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 temperature, 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]

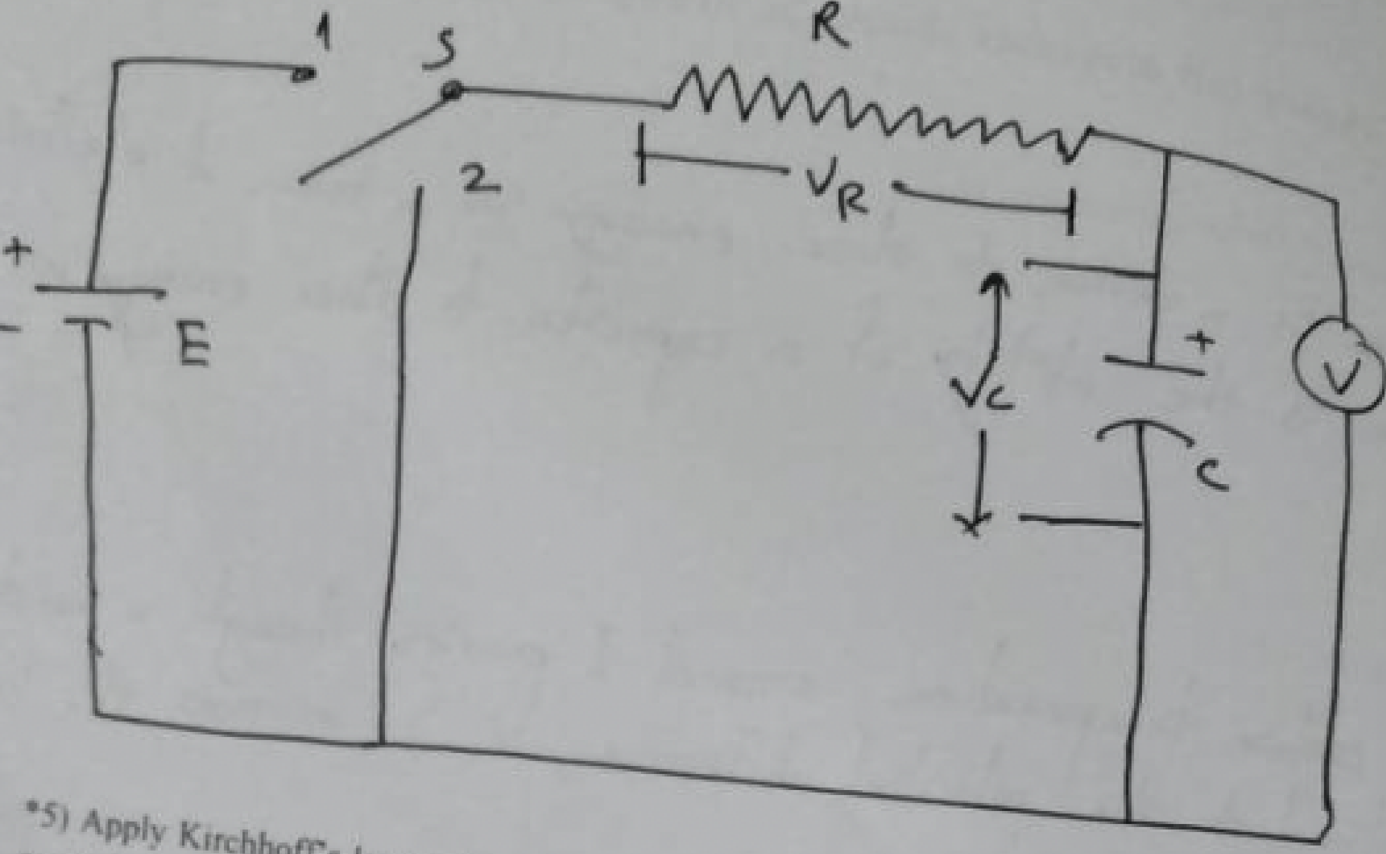
(a) (b) (c)

Ans:

(a)	(b)	(c)
$10\,M\Omega \pm 0.3\,M\Omega$	(56 ± 28)	$(20 \pm 1)\,\Omega$
$(10 \pm 0.5)\,M\Omega$	$(5600 \pm 280)\,\Omega$	

*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 kirchoff's loop voltage rule,

$$\cancel{E = \frac{Q}{C} + R}$$

$$E = V_c + V_R$$

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

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

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

*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: $$\frac{dQ}{dt} + \frac{Q}{\tau} = \frac{E}{R} \quad \text{—(i)}$$

(i) × integrating factor,

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

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

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

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

We now integrate both side of the equation:

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

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

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

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

Initially $t = 0$

$V_c = 0$

$A' = -E$

$V_c(t) = E\left(1 - e^{-t/\tau}\right)$

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

Ans: $V_C + V_R = 0$

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

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

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

*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]

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

Integrating,

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

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

$$V_c(t) = \frac{Q(t)}{C} = \frac{e^A}{C}e^{-t/\tau} = A'e^{-t/\tau}.$$

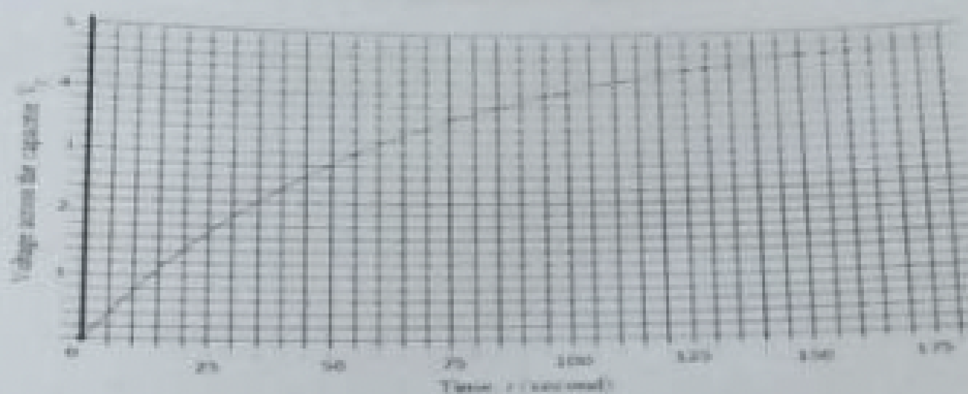
Initially $t=0$, ~~$V_c(t)$~~ $V_c(0) = E$, $A' = E$

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

*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 charged to obtain a voltage ~~acro~~ across it close to the applied voltage of the cell, during the charging process of the capacitor

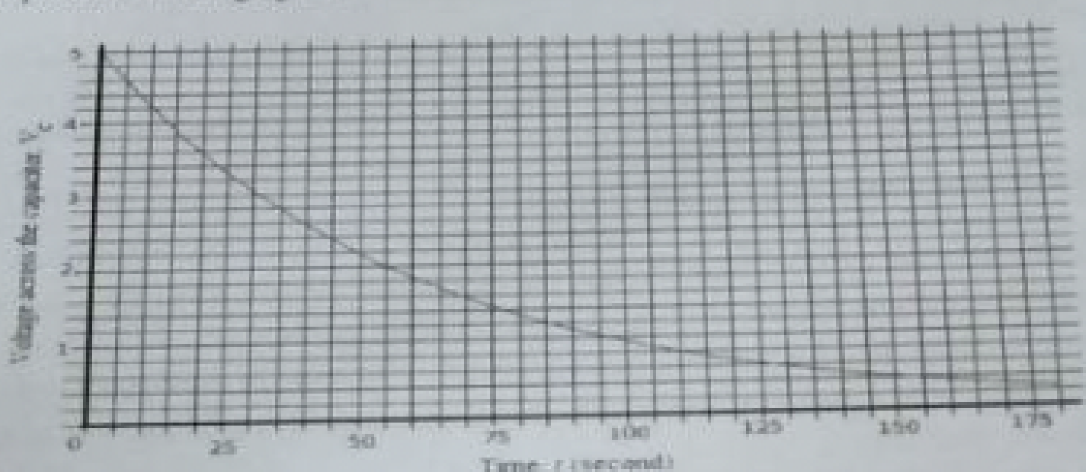
10) A voltage across the capacitor (in Volts) vs. time (in seconds) curve for a series RC circuit while the capacitor is charging is shown below. Find out the time constant τ. [0.5]



Ans: 0·63E, 3·15V

$\tau = 60s$

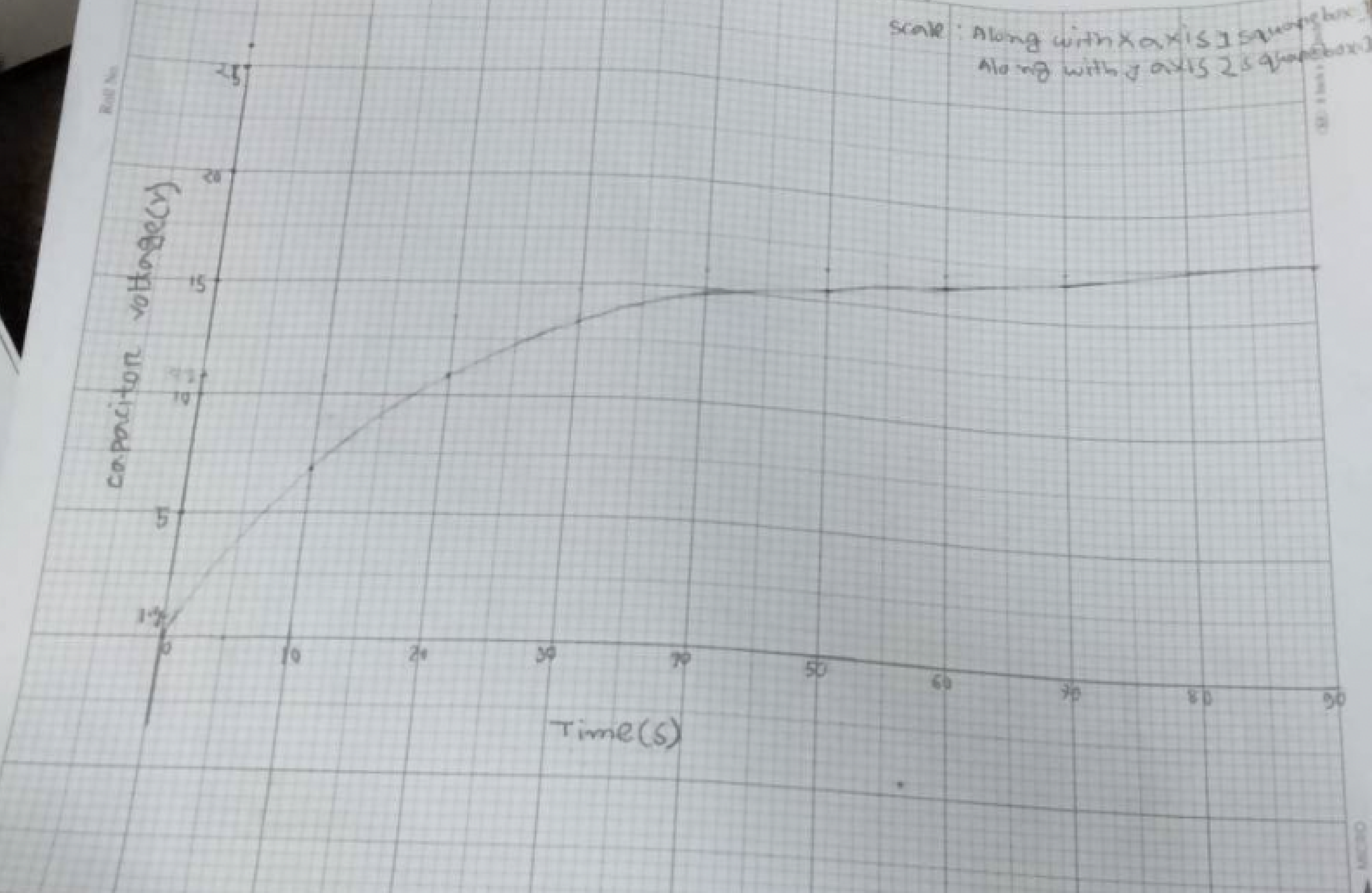
11) A voltage across the capacitor (in Volts) vs. time (in seconds) curve for a series RC circuit while the capacitor is discharging is shown below. Find out the time constant τ. [0.5]



Ans: 0·37E, 1·85V

$\tau = 52·5s$

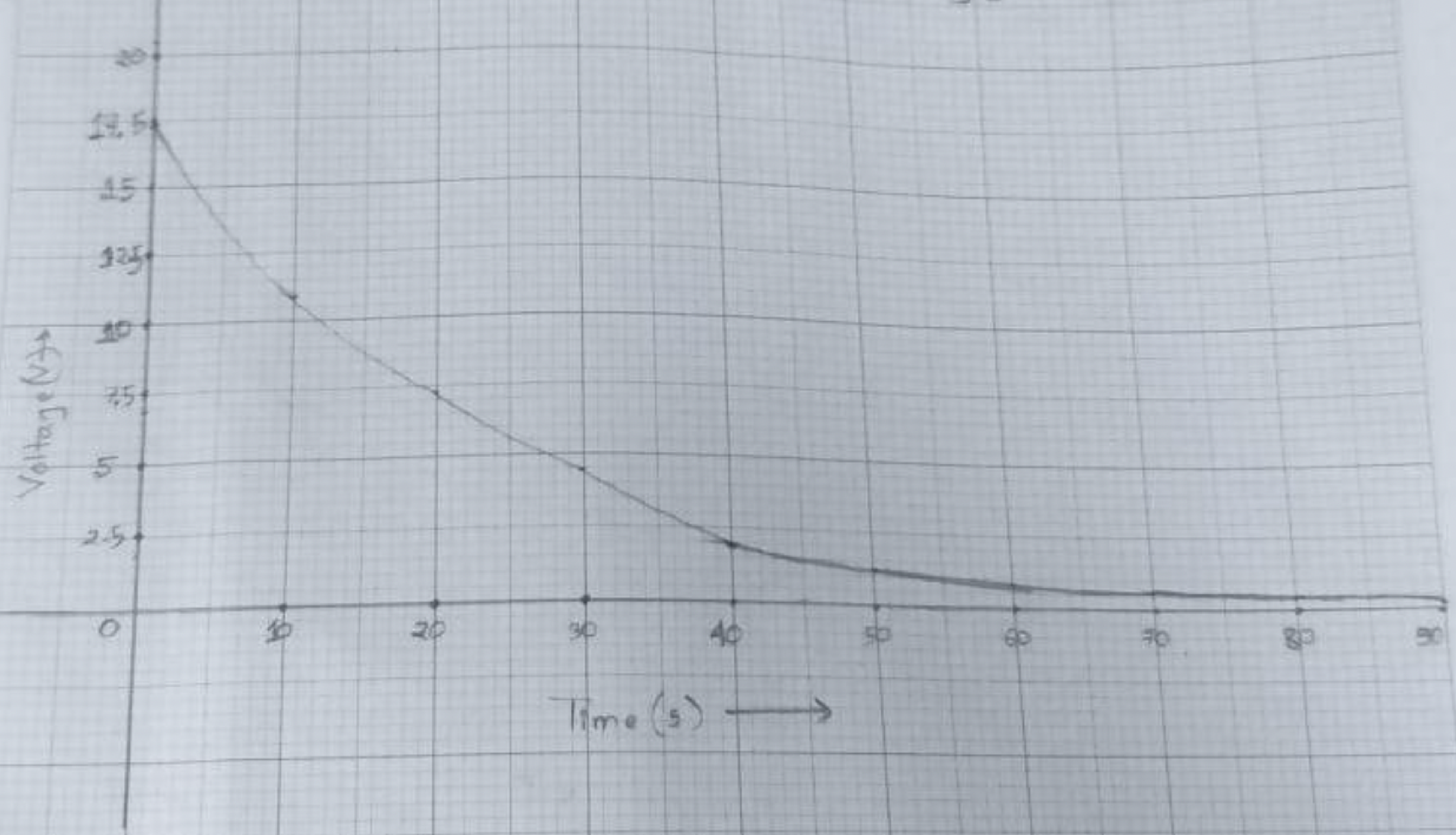
... the capacitor is charging



While the capacitor is discharging

Scale: Along the x axis, 1 squarebox = 1 unit

Along the y axis, 2 squarebox = 1 unit



Calculations

Results:

- 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.

From Theory:

$R = 220 \times 10^3 \ \Omega$

$C = 100 \ \mu F$

$\therefore \tau = R \times C = 220 \times 10^3 \times 100 \times 10^{-6} = 22 \ s$

From Graph:

~~V = 17.46 × [illegible] = 11~~

Charging

$V = 17.46 \times 0.63 = 11$

$\therefore \tau = 20 \ s$

Discharging

$V = 17.46 \times 0.37 = 6.47$

$\therefore \tau = 21 \ s$

Average, $\tau_a = \dfrac{20 + 21}{2} = 20.5 \ s$

$\tau \sim \tau_{g} = 22 - 20.5 = 1.5 \ s$