DISCHARGING OF RC CIRCUIT

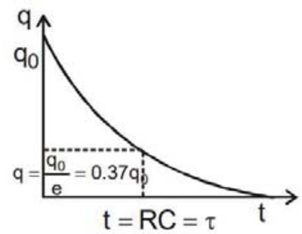
The discharging of an R-C (resistor-capacitor) circuit refers to the process where a charged capacitor releases its stored energy through a resistor, resulting in the gradual decrease of voltage across the capacitor and current flow through the circuit.

During the discharging process, the capacitor, which has been previously charged to a certain voltage, begins to discharge through the resistor. The discharging behavior can be described by the following differential equation, which represents the relationship between voltage, current, resistance, and capacitance:

$$\frac{dV}{dt} = -\frac{V}{MC}$$

This equation illustrates how the voltage across the capacitor decreases over time during the discharging process. The negative sign indicates that the voltage decreases with time, and the time constant RC determines the rate at which the capacitor discharges.

The charge present on the capacitor at any specific moment "t" can be expressed using the equation $q = q_0 e^{-(t/RC)}$. This equation demonstrates that the charge decreases exponentially over time. In this equation, "q" represents the charge at time "t", q_0 denotes the initial charge on the capacitor, "e" is Euler's number (approximately 2.71828), "t" stands for the elapsed time, "B" is a constant related to the circuit's properties, and "C" signifies the capacitance of the capacitor. Hence, as time progresses, the charge on the capacitor decreases in an exponential fashion.



When the product of resistance and capacitance (t = RC) equals the time constant, the charge on the capacitor (q) reaches $\frac{q_0}{e}$, which is approximately 37% of the initial charge q0. In other words, the time constant represents the duration over which the charge on the capacitor plates decreases to 37% of its initial value.

The charged capacitor is then connected in series to a resistor. When the connection is made, the capacitor starts to discharge through the resistor. The resistor limits the flow of current in the circuit.

As the capacitor discharges, the voltage across it decreases exponentially over time according to the equation:

$$V_c(t) = V_0 \times e^{-\frac{t}{t}}$$

the current flowing through the circuit during discharging is given by Ohm's law:

$$I(t) = \frac{V_z(t)}{R}$$

The capacitor continues to discharge until its voltage decreases to zero. At this point, the capacitor is fully discharged, and the current in the circuit ceases.

In summary, discharging of an RC circuit involves the gradual release of stored energy in a charged capacitor through a resistor, resulting in a decrease in voltage across the capacitor over time according to an exponential decay function.

Charge during Charging and discharging of R-C Circuit

- During charging, the current flows from the source through the resistor into the capacitor. The current decreases over time as the capacitor charges up.
- During discharging, the current flows from the capacitor, through the resistor, and back to the source. Similar to charging, the current decreases over time as the capacitor discharges.
- The current in the circuit is at its maximum at the instant when the switch is first closed (charging) or opened (discharging) and decreases exponentially over time.

In summary, during both charging and discharging of an R-C circuit, the behavior of the circuit and the flow of current follow exponential patterns determined by the values of resistance and capacitance in the circuit.

Force of Plate:

In a capacitor, the plates carry equal and opposite charges, leading to a force of attraction between them. To determine this force, we utilize the principle that the electric field is conservative, which allows us to derive it from the energy stored in the capacitor.

The energy stored in a capacitor (U) is expressed as U= $\frac{g^2}{2C}$, where q represents the charge on each plate and C denotes the capacitance.

For a parallel plate capacitor, the capacitance (C) is given by C= $\frac{50-A}{d}$, where ε_0 stands for the permittivity of free space, A denotes the area of each plate, and d represents the separation between the plates.

By substituting the expression for capacitance into the energy formula, we get

$$U = \frac{1}{2}\frac{q^2x}{\varepsilon_0 A}$$

To calculate the force of attraction (F) between the plates, we differentiate the energy U with respect to the separation (x) between the plates:

$$F = -\frac{d}{dx}\left[\frac{q^2}{2\varepsilon_0 A}x\right] = \frac{-1}{2}\frac{q^2}{\varepsilon_0 A}$$

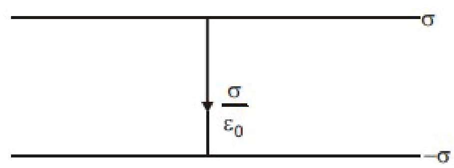
The negative sign indicates that the force is attractive, as expected.

Dielectric:

Effect of dielectric on charge density:

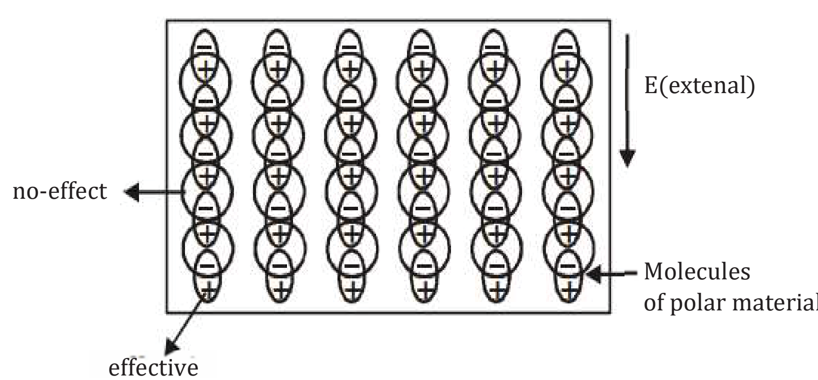
Capacitors with dielectric refer to capacitor components that incorporate a dielectric material between their plates. A dielectric is an insulating material that can be inserted between the plates of a capacitor to increase its capacitance. When a dielectric is introduced, it reduces the electric field between the plates, allowing for the storage of more charge at a given voltage.

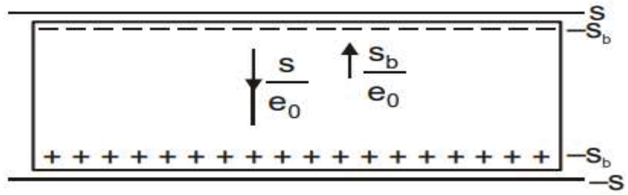
(i) In the absence of a dielectric material



$$E = \frac{\sigma}{\varepsilon_0}$$

(ii) When a dielectric material is introduced between the plates, molecules possessing dipole moments orient themselves along the direction of the electric field.





The induced charge density (σb), also known as bound charge, is generated within a material in response to an external electric field. It earns the name "bound charge" as it arises from the polarization of molecules within the material, rather than from the movement of free electrons. In the case of polar molecules, where the dipole moment is non-zero, σb is present. However, for non-polar molecules where the dipole moment is zero, σb does not emerge.

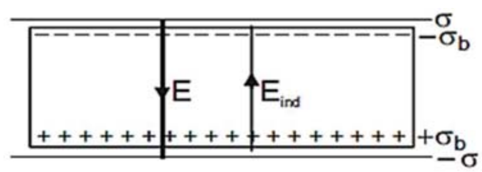
(iii) Capacitance with a dielectric present

$$C = \frac{\sigma A}{V} = \frac{\sigma A}{\frac{\sigma}{K\varepsilon_0}\cdot d} = \frac{AK\varepsilon_0}{d} = \frac{AK\varepsilon_0}{d}$$

In this scenario, capacitance is augmented by a factor K.

$$C = \frac{AK\ _0}{d}$$

(iv) Polarization of material: When an initially nonpolar substance is subjected to an electric field, it results in the induction of a dipole moment within the molecules of the material. This phenomenon, known as polarization, involves the alignment of molecular dipoles in response to the external electric field. Consequently, the induced charge distribution also generates an electric field within the material.



σb = the induced charge density, also referred to as bound charge density.

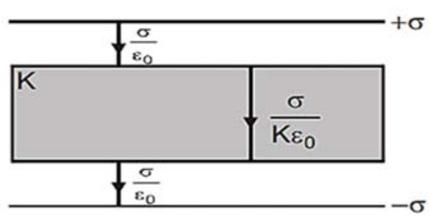
$$E_{in} = E - E_{ind} = \frac{\sigma}{\varepsilon_0} - \frac{\sigma_b}{\varepsilon_0}$$

It is observed that the ratio of the electric field strength between the plates in the absence of a dielectric to that in the presence of a dielectric remains constant for a given dielectric material. This consistent ratio is referred to as the 'dielectric constant' of the material and is denoted by $\varepsilon_x$or k.

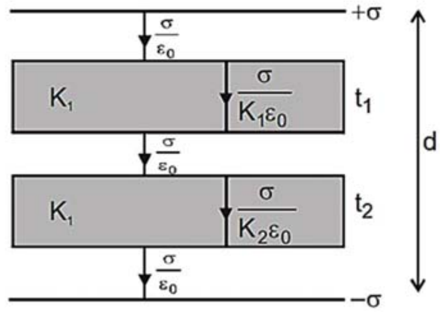
$$E_{in} = \frac{\sigma}{K\varepsilon_0}$$

⇒ $$\sigma_b = \sigma\left(1 - \frac{1}{K}\right).$$

(v) When the medium is not entirely filled between the plates, the electric field will be as depicted in the figure.



- The combined electric field resulting from the induced bound charge on the dielectric material outside the slab amounts to zero, as they mutually annul each other.
- Hence, the potential difference between the plates is.



$$v = \frac{\sigma}{\varepsilon_0}[\, d - t_1 - t_2] + \frac{\sigma}{k_1\varepsilon_0}t_1 + \frac{\sigma}{k_2\varepsilon_0}t_2$$

Therefore, the equivalent capacitance is

$$C = \frac{Q}{v}$$

$$C = \frac{\sigma A}{\frac{\sigma}{\varepsilon_0}\left[\, d - t_1 - t_2 + \frac{t_1}{k_1} + \frac{t_2}{k_2}\right]}$$

$$C = \frac{A\varepsilon_0}{d - t_1(1 - \frac{1}{k_1}) - t_2(1 - \frac{1}{k_2})}$$

Capacitors with dielectric materials find wide applications in various electronic circuits, such as in power supplies, filters, coupling, and decoupling circuits, among others. They play a crucial role in energy storage, signal filtering, and voltage regulation in electronic devices and systems.