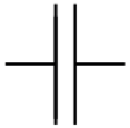
Module 6 Section 1: Capacitors

Capacitors



A capacitor consists of two parallel conducting plates, separated by an insulator.

A capacitor is used to store energy. When there is no p.d. across the capacitor the plates are neutral and they have an equal number of electrons and positive ions. When a p.d. is applied to the plates, electrons are forced to move and the plates acquire equal and opposite charge. This stores energy until the electrons can flow back.

Capacitance = $\dfrac{\text{charge on a plate}}{\text{pd between plates}}$ $\quad C = \dfrac{Q}{V}$

It is measured in units of F but more commonly will be given in μF or nF.

Energy Stored by capacitors

$$W = \tfrac{1}{2}QV$$

W = energy stored by capacitor (in J)

V = potential difference across capacitor (in V)

Q = charge on capacitor (in C)

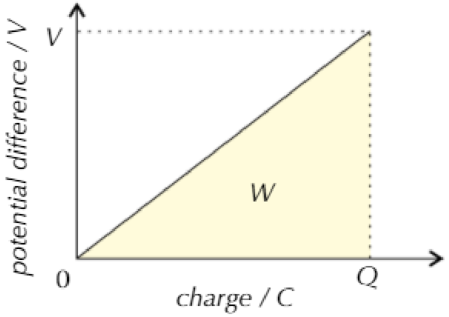
Using the capacitance equation $C = \frac{Q}{V}$, you can derive two more equations for the energy stored by a capacitor. Simply rearrange the capacitance equation for Q and V, and substitute them into the energy equation:

Using $Q = CV$:

$$W = \tfrac{1}{2}V^2C$$

Using $V = \frac{Q}{C}$:

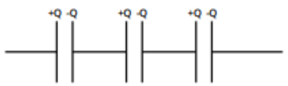
$$W = \frac{1}{2}\frac{Q^2}{C}$$



Capacitors in Circuits

Series

In series, the pd of the supply is shared (not always equally) across the capacitors but the charge on each capacitor is equal. This gives the following equation to calculate the total capacitance.

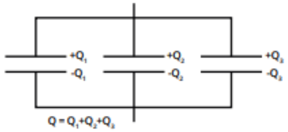


$$\frac{1}{C_{Total}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots$$

Parallel

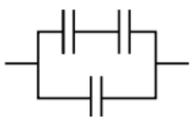
In parallel the pd across each capacitor is equal but the charge will be shared.

This gives the following equation:



$$C_{Total} = C_1 + C_2 + C_3 + \cdots$$

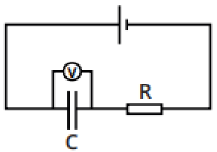
There may be examples where the total capacitance of a combination of series and parallel must be calculated.



Charging and Discharging Capacitors

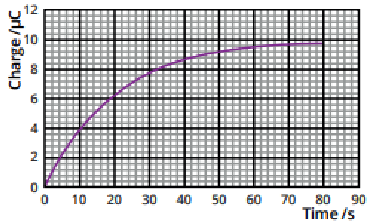
Charging:

When charging a capacitor, a current flows effectively causing electrons to move from one plate to the other.



This graph shows the how the charge increases when charging the capacitor.

As Q ∝ V, the graph for p.d. will be the same shape.

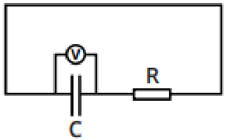


This equation can be used to calculate Q at a time t.

$$Q = Q_o\left(1 - e^{-\frac{t}{RC}}\right)$$

Discharging:

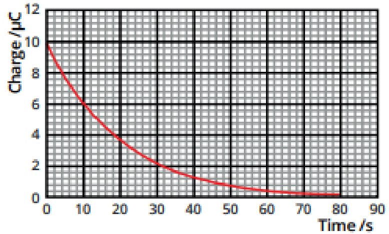
When discharging, the current will flow the opposite direction, effectively moving the electrons back.



This graph shows discharging a capacitor.

This equation can be used to calculate Q at a time t when discharging.

$$Q = Q_o\left(e^{-\frac{t}{RC}}\right)$$



RC is known as the **time constant**, τ. This is the time for the charge to decrease to $^1/_e$ = 37% of its original value.