Week of March 7

Grade 10 Physics

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2 Capacitors and Capacitances

2.1 Structure of a simple capacitor

A capacitor is an electrical equipment that we use to store charge. We also use other electrical devices such as a battery to store charges, but the difference is that a capacitor stores more charge at a lower potential. The simplest form of a capacitor contains two metal plates separated by a small distance we an insulator between them. Below, you will find a schematic diagram of a simple capacitor.

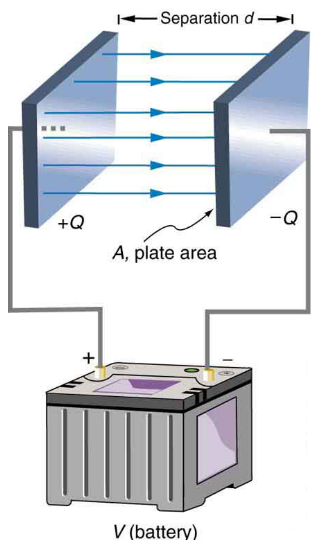

Figure 1: The structure of a simple capacitor

2.2 Concepts involving capacitors

Capacitance

Is the charge needed for each volt rise in the potential. In other words, it is how much charge can be stored within a given potential difference. That is,

$$C = \frac{Q}{V} \tag{1}$$

Where:

$$C = \text{Capacitance}$$
$$Q = \text{Charge stored}$$
$$V = \text{Potential difference/voltage between the plates}$$

The SI unit of capacitance is called the Farad(in honor of Michael Faraday) , where

$$1F = \frac{1C}{1V} \tag{2}$$

As we said earlier, capacitors are elements of circuits. Thus, we need special representation(symbols) for them so that we can know where they are located in circuits. In the diagram below, we see the representation of a capacitor in a circuit. Based on the type of capacitor it is, it might have different representations, but the first one will do for most of the topics we will be covering.

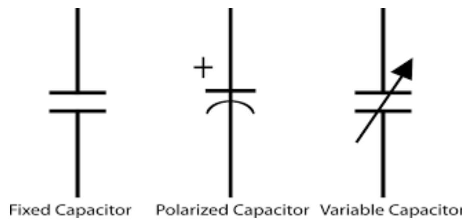

Figure 2: The structure of a simple capacitor

To understand how capacitors work, let's consider parallel plate capacitors. A system composed of two identical, parallel conducting plates separated by a distance is called a **parallel plate capacitor**. Look at Figure 1, to see the structure of parallel plate capacitors.

2.3 Charging and Discharging Capacitors

We have discussed earlier on that capacitors act as batteries while discharging through circuit elements such as resistors or bulbs. The difference is, with capacitors this charging and discharging process takes a much smaller amount of time, than say a time it takes a battery to fully drain its stored energy.

Let's for instance take a circuit that has a voltage source, a resistor and a capacitor. Assume the capacitor is charged to V_0 amount. When it is discharging, the initial current in the circuit is $\frac{V}{R}$(Recall Ohm's law), however, as time goes on, the potential differences decreases and as a result, the current also decreases. In capacitor terms, as time goes on, the potential difference(voltage) across the plates drops. When the current is higher(initially, since the voltage is higher), the capacitor empties really fast, but as time goes on, the current becomes lower and the capacitor also empties in a slower manner.

In the assignment that you did, you showed why the capacitor charging and discharging processes are exponential. The time it takes for a capacitor to charge to its 63 percent of its intended amount during charging or to drop to 37 percent of its full amount during discharging is **RC** seconds. RC is called the time constant and is represented by the Greek letter Tau(τ)

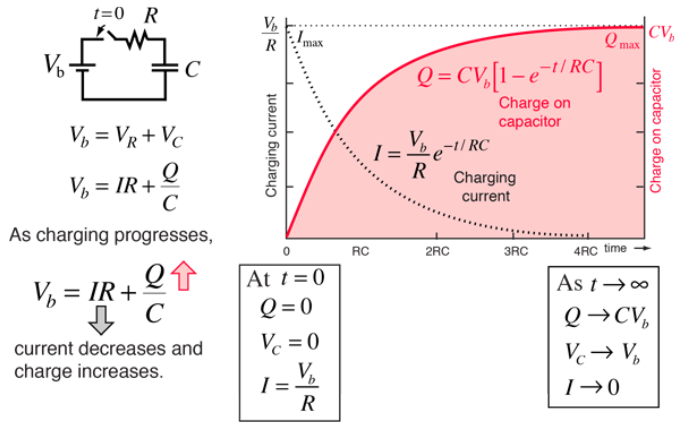

Figure 3: Capacitor Charging Curve(Source: Hyperphysics)

2.4 Factors Affecting Capacitance

A simple parallel plate capacitor contains parallel plates usually with an insulator in between them. The insulator in between the capacitors is called the **dielectric**. Capacitance can be affected by how much charge the plates can hold and the separation between them. Thus, the area of the plates(A) and the separation between them(d) are the main factors affecting the capacitance of a parallel plate capacitor.

$$C = \frac{\varepsilon_0 A}{d} \tag{3}$$

Where:

ε_0 is a quantity called permitivitty of free space(vacuum) and it is the measure of the tendency of free space to be polarized.

A is the area of the plates.

d is the separation distance between the plates

However, we have seen that we usually have an insulator(*dielectric*) between the plates. When that happens, instead of ε_0(Permitivitty of free space), we have ε(Permitivitty of dielctric). Our equation, then, becomes:

C = $\varepsilon A_{\overline{d}}$
(4)

Where:

ε is the permitivitty of the dielectric.

Permitivitty of a dielectric is related to the permitivitty of free space. The ratio between the permitivitty of a dielectric to that of free space is called **relative permitivitty** or **dielectric constant** and it is given by the Greek letter kappa(κ).

$\kappa = \frac{\varepsilon}{\varepsilon_0}$
(5)