Experiment No. 6

To determine the time constant of an RC circuit.

6.1 Objectives

The main objective of this lab is to construct an RC circuit and determine the time constant of that RC circuit.

6.2 Prelab

Student should read the lab manual and have clear idea about the objective, time frame and outcomes of the lab.

6.3 Outcomes

After completing this lab work, students will be able to answer the following questions:

- What is capacitor and capacitance? How a capacitor can be charged and discharged in a circuit.
- What is the significant of time constant in an RC circuit?
- How the time constant of an RC circuit can be obtained?
- How the voltage across the capacitor in an RC circuit varies with time for charging and discharging of the capacitor?

6.4 Timing and Length of Investigation (Total 3 Hours)

- **Lab Preparation (15 minutes):**
    - To connect with the students and take class attendance.
- **Lecture on Theory (30 minutes):**
    - Teacher will clarify the objective and theory of the experiment.
- **Lecture on Procedure (15 minutes):**
    - Student will try to understand the procedure of the experiment through a video lecture.
- **Experimental Work (90 to 100 minutes):**
    - A sample data will be provided to students and teacher will clarify every part of it.
    - Students will do all the calculations, draw graphs in excel and complete the result part.
- **Post Lab Discussion (15 to 20 minutes):**
    - Teacher will summarize the total lab work and have a discussion with the students related with the questions given in the outcomes part.
- **Report Submission:**
    - After completing the lab reports students will upload their lab reports as groups in teams.

6.5 Theory

Capacitors are used in timing circuit in many devices. The time that the dome lights inside a car stay on after turning off the cars ignition at night is one example of how a capacitor can be used to maintain the lighting long enough to remove the key and collect things before exiting. The values we use to characterize these kinds of circuits is given by the time constant defined as: $\tau = RC$, where R is the circuit resistance and C is the capacitance. In this lab, we will observe the charging and discharging of a capacitor and determine the time constant of a RC circuit.

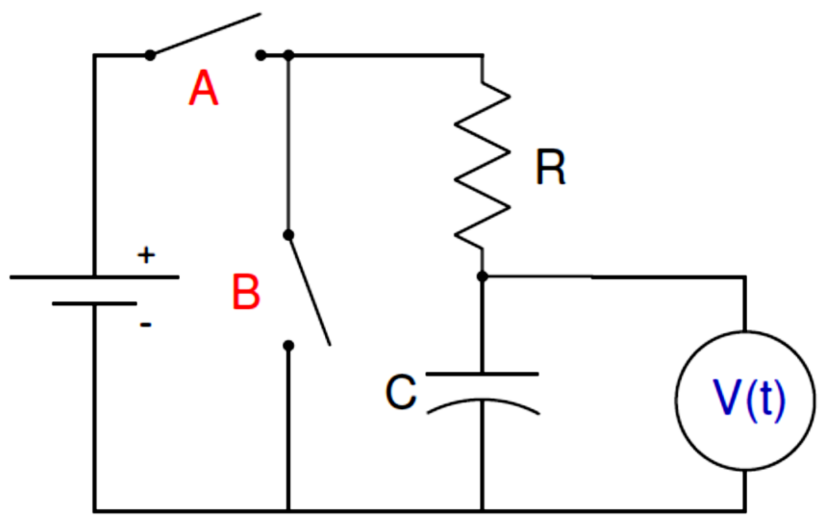

Figure 6.1: Circuit for RC charge-discharge measurement where V(t) is the potential difference across the capacitor as a function of time.

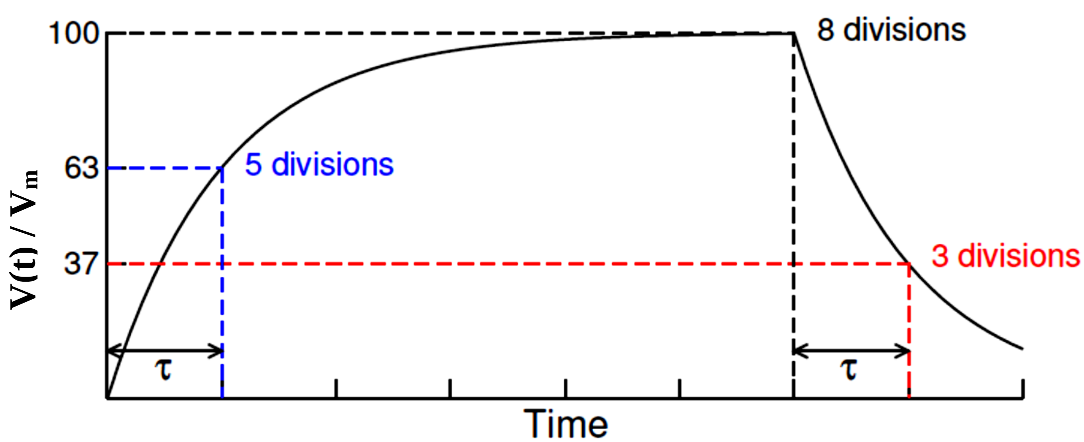

Figure 6.2: Potential difference across a capacitor in an RC circuit as a function of time.

The time constant can be determine by observing the either the charging and discharging process of the capacitor as the Fig. 6.2 shows. For the charging process, τ is the time for V(t) to reach 63%

of its final value. For the discharging process, τ is the time for V(t) to fall 63% from its initial value.

In the RC circuit in fig. 6.1, if at t = 0 switch A is closed (switch B remains open) charges will begin to build up in the capacitor. These charges do not accumulate within the capacitor instantaneously due to the resistance provided by the resistor. The potential difference across the capacitor for this process can be expressed as

$$\boldsymbol{V(t) = V_m\left(1 - e^{-t/\tau}\right),} \qquad \textbf{(1)}$$

where V_m is the maximum potential difference across the capacitor.
After a sufficiently long time (much larger than time constant), if switch A is open while switch B is closed, the capacitor will discharge all of its accumulated charges. The potential difference across the capacitor can be expressed as

$$\boldsymbol{V(t) = V_m\, e^{-t/\tau}} \qquad \textbf{(2)}$$

For charging, Eq. 1 can be written as

$$\boldsymbol{ln\left[1 - \frac{V(t)}{V_m}\right] = \left(-\frac{1}{\tau}\right) t} \qquad \textbf{(3)}$$

On the other hand, for discharging, Eq. 2 can be written as

$$\boldsymbol{ln\,\frac{V(t)}{V_m} = \left(-\frac{1}{\tau}\right) t} \qquad \textbf{(4)}$$

Comparing Eq. 3 and 4 with y = mx and plotting a graph of "$\boldsymbol{ln\left[1 - \frac{V(t)}{V_m}\right]\ vs\ t}$" for charging and "$\boldsymbol{ln\,\frac{V(t)}{V_m}}$ **vs t"** for discharging**,** we get the value of τ as $\tau = -\frac{1}{m}$, where m is the slope of the graphs.

6.6 Apparatus

Power supply, circuit board, resistor, capacitor, multi meter, stop watch and connecting wires.

6.7 Procedure

- Construct an RC circuit on the circuit board as the circuit diagram shows.
- Applying a sufficient voltage from the power supply, observe the charging of the capacitor and note the voltage differences across the capacitor with time.
- Disconnect the power supply from the circuit, observe the discharging of the capacitor with time. Also note the voltage differences across the capacitor with time.

6.8 Experimental Data

Table 6.1: Charging & Discharging of an RC circuit.

Maximum potential difference, V_m = ________ Volts

Time (seconds)	**Charging capacitor**		**Discharging capacitor**	
	V (t) (Volts)	$\ln\left[1-\frac{V(t)}{V_m}\right]$	V (t) (Volts)	$\ln\frac{V(t)}{V_m}$

6.9Analysis and Calculation

- Use EXCEL to plot "***V(t) versus t*** " graphs for charging and discharging.
- From the relation: τ= RC, estimate the value of time constant.
- For charging, plot a graph of "$\boldsymbol{ln}\left[\mathbf{1}-\frac{\boldsymbol{V(t)}}{\boldsymbol{V_m}}\right]\ \boldsymbol{vs\ t}$" and from the value of slope calculate the value of time constant.
- For discharging, plot a graph of "$\ln\frac{V(t)}{V_m}\quad \boldsymbol{vs\ t}$" and from the value of slope again calculate the value of time constant.

6.10 Result

Table 6.2: Values of time constant, τ.

<table>
<tr><th colspan="2">From the graphs</th><th rowspan="2">Estimated Values of τ (=RC) in seconds</th><th>Comments</th></tr>
<tr><th>Process</th><th>Values of τ
in seconds</th><td rowspan="3"></td></tr>
<tr><td>Charging</td><td></td><td rowspan="2"></td></tr>
<tr><td>Discharging</td><td></td></tr>
</table>

6.11 Resources

For further understanding students may go through the following resources:

- **Fundamental of Physics (10th Edition):** Capacitor (Chapter 25, page 717-721),
  RC circuit (Chapter 27, page 788-791).

- **Video Links:**
  - https://www.youtube.com/watch?v=f_MZNsEqyQw
  - (4) 22 - Circuits - Time constant of an RC circuit - YouTube