Discharging a capacitor

Science background

PHYSICS
Electric fields

Capacitors

A capacitor is a device that is used in a variety of electronic circuits and which can store electrical charge. The simplest capacitor is a pair of conducting plates separated by a small distance, but not touching each other.

When a capacitor is charged from a battery (see figure 1) charge flows on to one side of the capacitor from the battery; and equal amount of flows away from the other side of the capacitor into the other battery terminal. Charge flows until the potential difference across the plates becomes the same as that across the battery.

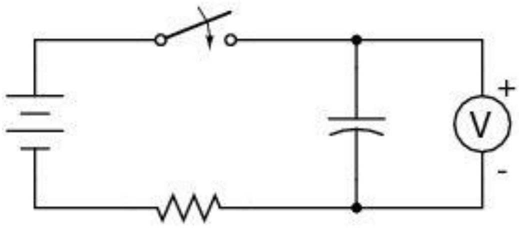

Figure 1. Electrical circuit for charging a capacitor

The charge *Q* on a capacitor's plate is proportional to the potential difference *V* across the capacitor.

$Q = C * V$, where *C* is the capacitance of the capacitor.

Capacitance is the amount of charge stored per unit potential difference across the plates. Capacitance informs us about the ability of a capacitor to store energy in the form of electrically separated charges and depends for example on the size and shape of the capacitor. The SI unit of capacitance is the farad F (1F=1/CV) which is very large capacitance. Capacitances generally range between 1 picofarad (pF) to 10 000 microfarads (μF).

Once a capacitor is charged, the two plates of the capacitor remain charged unless they are connected with a material that conducts. Once the plates are connected, by a circuit with resistance R, a current flows and capacitor is 'discharged'.

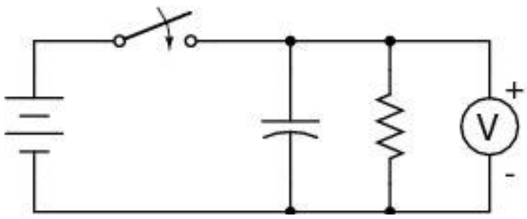

Figure 2. Electrical circuit for discharging a capacitor

According to Ohm's law $I = \frac{V}{R} = \frac{Q}{RC}$

and the current definition $I = -\frac{DQ}{Dt}$

we can write the equation $\frac{DQ}{Dt} = -\frac{Q}{RC}$,

which says that the rate of flow charge is proportional to the charge itself.

This equation is actually equivalent to $\frac{\Delta Q}{Q} = -\frac{1}{RC} * \Delta t$.

This equation describes a capacitor discharge curve by telling us how the gradient at any one time is related to the stored charge at that time. From here we can derive

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

The Q_0 is the charge stored when t=0 and e is a number known as the exponential number e ≈ 2.718.

This equation can be used to tell us how the voltage and current change as well:

$$V(t) = V_o e^{\frac{-t}{RC}} \text{ and } I(t) = I_o e^{\frac{-t}{RC}}.$$

In other words, the voltage and current also decreases exponentially with time.

The time taken to decrease the charge by a factor 1/e (decrease by 37%) is the time *RC* called the **time constant** of the circuit. The constant is used as a measure of how fast the resistor-capacitor combination discharges.

How to determine the time constant of the circuit in the Coach program

To find the time constant (the product of resistance in ohms and capacitance in farads.) one of the following methods can be used:

- Method 1:
  Fit the exponential function to the data of the potential difference measured across the capacitor V versus time.

- Method 2:
  The natural logarithm of the equation describing the potential difference across the capacitor is:
  $$\ln(V) = -\frac{1}{RC} * t + \ln(V_0)$$
  therefore a graph of ln(V) versus time should be linear. Find the slope of this graph.