AIM - To study the charging and discharging of a capacitor to find the time constant.

APPARATUS - Multimeter, stop watch, connecting wires, bread board, capacitors, resistors.

THEORY - Charging of a capacitor.

Let us consider a series RC circuit with a DC voltage source. When the key is closed, the charge Q on the capacitor starts building up increasing the voltage V_c across it.

At any instant t, the emf equation for the circuit is

$$V_0 = V_c + iR$$
$$= \frac{Q}{C} + R\frac{dQ}{dt}$$

Rearranging, we get.

$$\frac{dQ}{V_0 - (Q/C)} = \frac{dt}{R}$$

Integrating

$$-C \ln\left(V_0 - \frac{Q}{C}\right) = \frac{t}{R} + A$$

Since $Q=0$ at $t=0$, $A = -C \ln V_0$.

$$C\left[\ln V_0 - \ln\left(V_0 - \frac{Q}{C}\right)\right] = \frac{t}{R}$$

$$\ln\left[\frac{V_0}{V_0 - (Q/C)}\right] = \frac{t}{RC}$$

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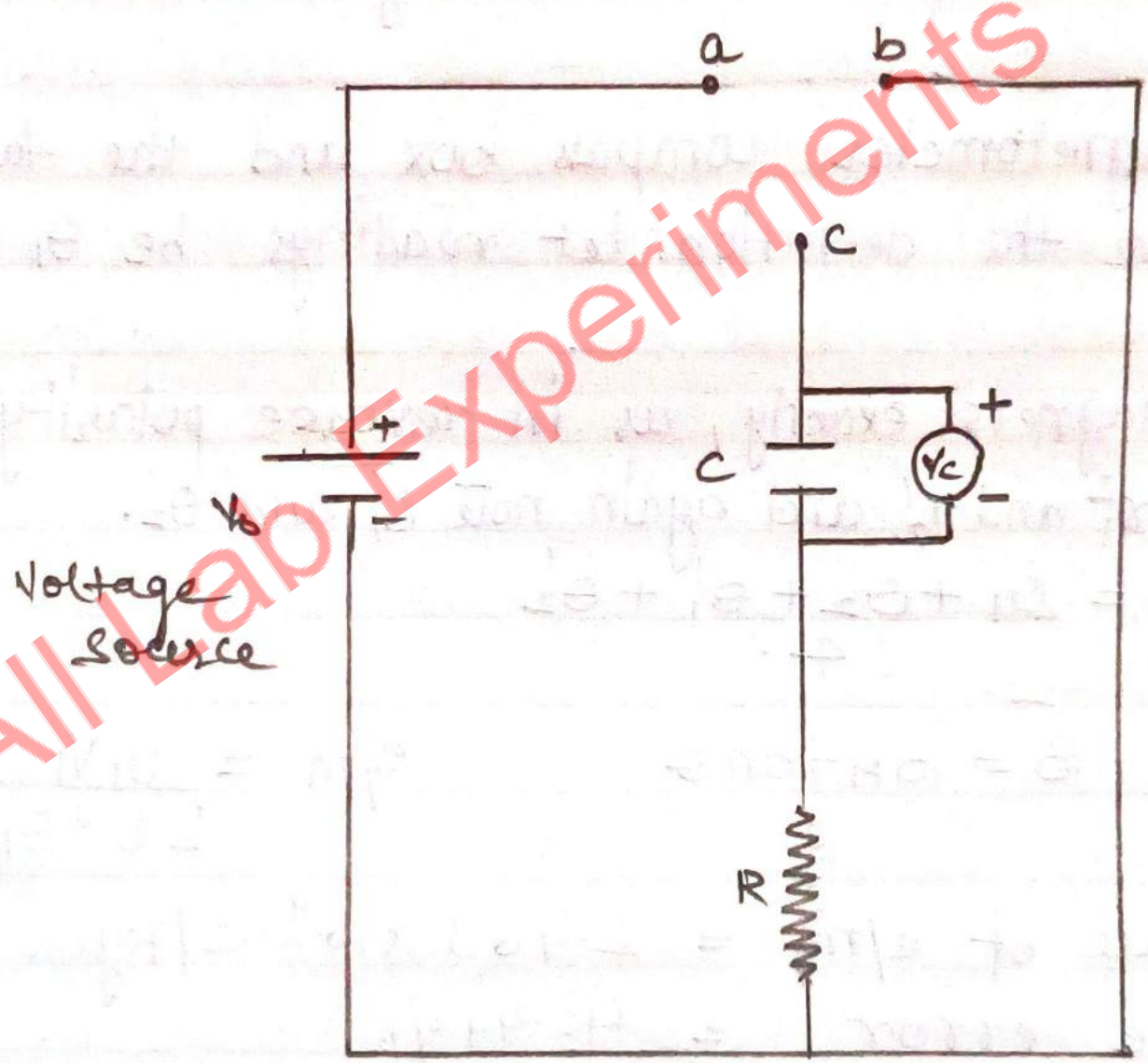
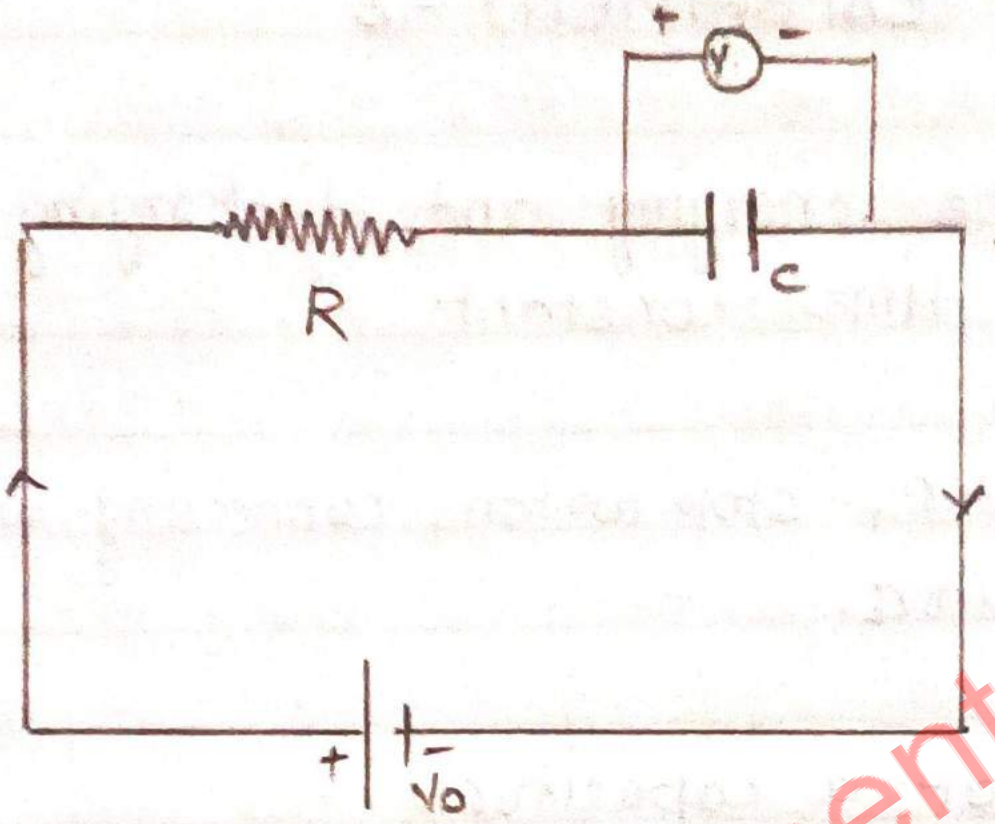
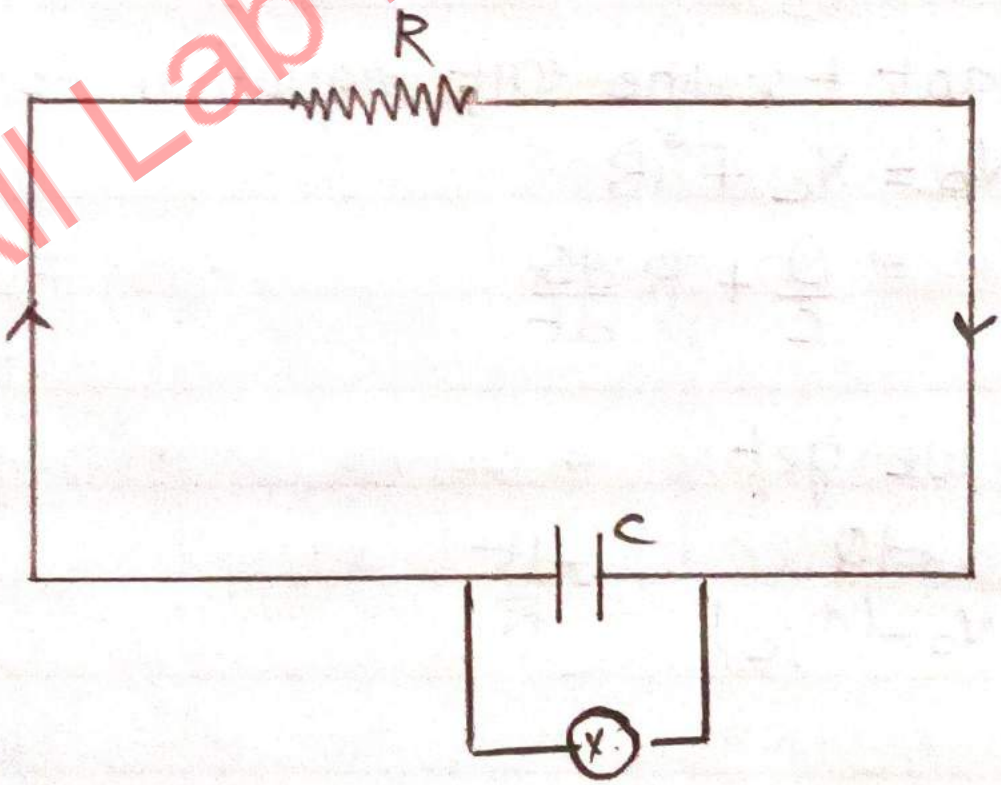


circuit diagram for charging and discharging of a capacitor



charging of a capacitor



discharging of a capacitor

$$1 - \frac{Q}{CV_0} = e^{-t/RC}$$

$$\frac{Q}{CV_0} = 1 - e^{-t/RC}$$

$$V_C = V_0 (1 - e^{-t/RC})$$

@ $t = RC$,

$$V_C = V_0 \left(1 - \frac{1}{e}\right) = 0.632\, V_0$$

Here the $t = RC$ is called the time constant.

Time constant of an RC circuit is defined as charging time of capacitor C in which the charge / voltage across it becomes 0.632 times the final maximum charge / voltage.

Discharging of a capacitor.

Let us consider the discharging of a capacitor C through a resistor R after charging is fully. At any istant t, if i is the current in the circuit and V_c is the voltage across the capacitor.

$$iR + V_c = 0$$

$$R\frac{dQ}{dt} + \frac{Q}{C} = 0$$

$$\frac{dQ}{Q} = \frac{-1}{RC} dt$$

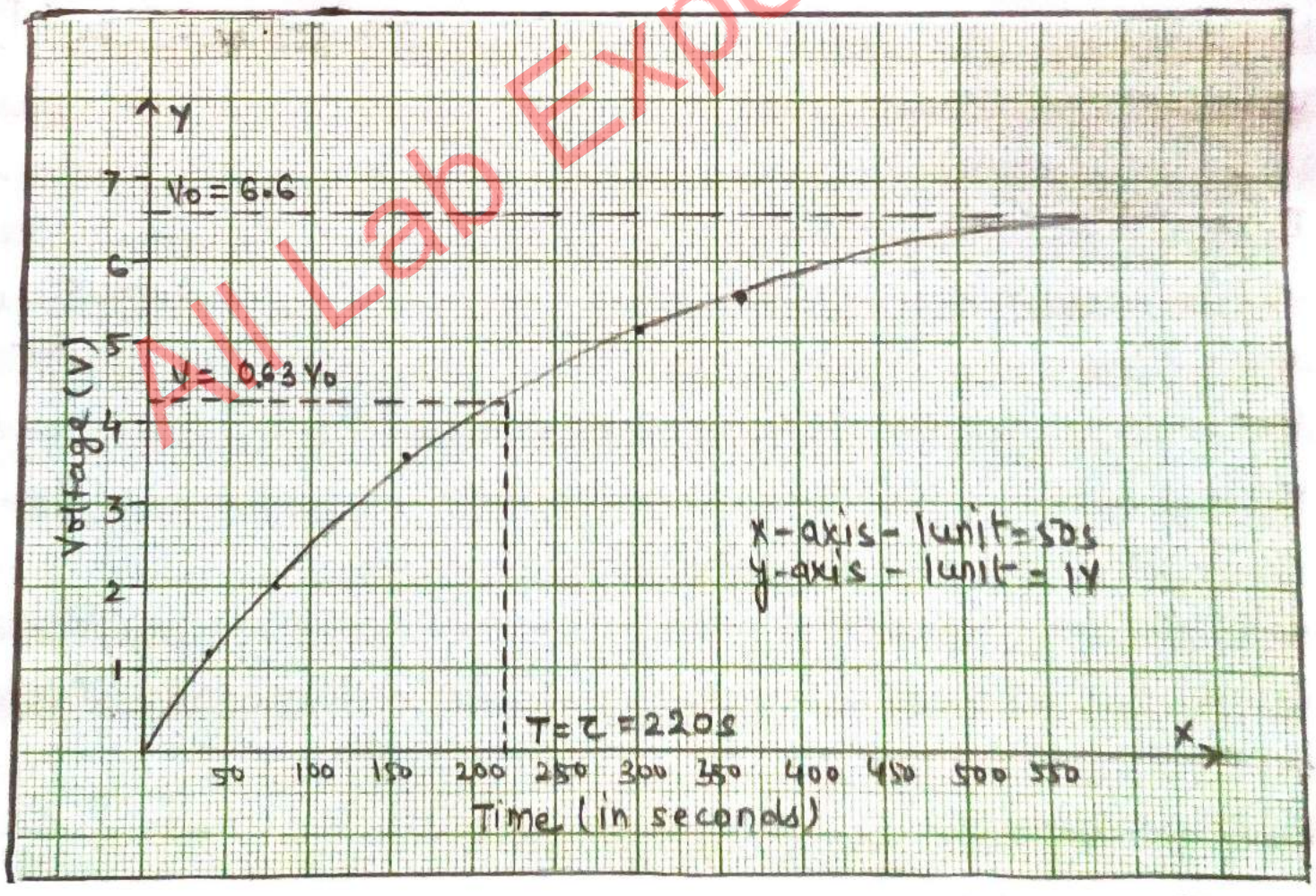
Integrating, $\ln Q = \frac{-t}{RC} + B$

Since $Q = Q_0$ at $t = 0$, $B = \ln Q_0$.

observations

I. charging of a capacitor

S.No.	Voltage across capacitor (in V)	time (in seconds)
1	1.2	41
2	2.0	77
3	3.6	157
4	5.15	303
5	5.54	364



$$\ln \frac{Q}{Q_0} = -\frac{t}{RC}$$

$$Q = Q_0 e^{-t/RC}$$

$$V_c = V_0 e^{-t/RC} \quad \left[V_c = \frac{Q}{C} \text{ and } V_0 = \frac{Q_0}{C}\right]$$

When $t = RC$, $V_c = \frac{V_0}{e}$.

$$V_c = 0.368 V_0.$$

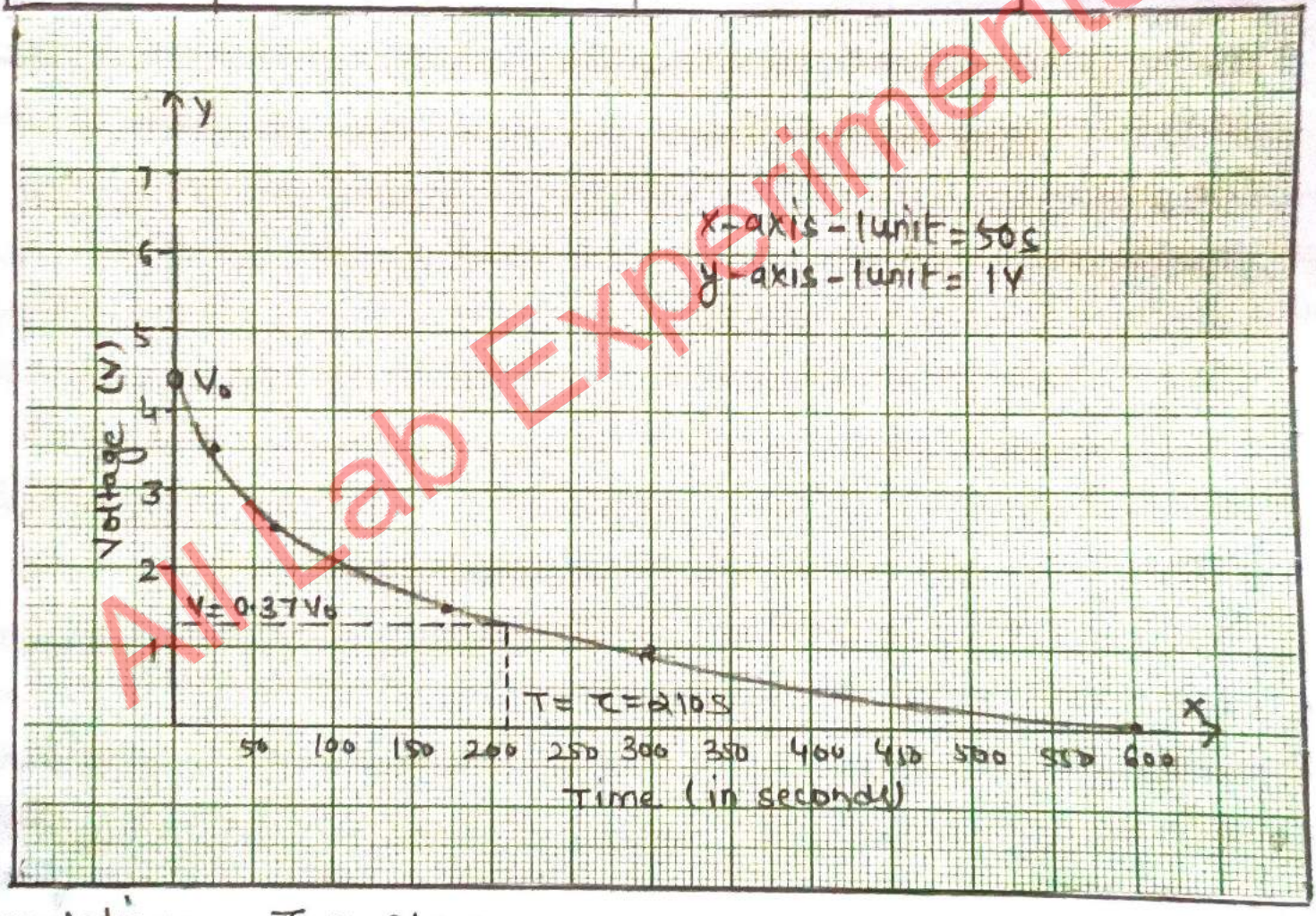
Time constant of an RC circuit can also be defined as the discharging time of the capacitor through a resistor in which the charge/voltage across it becomes 0.37 times the initial charge/voltage across capacitor.

PROCEDURE - charging of a capacitor.

- Make the circuit as shown in figure.
- Make the connections between a and c by pressing the Morse key k and simultaneously switch on stop watch.
- Note down the charging time in seconds and the corresponding voltage V_c across C. Take readings till V_c reaches its maximum.
- Plot time t along x-axis and corresponding voltage V_c along y-axis and draw the charging curve.
- From this curve determine the time constant as the time corresponding to $V_c = 0.63 V_0$.

II Discharging of a capacitor

S.No.	Voltage across capacitor (in V)	Time (in seconds)
1	3.5	25
2	2.5	62
3	1.5	172
4	1.0	303
5	0.1	602



Calculations. $\tau_1 = 210\,s$ $\tau_2 = 220\,s$

$$\tau_{mean} = \frac{210 + 220}{2} = 215\,s.$$

$$\%\ error = \frac{215 - 200}{200} \times 100 = 7.5\%$$

Discharging of a capacitor.

- Charge the capacitor C by pressing the Morse key K. (a and c are joined) till V_c reaches its maximum value V_0.
- Release the Morse key (b and c are joined) and simultaneously start the stop-watch. The capacitor is discharging now.
- Note down the discharging time in seconds and corresponding voltage V_c across the capacitor. Take reading till the voltage V_c is less than 1.
- Draw discharging curve by plotting the time t along x-axis and the corresponding voltage V_c along y-axis.
- From the curve, determine time constant as time corresponding to $V_c = 0.37 V_0$.

RESULT - The time constant of RC circuit as determined by charging and discharging of capacitor

Theoretical Value =

% error =

PRECAUTIONS - • The value of capacitor C and resistance R should be choosen as to keep the time constant RC large.

- The capacitor should not be leaky.