Experimental No. (10)

CHARGING AND DISCHARGING OF A CAPACITOR

OBJECTIVE:

1) To study charging and discharging characteristics of a capacitor.

2) To find the time constant RC for an RC-circuit.

APPARATUS:

Capacitor, C = 100μF, Resistor R = 1MΩ, D.C. power supply, Voltmeter, Timer, Connecting wires.

THEORY:

Capacitance is created when two conductors are separated by a dielectric. The symbol for capacitance is C, and its unit is farad F, smaller units are: μF, nF, pF. In electric circuits, capacitors are used for many purposes. For example, they are used to store energy, to pass alternating current while blocking direct current, and to shift the phase relationship between current and voltage. Also used in filters and resonance circuits. In this experiment they will be used in timing circuits. A capacitor can store a charge of electrons over a period of time. When a voltage V is applied across a capacitor, electrical charges will be forced onto one plate and pulled off the other. The process of building up the charge of electrons in a capacitor is known as charging. The magnitude of the charge (Q) thus displaced from one plate to the other is proportional to the capacitance (C) and to the voltage V across the capacitor: $V = \frac{Q}{C}$

CHARGING A CAPACITOR:

The circuit in Figure(22), the capacitor is initially uncharged; the initial potential difference across it is zero (V_c = 0). At the instant the switch (S) is moved to position (a), the charge of electrons rush to the capacitor, but the resistor works to hold up this rush, and the entire input voltage appears across the resistor (V_R = V).

At this instant the current in the circuit is maximum and equal to I = V/R. As the capacitor charges, its voltage increases with time, opposing the source voltage, and the voltage across the resistance decreases, as a result, the current I decrease also. Finally, when the capacitor becomes fully charged, its voltage Vc is equal and opposite to the applied voltage V, i.e,(Vc = V , VR = 0 and I = 0).

At some time (t), after the switch has been moved to position (a), let Q represent the charge on the capacitor, and I the current in the circuit, thus, applying Kirchhoffs second low, we obtain:

$$V_o = V_R + V_c \quad (25)$$

$$V_o = IR + \frac{Q}{C} \quad (26)$$

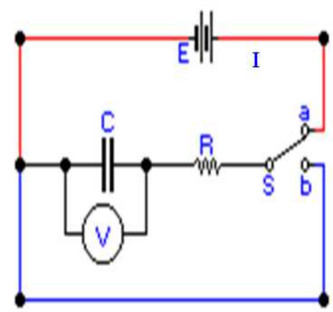

Figure 22:

The rate at which charge flows through the resistor: $I = \frac{dQ}{dt}$ is equal the rate at which the charge accumulates on the capacitor, thus we can write:

$$V_o = \frac{Q}{C} + R\frac{dQ}{dt} \quad (27)$$

This equation can be solved, the solution is:

$$Q = Q_o(1 - e^{\frac{-t}{RC}}) \quad (28)$$

$$V_c = V_o(1 - e^{\frac{-t}{RC}}) \quad (29)$$

The charging current Ic in the circuit at any moment can be calculated by the derivative of the charge Q with respect to the time t in equation (30):

$$I_c = I_o e^{\frac{-t}{RC}} \quad (30)$$

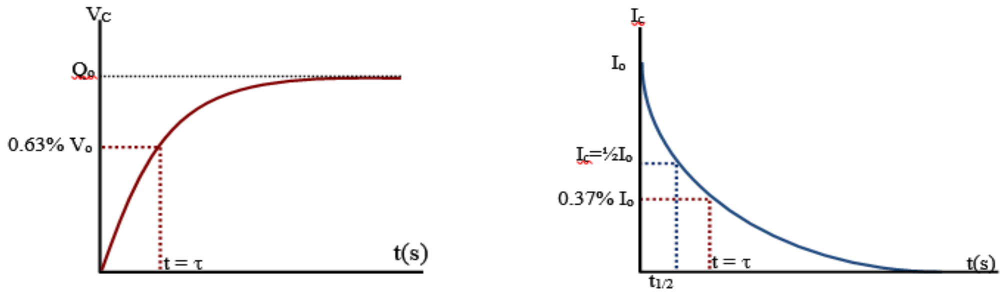

Figure 23:

From equation-28, Figure -23 is the plot of the charging voltage Vc versus time t . At t =RC , the value of Vc reach 63 % of its maximum value Vo, this quantity is called the time constant τ of the RC circuit. So at t = τ , the voltage across the capacitor has decreased to a value:

$$V_c = (1/e)V_o \approx 0.63V_o \tag{31}$$

Similarly, for equation-6, Figure-3 is the plot of the charging current Ic versus time t . So at:

$$t = RC = \tau, and I_c = 0.37 I_o \tag{32}$$

A quantity, which is easy to measure experimentally, is the time required for the charge Q to become 1/2 of its original value Q_o. Denoting this time as $t_{1/2}$, we have from equation (28):

$t_{1/2}$ **= 0.693** τ

Thus the product RC is a measure of how quickly the capacitor gets charge. You can demonstrate that a capacitor does not charge instantaneously; it takes time to charge, because all circuits contain some resistance.

DISCHARGING A CAPACITOR:

As soon as the power source is disconnected, (switch S is at position b, Fig.24), the charge begins to flow from one plate of the capacitor towards the other, forming a current I through the resistance R until the capacitor is fully discharged. Applying Kirchhoffs second low, since there is no applied voltage, we obtain : VR + Vc = 0 , or $\frac{dQ}{dt}R + \frac{Q}{C} = 0$ **This equation has the solution:**

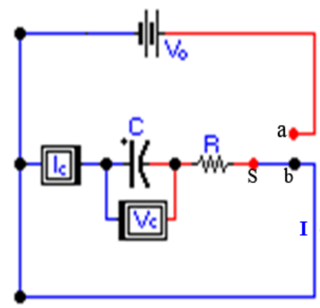

Figure 24:

$$Q = Q_o e^{\frac{-t}{RC}} \quad (33)$$

$$I_c = -I_o e^{\frac{-t}{RC}} \quad (34)$$

$$V_c = V_o e^{\frac{-t}{RC}} \quad (35)$$

After time t =RC= τ **the voltage across the capacitor has decreased**

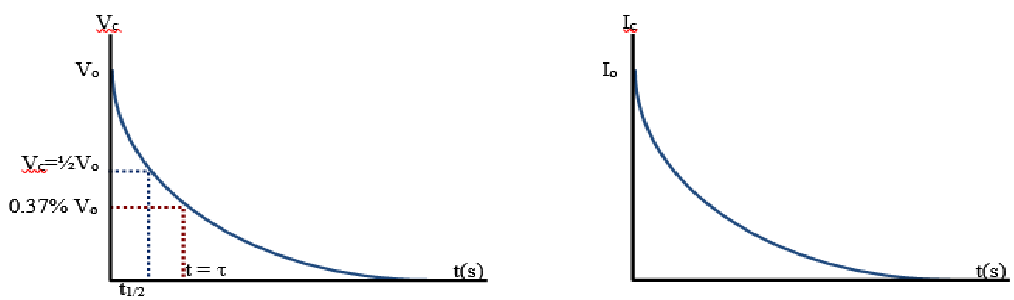

Figure 25:

to a value:

$$V_c = 0.37V_o \quad (36)$$

Figures (25) shows the discharging graphs Vc versus t and Ic versus t .

EXPERIMENTAL PROCEDURE:

1) Record the value of the capacitance C , the resistance R , the applied voltage Vo and the initial current Io in table (1). Connect the circuit as shown in Figure (22), have the instructor check your circuit before closing the switch. Short the capacitor. In order to be familiar with the procedure, close the circuit, (switch S is at position a), Dis-short the capacitor , note the voltage rise and the current decay in the capacitor during charging.

When the capacitor is fully charged ($V_c \approx V_o$, and $I_c \approx 0$), disconnect the power source, (switch S is at position b Figure.24), note the voltage and current decay as the capacitor discharges.

2) Now, simultaneously, close the circuit and, Dis-short the capacitor , start the timer. At regular time intervals of 10 seconds, read the current I(μA), and voltage Vc until the capacitor is nearly fully charged. Record your data in table (1). Reset the timer.

3) Simultaneously set the switch S at position (b), Fig.24, and start the timer. At regular time intervals of 10 seconds, read the current I(μA), and voltage Vc until the capacitor is nearly discharged (Vc$\approx$0 , and I_c $\approx$0), . Record your data in table (2).

Name: **Grade:**

Students No.: **Date:**

Data and calculation

V_o=........., I_o=..........., **R=............., C=.............**

Table 1 Charging

t(s)	**I(μA)**	V_c**(volts)**

Table 2 Discharging

t(s)	**I(μA)**	V_c**(volts)**	**Ln V**

Charging of a Capacitor.

1) Plot the charging voltage V_C versus t(s) . From the graph find the time constant τ .

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-Use the graph to Calculate the value of Q_o as shown in Figure (22) .

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-Compare With the theoretical value $Q_o = CV_o$

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2) Plot the charging current I_C versus t(s). From the graph find the time constant τ

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3) Calculate the value of the charge Q stored in the capacitor at t $=\tau$

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4) Calculate the value of $\frac{Q}{Q_o}$

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5) From the graph, determine the value of $t_{1/2}$ and then calculate τ .

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Discharging of a Capacitor.

6) From the data of the discharge current in table (2) plot ln I_C versus t for the discharging process. Draw the best straight line. Find the slope of this graph.

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7)Using equation (34), where. $\tau = \frac{1}{slope}$, From the slope calculate the time constant τ,

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8)You have already found τ by many methods, Find the mean value , and find the standard deviation of τ.

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