# 13 Discharge of a Capacitor through a Resistor

**Objectives:**

The objective of this experiment is to:

i: Study the discharge of a capacitor through a large resistor and verify the Q=CV relation,

ii: Determine the RC time constant.

**Theory:**

The device needed in electric circuits to store and release energy is called a capacitor. . A capacitor is made in the form of two conductors called the plates that are close together but are insulated from one another.

The basic property of a capacitor which characterizes its ability to store energy is its capacitance C. By capacitance, it is meant the ratio of the magnitude of the charge Q on each plate to the magnitude of the potential difference V across the plates, that is $C=Q/V$.

Capacitance is measured in Farads (F) but 1 Farad is , rather, a large unit of capacitance and, in electric circuits, the capacitance of capacitors is typically found in the range from $10^{-12}$ F (1pF) to $10^{-6}$ F ( 1μF).

A capacitor of capacitance C that is, initially, charged through a potential difference V will hold a charge $Q=CV$. If it is, now, allowed to discharge through a resistor of resistance R, a transient current i (which does not last very long) will flow in the circuit until the capacitor is completely discharged. The transient current flowing in the circuit can be obtained by using Kirchoff's voltage law around a closed loop, that is:

$$Ri+\frac{q}{C}=0 \tag{1}$$

where q(t) is amount of charge remaining on each plate at any time t, Ri is the voltage across the resistor and is the voltage across the capacitor. Differentiating Eq.(1) with respect to time yields:

$$R\frac{di}{dt}+\frac{1}{C}\frac{dq}{dt}=0 \tag{2}$$

Since $i=\frac{-dq}{dt}$, Eq.(2) becomes then:

$$\frac{di}{dt}+\frac{1}{RC}i=0 \tag{3}$$

Eq. (3) is a differential equation in i whose solution is:

$$i(t)=\frac{V}{R}e^{-\frac{t}{RC}} \tag{4}$$

The constant RC appearing in expressions (3) and (4) is called the time constant and is usually denoted by $\tau$ =RC and has the unit of time. The time constant is an indication of how fast ( or slow ) a charged capacitor discharges through a resistor.

Observe that i(t) is a decaying exponential function of time. This decay is represented, for example, by the curve of figure 1 for the current as a function of time and as given by Eq. (4).

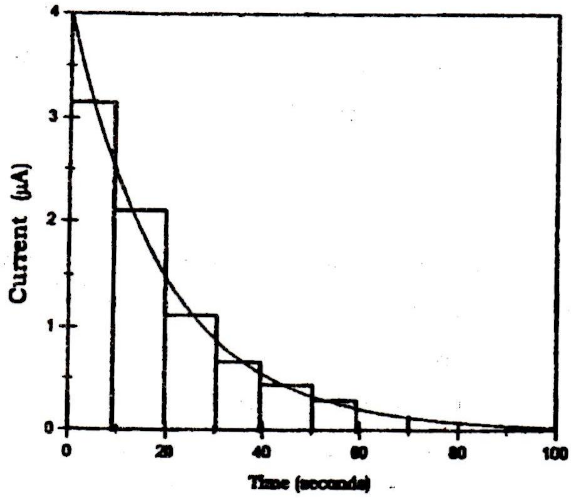


Figure 1: Current Decay as a Function of Time

**Apparatus:**

DC Power source, electronic galvanometer with a range of 0.4μA, electronic timer, 4.7μF capacitor, 2.2 μF capacitor, decade resistor box, board and switches.

**Procedure:**

1. Connect the circuit illustrated in figure (2) with V = 4 V, C = 4.7 μF and R =10 MΩ. Note that when switch A is closed and switch B is open, the capacitor charges. By opening A and closing B you will allow the capacitor to discharge through the resistor R.

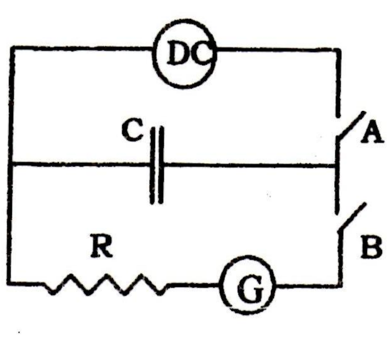


Figure (2): Circuit for the Charge and Discharge of a Capacitor.

2. To study the decay, you will have to record the current at different times. One way to proceed is as follows:

a) First, observe that the galvanometer response is slow: its illuminated spot (pointer) does not read maximum current instantaneously as soon as the discharge starts. So, it is more convenient to take your first current reading few seconds after the discharge has started. Record this first reading as $I_0$ and take it as your reference for the next readings.

b) Recharge the capacitor by opening B and closing A. Let it, now, discharge and start your timer when the galvanometer reads $I_0$. Read the current 5 seconds later. Repeat this step three times and record the average current reading as $I_1$ and time as $t_1$.

c) Repeat step (b) by allowing the current to decay to smaller values than observed before until the current $I_i$ is nearly zero.

3. Repeat the whole procedure for C = 2.2 μF.

**Analysis:**

Draw, on a sheet of millimetric paper, i(t) versus t for each capacitor. The curve should be similar to the one represented in figure (1).

After plotting the curve, divide the area under it into rectangles as illustrated in figure (1). It will be convenient to use $\Delta t$' s of constant width, and the value of $I_i$ should be such that the curve intersects each rectangle about the center of its base. Compute the approximate total charge on the capacitor by summing up the area of all the rectangles under the curve, that is,

$$Q = \sum_{i=1}^{i=n} I_i \, \Delta t_i \, .$$

Compare the charge stored by the capacitor you calculated using the area under the i(t) versus t curve with the value obtained using the formula Q=CV.

Alternatively, you may compute the charge stored by the capacitor using the fact that:

$$Q = \int_0^{\infty} i \, dt$$

Draw, on a semi-Log paper, i(t) versus t for each capacitor. The curve should be a straight line whose slope is negative.

Determine the slope of each of the line and find the time constant τ. Compute the value of RC from the actual circuit and compare to the value of τ obtained graphically.