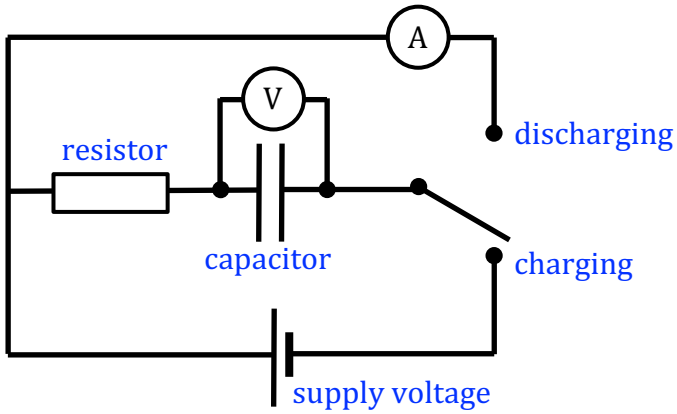
7.10 Capacitor charge and discharge

videos

The following circuit can be used to investigate charging and discharging a capacitor:



The resistor has resistance *R*, the capacitor has capacitance *C*, and the supply has a voltage *V*.

With the two-way switch in the 'charging' position the capacitor will charge up to its maximum value:

$$Q = VC$$

where Q is the charge, V is the supply voltage and C is the capacitance

(1) Work out the total charge stored, for a capacitor with capacitance = 5.0μF, and a supply voltage of 9V.

When discharging the capacitor, the charge (Q), current (I) and voltage (V) follow an exponential decay:

$$Q = Q_0 e^{-\left(\frac{1}{CR}\right)t}$$

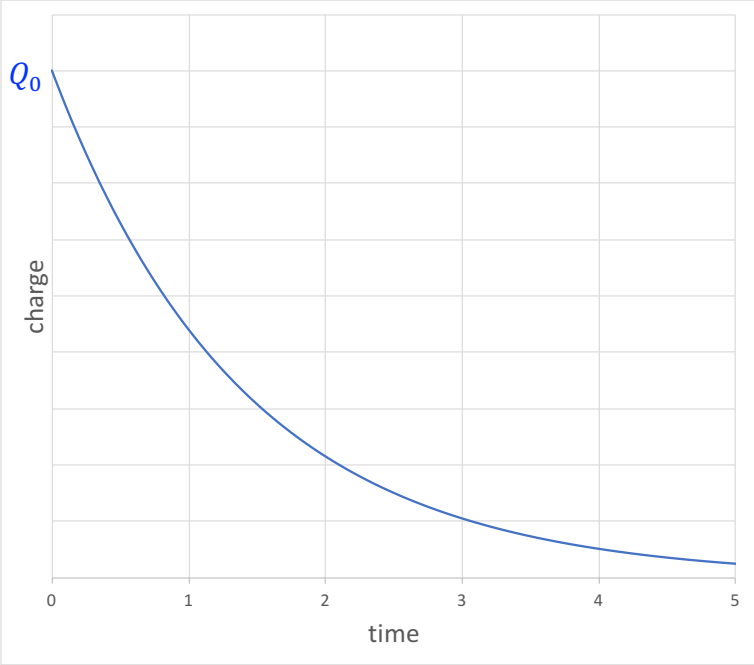
$$I = I_0 e^{-\left(\frac{1}{CR}\right)t}$$

$$V = V_0 e^{-\left(\frac{1}{CR}\right)t}$$

The constant *CR* is known as the 'time constant'. The unit of *RC* is the second. At a time $t = RC$, the three quantities will have fallen to 0.37 (e^{-1}) of their initial values (or 37%).

(2) The capacitor in the previous question is discharged through a resistor with a resistance of 3MΩ. What is the charge remaining on the capacitor after 3s?

Consider the graph of capacitor discharge:



(3) Explain why the charge on the capacitor to start with (Q_0) is given by the expression:

$$Q_0 = CV_0$$

(4) Explain why the initial current in the circuit containing a resistor with resistance R is given by the expression:

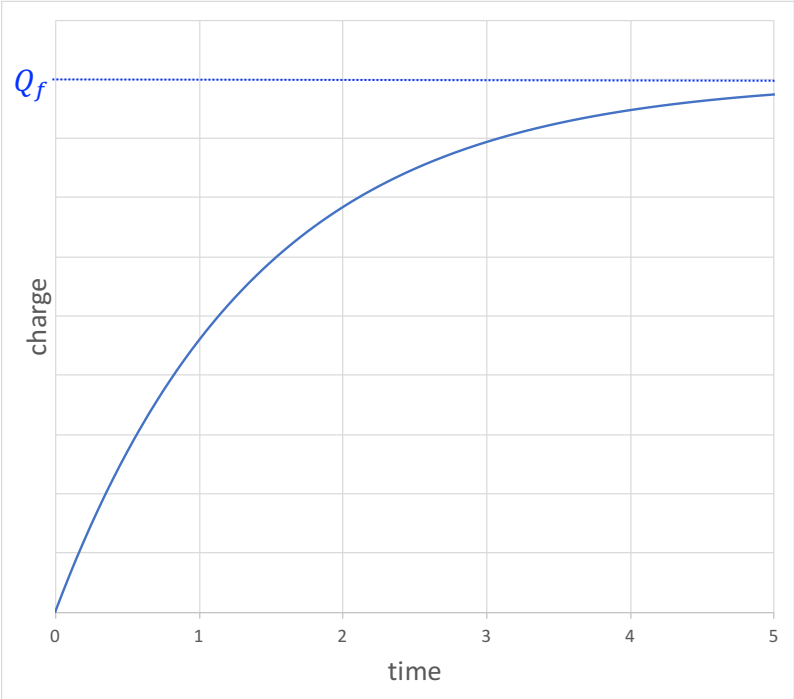
$$I_0 = \frac{V_0}{R}$$

(5) Given that the time is in seconds, in the graph above, work out a value for the time constant for this capacitor.

(6) The capacitor has a capacitance of $2\mu F$. Work out the resistance of the resistor through which the capacitor is discharging.

Capacitor charging

Consider the graph for charging a capacitor:



The graph is just a mirror image of the discharge graph.

In this case, the time constant *RC* represents the time for the charge to reach 63% of its final charge (Q_f).

The formula for the charge on the capacitor as it is charging is:

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

where V is the supply voltage

(7) A capacitor with a capacitance of $3.5\mu F$ *is charged through a resistor with a resistance of* $8M\Omega$*. The supply voltage is 12V. How long will it take for the voltage across the capacitor to reach 6V, if charged from zero?*

(8) How could we work out the initial current that flows in the circuit from a graph of charge versus time?