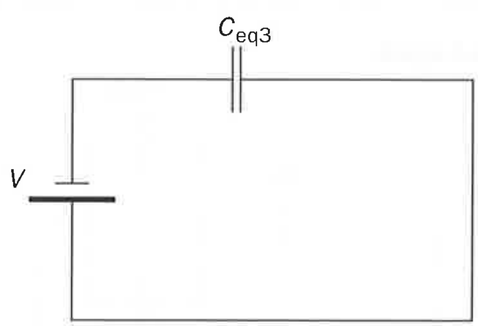
Next, find the equivalent of capacitors C_{eq1} and C_4. These capacitors are in parallel, so they add simply.



$$C_{eq2} = C_{eq1} + C_4 = 4\ \mu F + 6\ \mu F = 10\ \mu F$$

3) Find the equivalent capacitance of the network.

Finally, find the equivalent of capacitors C_1 and C_{eq2}. Similar to step 1, these capacitors are in series.



$$\frac{1}{C_{eq3}} = \frac{1}{C_1} + \frac{1}{C_{eq2}} = \frac{1}{30} + \frac{1}{10} = \frac{1}{30} + \frac{3}{30} = \frac{4}{30}$$

$$C_{eq3} = \frac{30}{4} = 7.5\ \mu F$$

4) Find the total charge in the circuit.

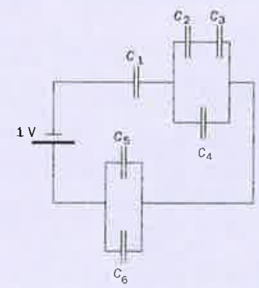
The reason to find the equivalent capacitance is so that we can determine the total charge in the circuit. Use the relation $Q = VC$ to find the charge stored in the equivalent capacitor C_{eq3}.

$$Q_{eq3} = VC_{eq3} = (4\ V)(7.5\ \mu F) = 30\ \mu C$$

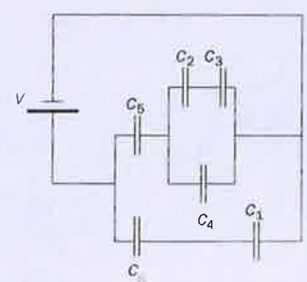
Similar Questions

1) Four 1 μF capacitors are attached in parallel across a 9 V battery. What is the total charge stored in the circuit?

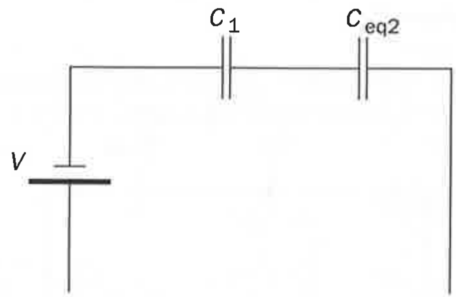
2) Each capacitor in the diagram below has a capacitance of 10 μF. What is the voltage across C_5?



3) In the circuit shown below, $C_1 = C_2 = C_3 = 5\ \mu F$ and $C_4 = C_5 = C_6 = 15\ \mu F$. If the total charge stored in the circuit is 30 μC, what is the voltage of the battery?



5) Expand the circuit.

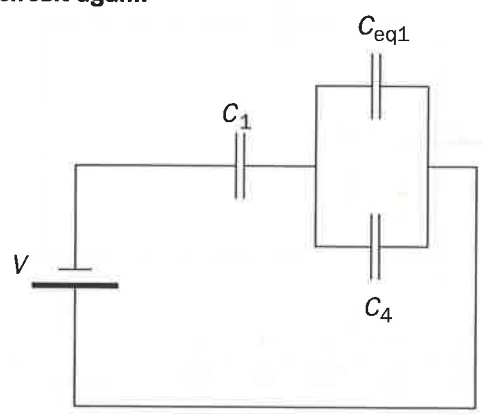


The key to solving capacitor networks is knowing that any capacitors in series must hold the same charge. Solve for the voltage across C_{eq2} so that we can expand the circuit again and determine the charge in each branch.

$$Q_{eq3} = Q_1 = Q_{eq2} = 30\ \mu C$$
$$V_{eq2} = \frac{Q_{eq2}}{C_{eq2}} = \frac{30 \mu C}{10 \mu F} = 3\ V$$

Remember: *Think of charge in capacitor problems as being similar to current in resistor problems.*

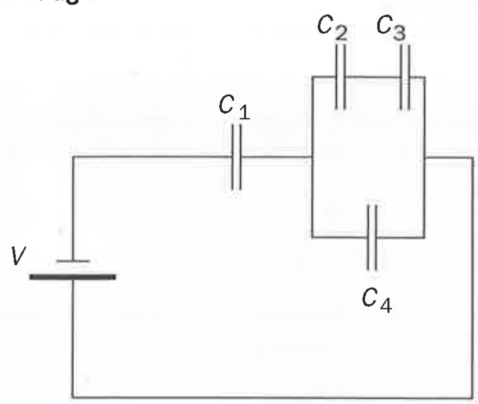
6) Expand the circuit again.



The voltage across any capacitors in parallel must be the same. This is also true for resistors. Once you know the voltage across C_{eq1}, solve for the charge stored on C_{eq1}.

$$V_{eq2} = V_{eq1} = V_4 = 3\ V$$
$$Q_{eq1} = V_{eq1} C_{eq1} = (3\ V)(4\ \mu F) = 12\ \mu C$$

7) Expand the circuit again.



Just like in step 5, the charge on C_{eq1} must equal the charge on C_2 and C_3. $Q_{eq1} = Q_2 = Q_3 = 12\ \mu C$.