Experiment N°3: Charging and discharging a capacitor

I. Purpose

1. Charging and discharging a capacitor.
2. The time constant measurement of charging and discharging.

II. Principle

A capacitor is an electronic component capable of accumulating electrical charges. It is composed of two conductive metal plates, called armatures, between which is an insulating layer, called a dielectric. When a capacitor is placed in a circuit with a current i flowing through it for a time t, the armature bonded to the positive pole of the generator accumulates the electric charge +Q. An opposite electrical charge -Q then appears on the other armature.

The capacitance is the ratio of its armatures charge to the potential difference between its armatures:

$$C=Q/(V_1-V_2) \quad (3.1)$$

When Q is expressed in Coulombs (symbol C) and the voltage in Volts, capacitance C is expressed in Farads F).

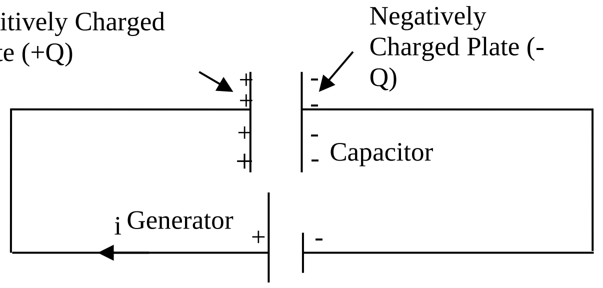

Figure 3.1 : Charging a capacitor

III. Charging a Capacitor

Consider the circuit in Figure 2, when the circuit switch is closed, the voltage across the capacitor and the current flowing through it, according to Kirchhoff's law, are written as:

$$U_c(t)=E(1-e^{-t/\tau}) \quad (3.2)$$

$$i(t)=\frac{E}{R}e^{-\frac{t}{\tau}} \quad (3.3)$$

With $\tau = RC$

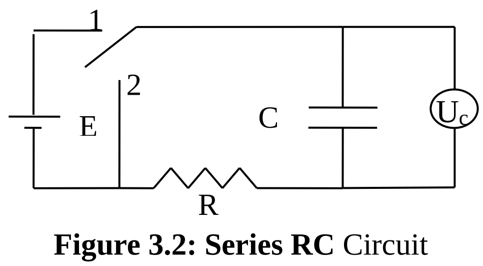

Figure 3.2: Series RC Circuit

The term τ =RC is called the circuit time constant. It characterizes the greater or lesser ease with which the circuit responds to excitation E. There are three methods for determining the **τ** value.

a) Calculation of U_c at $t = \tau$ during charging: The time constant τ means that after a time interval $t = \tau$ after the switch is closed, the values of the voltage and current given by :

$U_c = E\left(1 - e^{-\frac{\tau}{\tau}}\right) = E(1 - e^{-1}) = E \times 0{,}63$ and $i = Ie^{-1} = 0{,}37I$

The point with this ordinate is located on the curve. The time constant τ is the abscissa of this point (see Figure 3.3).

b) Half-charge time: We have at $U_C = E/2$, $t = \tau \ln 2$.

c) The curve $U_C = f(t)$ tangent at $t=0$: τ is the abscissa of the tangent intersection point (shown in red in Figure 3) to the curve $U_C(t)$ at $t = 0$ s and the line has equation :

$U = U_C^{max} \approx E$.

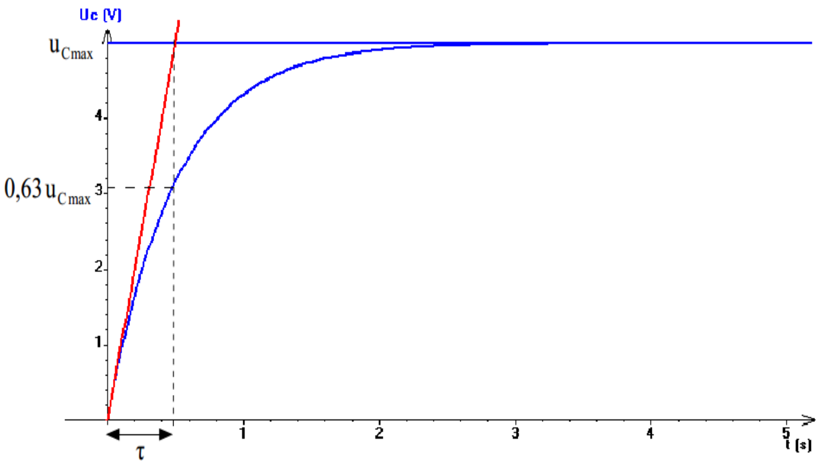

Figure 3.3: Courbe de charge d'un condensateur

The calculation shows that after a time interval $t = 5\tau$, U and i reach their final value to within one thousandth. The steady-state (permanent) regime is said to have been reached; U and i are no longer independent of time.

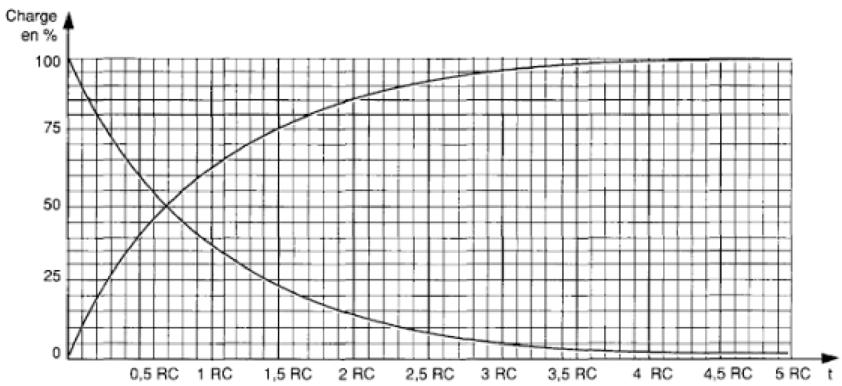

Figure 3.4: Universal Capacitor Charge and Discharge Curves.

During this experiment, you will learn how to measure the time constant of RC circuit using the voltmeter and stopwatch in charging and discharging the capacitor circuit using a DC generator. You will be able to check your measurement by comparing it with the R and C values of the resistor and capacitor (Resp).

IV. Used Materials

DC generator : *E=12 V,* capacitance of *C=100 µF*, resistor of *R= 200 kΩ*, voltmeter and stopwatch

V. Handling 2: Slow charging and discharging

- Curry out the RC circuit by taking: *C= 100µF*, *E=12 V* and *R=200 or 300 kΩ.*
- Check that the capacitor is completely discharged, otherwise short-circuit its two armatures.

b) **Slow charging**

- Toggle the switch to position 1 and at the same time engage the stopwatch and read the UC voltage indicated by the voltmeter for different times and present the results in following table:

Time *t (s)*	5	10	20	30	40	60	80	100	140	180	240
P.D U_C *()*											

- Draw the curve $U_C(t)$.
- Determine graphically the time constant τ and compare it with the theoretical value.
- - Deduct the current *i(t)* flowing through the circuit. Draw its curve.

c) Slow Discharging

- With the capacitor fully charged at U_{C0} = E=12 V, turn the switch to position 2
- Answer the same previous questions.

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Note: Please leave your bench in a tidy fashion. Thank you