Experiment no: 05

Name of the Experiment: Determination of the time constant of an RC series circuit

Questions on theory (all diagrams should be drawn by using a pencil and a scale)

*1) What is a capacitor? Define capacitance. [0.25]

Ans: Capacitor is a device to store energy in a form of electric charge. Capacitance is the ability of a capacitor to store energy as a form of charge

*2) State Ohm's law. [0.25]

Ans: At a certain temparature, current I passing through a conductor is directly proportional to the potential difference, V accross it. i.e $I \propto V$

3) Read the color code of the following resistors and find out their resistances. [0.5]

(a) (b) (c)

Ans:

$10M\Omega \pm 0.5M\Omega$

$= (10 \pm 0.5) M\Omega$

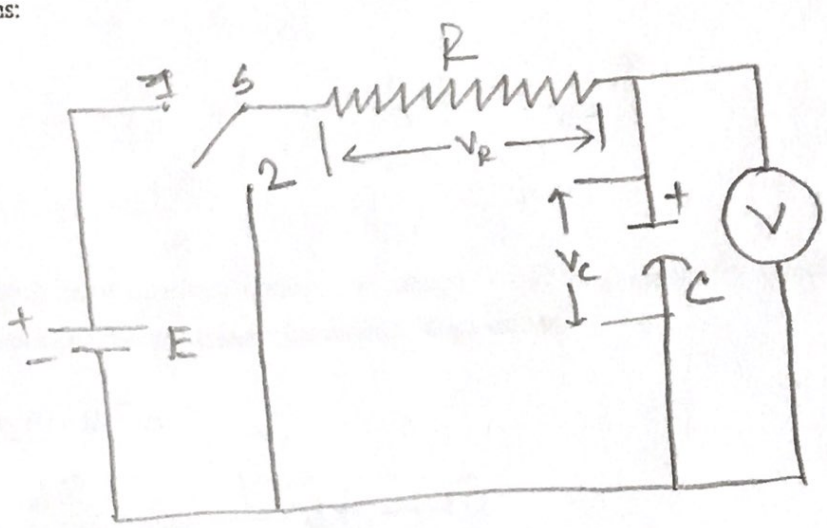
$(56 \pm 28)00\Omega$

$= (5600 \pm 280)\Omega$

$(20 \pm 1)\Omega$

*4) Draw the circuit construction for the experiment [0.25]

Ans:



*5) Apply Kirchhoff's loop voltage rule around the circuit when the capacitor gets charged and find the associated differential equation. [0.25]

Ans: According to Kirchhoff's loop voltage rule,

$$E = V_C + V_R$$

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

$$\Rightarrow \frac{dQ}{dt} + \frac{Q}{RC} = \frac{E}{R}$$

$$\frac{dQ}{dt} + \frac{Q}{t} = \frac{E}{R}$$

7) Apply Kirchhoff's loop voltage rule around the circuit when the capacitor gets discharged and find the associated differential equation. [0.25]

Ans: By applying kirchhoff's loop voltage rule,

$$V_c + V_R = 0$$

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

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

$$\Rightarrow \frac{dQ}{Q} = -\frac{1}{\tau}dt$$

*8) Solve this equation of the answer of question 7 to find charge stored in the capacitor as a function of time t, i.e., $Q(t)$ during discharging process. Next, show that

$V_C(t) = Ee^{\frac{-t}{\tau}}$ [1]

$$\frac{dQ}{dt} = -\frac{1}{\tau}dt \quad \text{---} (1)$$

Integrating both sides of the above eqn,

$$\ln Q = -\frac{1}{\tau}t + A$$

$$\therefore Q_t = e^A e^{-t/\tau}$$

$\therefore$ Voltage across capacitor,

$$V_c(t) = \frac{Q(t)}{C} = \frac{e^A}{C}e^{-t/\tau} = A'e^{-t/\tau} \quad \left[\text{let } \frac{e^A}{C} = A'\right]$$

Initially, $t = 0$, $V_c(0) = E$

$$A' = E$$

$$V_c(t) = Ee^{-t/\tau}$$

For Charging

*6) Solve this equation of the answer of question 5 to find charge stored in the capacitor as a function of time t, i.e., $Q(t)$ during charging process. Next, show that $V_c(t) = E\left(1 - e^{-\frac{t}{\tau}}\right)$ [1]

Ans: From ques-5, $\frac{dQ}{dt} + \frac{Q}{t} = \frac{E}{R}$ —(1)

(1) × integrating factor.

$e^{\int \frac{1}{\tau} dt} = e^{t/\tau}$

$\Rightarrow e^{\frac{t}{\tau}} \frac{dQ}{dt} + \frac{Q}{C} e^{t/\tau} = \frac{E}{R} e^{t/\tau}$

By using Leibnitz rule, $\frac{d}{dt}\left(e^{t/\tau} Q\right) = e^{t/\tau} \frac{dQ}{dt} + \frac{Q}{\tau} e^{t/\tau}$

$\therefore \frac{d}{dt}\left(e^{t/\tau} Q\right) = \frac{E}{R} e^{t/\tau}$

Now we integrate both sides of this eqn:-

$e^{t/\tau} Q = \frac{E}{R} \int e^{t/\tau} dt = \frac{E}{R} \times \frac{e^{t/\tau}}{\frac{1}{C}} + A = \frac{E}{R} \tau e^{t/\tau} + A$

$\Rightarrow Q = \frac{E}{R} \tau + A e^{-t/\tau} = \frac{E}{R} \cdot RC + A e^{-t/\tau}$ $[\tau = RC]$

$\Rightarrow \frac{Q}{C} = E + \frac{A}{C} e^{-t/\tau}$

$\Rightarrow \frac{Q}{C} = E + A' e^{-t/\tau}$ $\left[A' = \frac{A}{C}\right]$

Initially, $t = 0$

$V_c = 0$

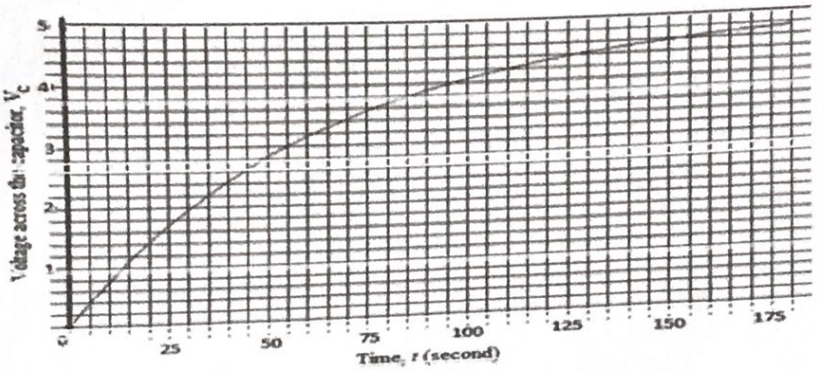
$A' = -E \Rightarrow V_c(t) = E\left(1 - e^{-t/\tau}\right)$

For Charging

*9) What is the physical significance of the time constant of an RC series circuit?[0.25]

Ans: Time constant of an RC series is a measure of how slowly the capacitor gets changed to attain a voltage across it close to the applied voltage of the cell, during the charging process of the capacitor

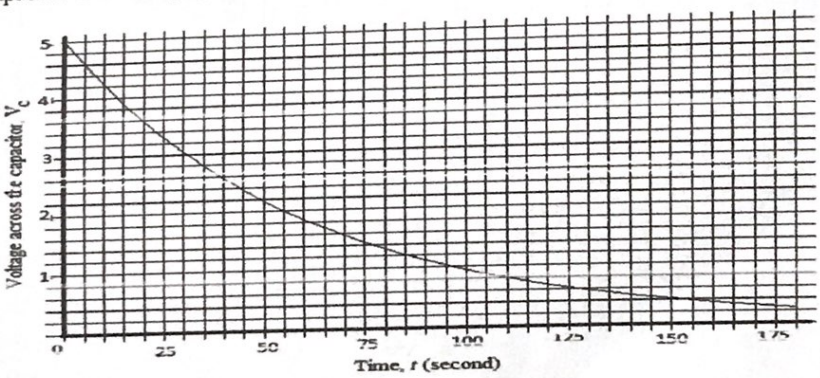
10) A voltage across the capacitor (in Volts) vs. time (in seconds) curve for a series RC circuit while the capacitor is charging is shown below: Find out the time constant τ. [0.5]



0.63 E
= 3.15V

Ans: $\tau = 60s$

11) A voltage across the capacitor (in Volts) vs. time (in seconds) curve for a series RC circuit while the capacitor is discharging is shown below: Find out the time constant τ. [0.5]

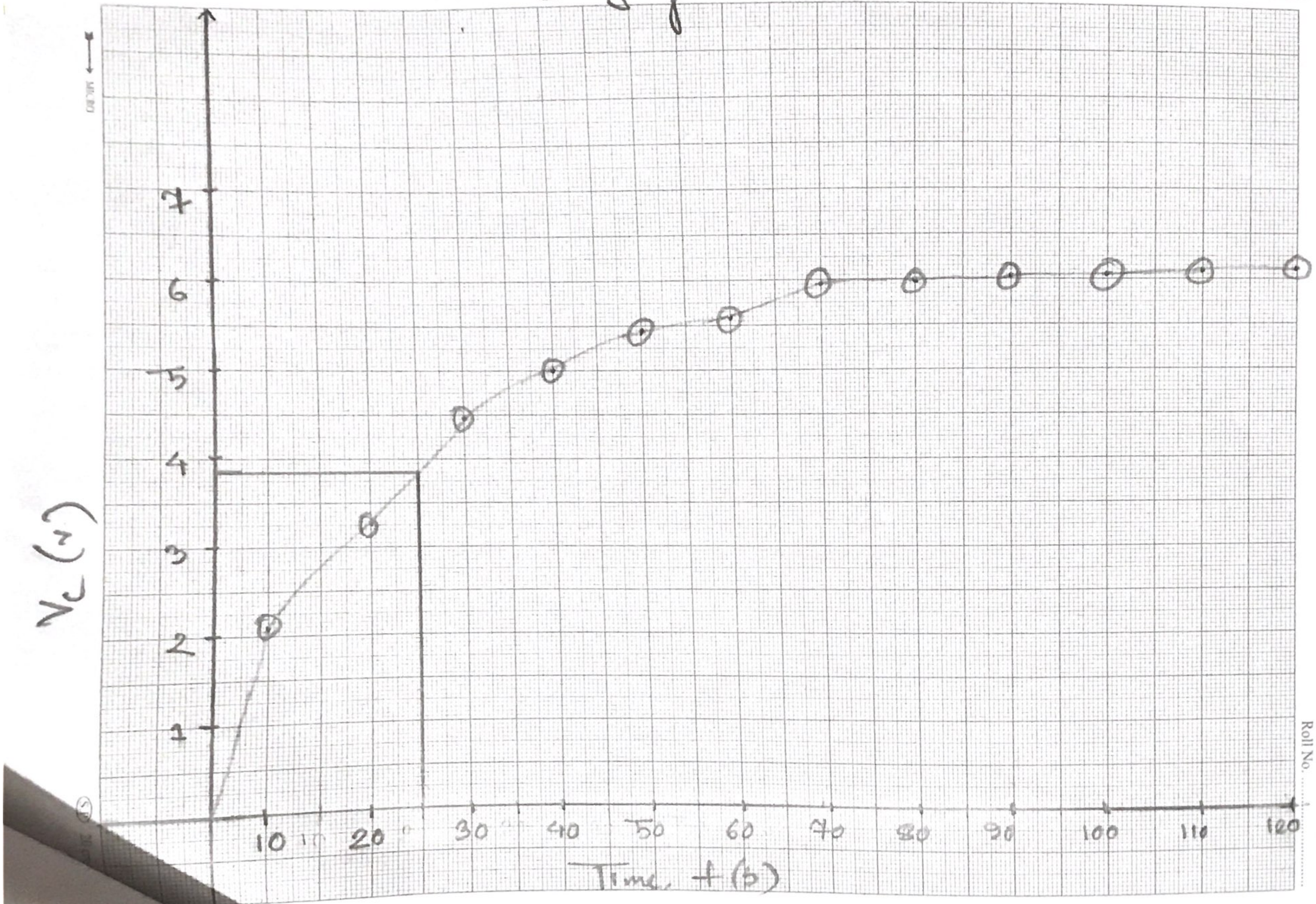


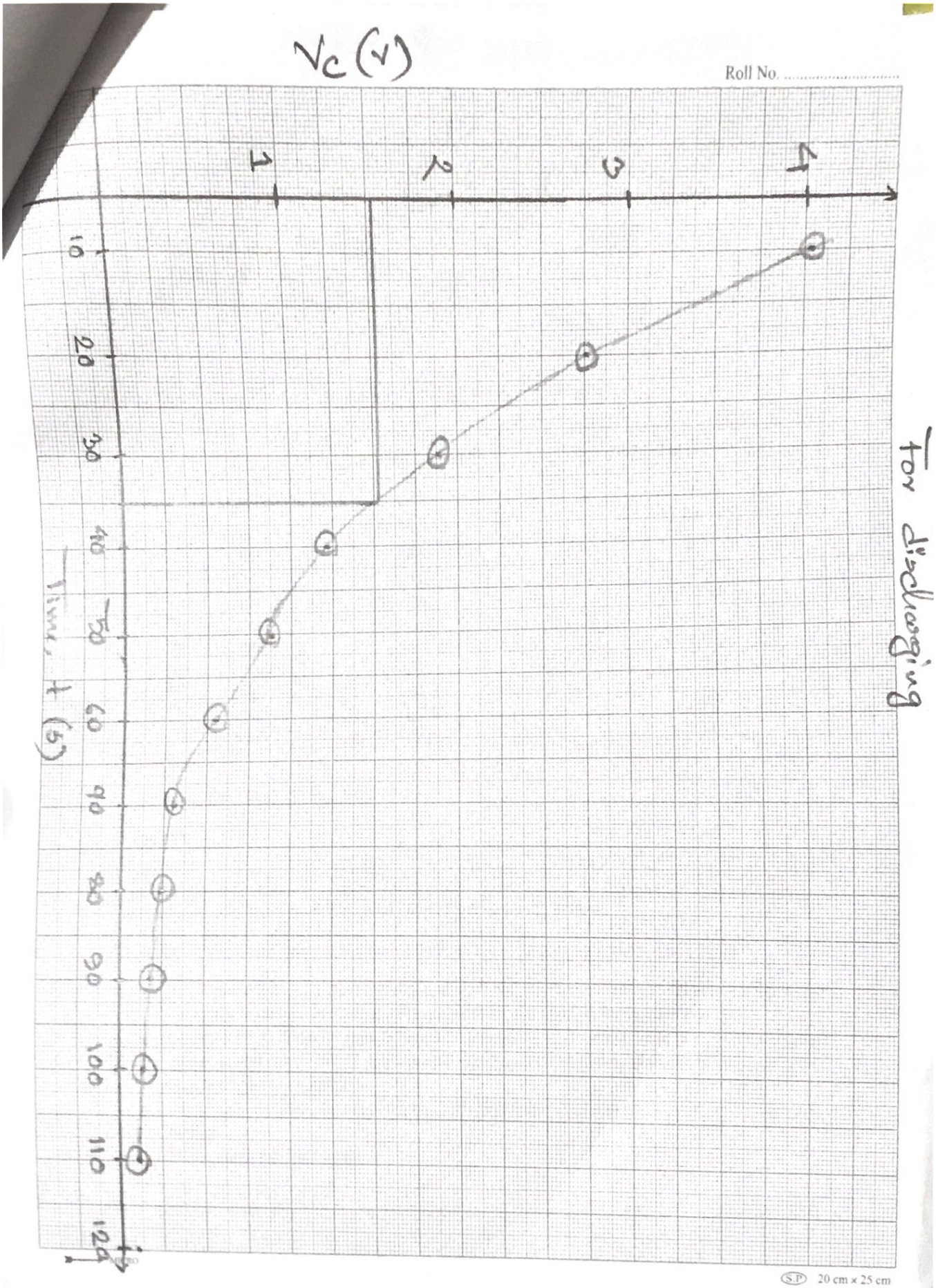
0.37E
= 1.85V

Ans: $\tau = 52.5s$

For Charging

For charging




V_C (V)
Roll No. .....
1
2
3
4
10
20
30
40
50
60
70
80
90
100
110
120
Time, t (s)
for discharging

- Draw the data table(s) and write down the variables to be measured shown below (in the 'Data' section), using pencil and ruler BEFORE you go to the lab class.

- Write down your NAME and ID on the top of the page.
- This part should be separated from your Answers of "Questions on Theory" part.
- Keep it with yourself after coming to the lab.
- Do not forget to bring a graph paper.

Data

Table: Data showing the time dependence of voltage across the capacitor

Observation	Time, t (S)	Voltage across the capacitor V_C During charging process,(V)	Voltage across the capacitor V_C during discharging process (V)
1	10	2.20	4.10
2	20	3.58	2.76
3	30	4.48	1.81
4	40	5.06	1.23
5	50	5.46	0.80
6	60	5.72	0.55
7	70	5.91	0.36
8	80	6.04	0.25
9	90	6.12	0.17
10	100	6.16	0.11
11	110	6.21	0.08
12	120	6.24	0.05

Capacitance:

Capacitance, C = 100 μF

Resistance:

Color	Red	Red	Yellow	Golden
Digit/Multiplier/Tolerance	2	2	10K	5%

Value of resistance from the multi-meter, R = (22×10K)±5%

Theoretically predicted value of the time constant: $RC = ((22\times10K)\pm5\%)\times100$

- READ the PROCEDURE carefully and perform the experiment by YOURSELVES. If you need help to understand any specific point draw attention of the instructors.
- DO NOT PLAGIARIZE data from other group and/or DO NOT hand in your data to other group. It will bring ZERO mark in this experiment. Repetition of such activities will bring zero mark for the whole lab.
- Perform calculations by following the PROCEDURE . Show every step in the Calculations section.
- Write down the final result(s)

Calculations For charging $t = 25$ s, for discharging $t = 35$ s

Results: Average, $t = \frac{25+35}{2} = 30$ s

- **TAKE printout of the 'Questions for Discussions' BEFORE you go to the lab class. Keep this printout with you during the experiment. ANSWER the questions in the specified space AFTER you have performed the experiment.**
- **Attach Data, Graph, Calculations, Results and the Answers of 'Questions for Discussions' parts to your previously submitted Answers of 'Questions on Theory' part to make the whole lab report.**
- **Finally, submit the lab report before you leave the lab.**

Questions for Discussions

1) In this experiment what type of capacitor have you used? Is it polarized or non-polarized capacitor? What type of precaution is required while connecting polarized capacitor in the circuit? [1]

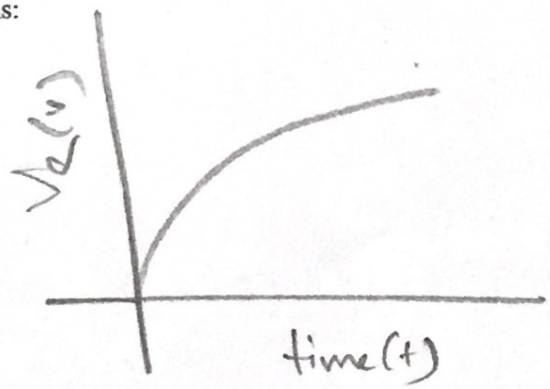
Ans. We need polarised capacitor. It must be connected with the corresponding polarity of EMF. (+)ve part should be connected to the (+)ve end and (-) with (-) of battery.

2) Sometimes it is observed that the capacitor is getting discharged, although the two electrodes of the capacitor are not anyhow connected. What might be the possible reason for it? [0.5]

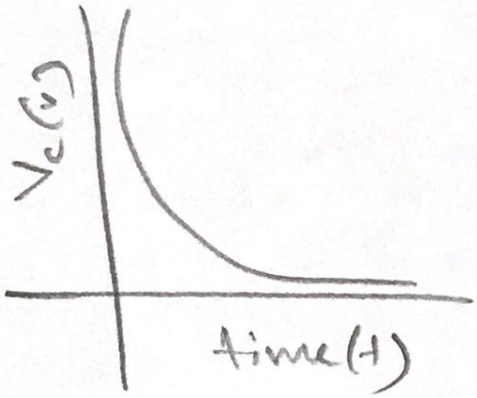
Ans: Some of the charge is lost through the dielectric over time, no matter how good insulator is used.

3) Sketch voltage across the resistor, V_R vs. time, t curve during charging and discharging process of the capacitor. [0.5]

Ans:



For charging



For discharging