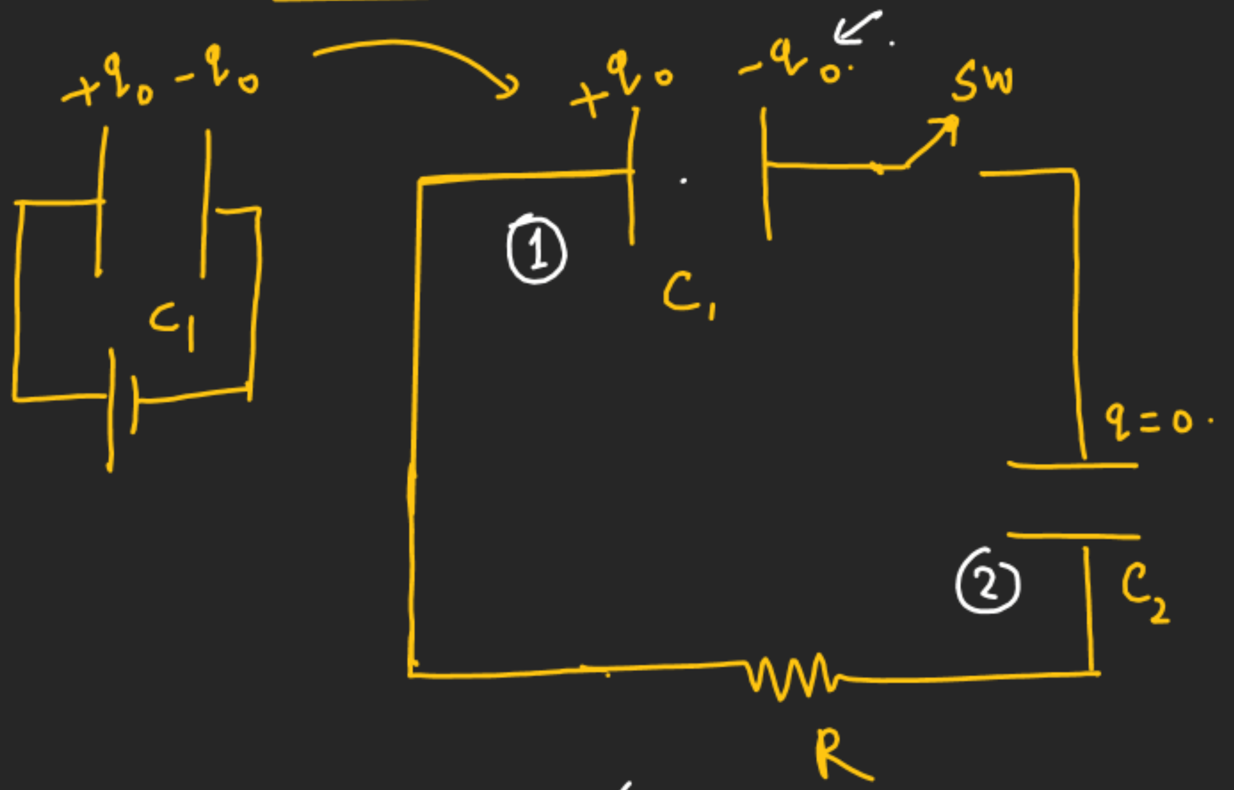
Nishant Jindal

RC ckt

CURRENT ELECTRICITY

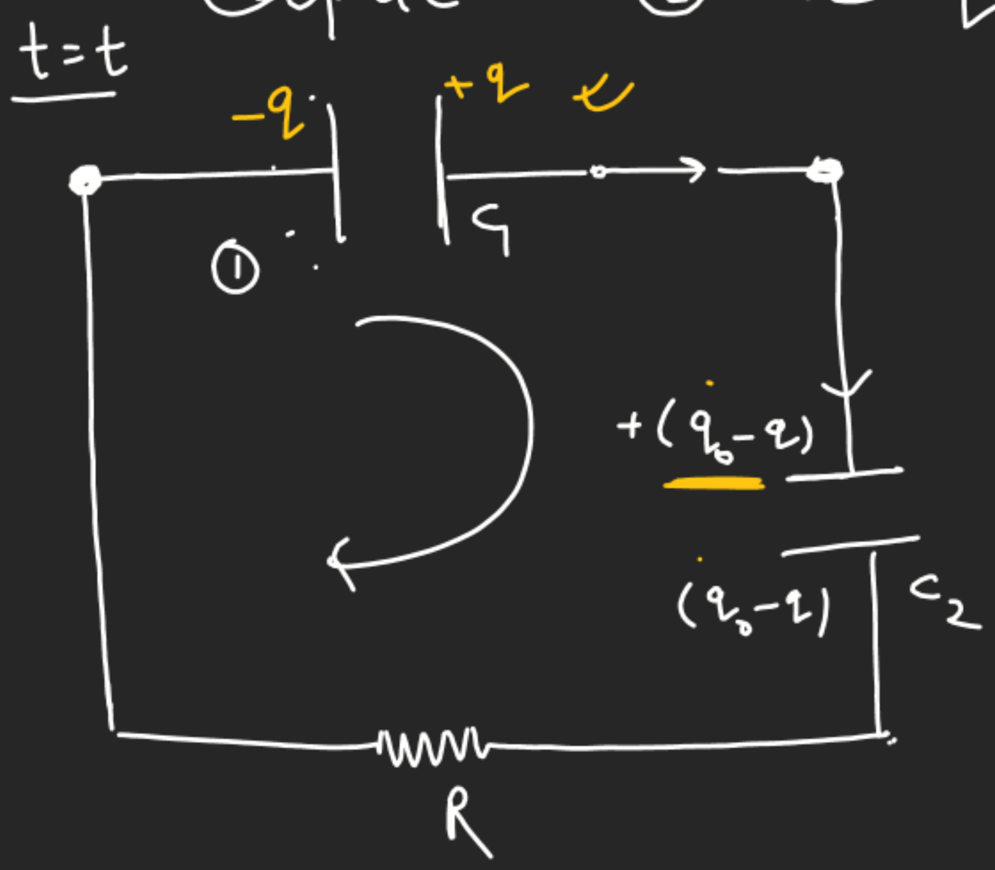
Case of 2-Capacitors in R-C Ckt (one discharging and other Charging)



(flow of Charge in the Ckt $\rightarrow (q_0 - q)$)

Switch is closed at $t = 0$. find $I = f(t)$.

At any time $t = t$; let Charge on the Capacitor ① be q.



$I = \frac{d}{dt}(q_0 - q)$ ← Charge flow in the Ckt

$I = \left(-\frac{dq}{dt}\right)$

$$\left[V_{C_1} = V_{C_2} + V_R\right]$$

$$\frac{q}{C_1} = \frac{q_0 - q}{C_2} + IR$$

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$$\frac{1}{C_1}+\frac{1}{C_2}=\frac{1}{C}$$

$$\frac{q}{C_1}=\left(\frac{q_0-q}{C_2}\right)+IR \qquad I=\left(-dq/dt\right)$$

$$q\left(\frac{1}{C_1}+\frac{1}{C_2}\right)=\frac{q_0}{C_2}-R\frac{dq}{dt}$$

$$R\frac{dq}{dt}=\frac{q_0}{C_2}-q\left(\frac{1}{C}\right)$$

$$\frac{dq}{dt}=\frac{Cq_0-C_2q}{RC_2C}$$

$$\int_{q_0}^{q}\frac{dq}{Cq_0-C_2q}=\frac{1}{RC_2C}\int_0^t dt$$

$$\frac{\ln\left[Cq_0-C_2q\right]_{q_0}^{q}}{-C_2}=\frac{1}{RC_2C}t$$

$$\ln\left[Cq_0-C_2q\right]-\ln\left(Cq_0-C_2q_0\right)=-\frac{1}{RC}t$$

$$\ln\left[\frac{Cq_0-C_2q}{Cq_0-C_2q_0}\right]=\frac{-1}{RC}t$$

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$$\ln\left[\frac{Cq_0 - C_2 q}{Cq_0 - C_2 q_0}\right] = -\frac{1}{RC}t$$

$$C = \frac{1}{C_1} + \frac{1}{C_2}$$

$$C = \left(\frac{C_1 C_2}{C_1 + C_2}\right) \checkmark$$

$$Cq_0 - C_2 \underline{q} = (Cq_0 - C_2 q_0)\, e^{-\frac{t}{RC}}$$

$$C_2 q = Cq_0 - (Cq_0 - C_2 q_0)\, e^{-t/RC}$$

$$\boxed{q = \frac{Cq_0}{C_2} - \left[\frac{Cq_0}{C_2} - q_0\right] e^{-t/RC}}$$

**

$$\boxed{q = \frac{q_0 C}{C_2} + \frac{q_0 C}{C_1} e^{-t/RC}}$$

$$q = \frac{C_1 q_0}{C_1 + C_2} - \left[\frac{C_1 q_0}{C_1 + C_2} - q_0\right] e^{-t/RC}$$

$$q = \left(\frac{C_1 q_0}{C_1 + C_2}\right) - \left[\frac{-C_2 q_0}{C_1 + C_2}\right] \underline{\underline{e^{-t/RC}}}$$

$$q = \frac{q_0}{C_1 + C_2}\left[C_1 + C_2 e^{-t/RC}\right] \checkmark$$

$$q = q_0\left(\frac{C_1}{C_1 + C_2}\right) + q_0\left(\frac{C_2}{C_1 + C_2}\right) e^{-t/RC}$$

$$q = \frac{q_0}{C_2}\underbrace{\left(\frac{C_1 C_2}{C_1 + C_2}\right)}_{C} + \frac{q_0}{C_1}\underbrace{\left(\frac{C_1 C_2}{C_1 + C_2}\right)}_{C} e^{-t/RC}$$

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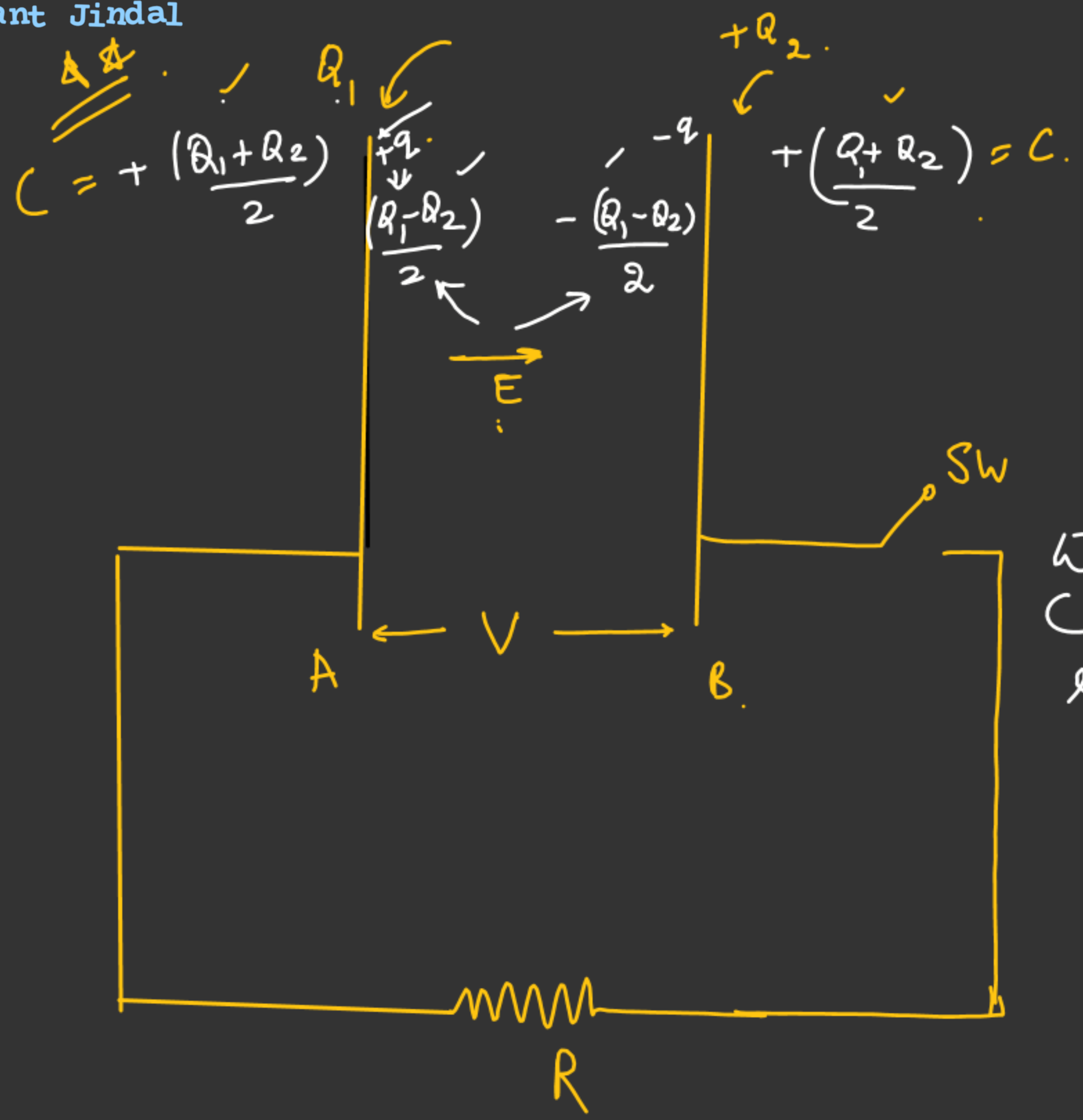

Initially sw is open.

Q_1 and Q_2 be the Charges given to plate A and B. find the charge on plate A and B as a function of time when switch is closed.

take $t=0$ when sw closed.

$$q = Q_1 - \left(\frac{Q_1+Q_2}{2}\right)$$

$$q = \frac{2Q_1 - Q_1 - Q_2}{2}$$

$$q = \left(\frac{Q_1 - Q_2}{2}\right)$$

When sw is closed only charges inside the plate will change.

At $t = t$

$$q_0 = \left(\frac{Q_1-Q_2}{2}\right)$$

$$q_{inside} = q_0 e^{-t/RC}$$

$$q_{inside} = \left(\frac{Q_1-Q_2}{2}\right) e^{-t/RC}$$

$$(q_T)_{left\ plate} = \left(\frac{Q_1+Q_2}{2}\right) + \left(\frac{Q_1-Q_2}{2}\right) e^{-t/RC}$$

$$(q_T)_{Right\ plate} = \left(\frac{Q_1+Q_2}{2}\right) - \left(\frac{Q_1-Q_2}{2}\right) e^{-t/RC}$$

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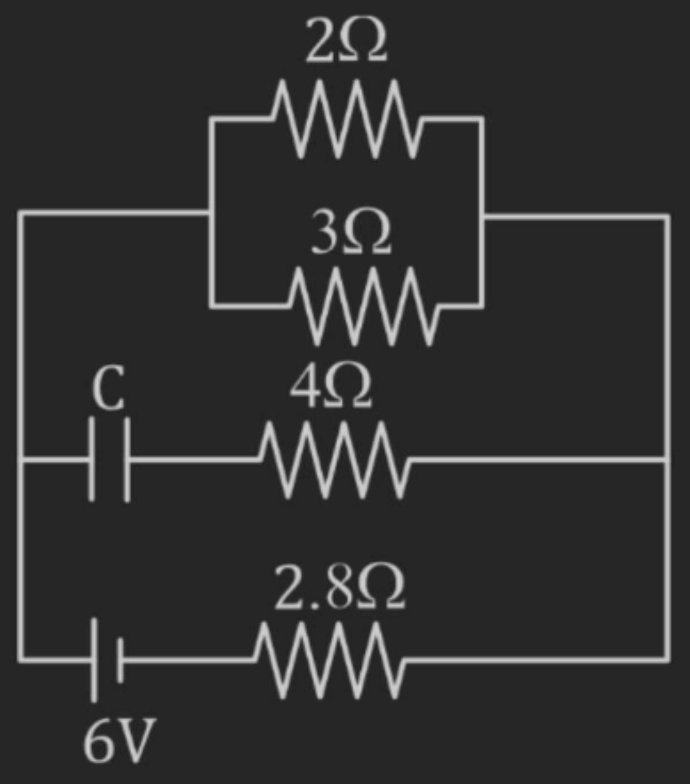
RC ckt

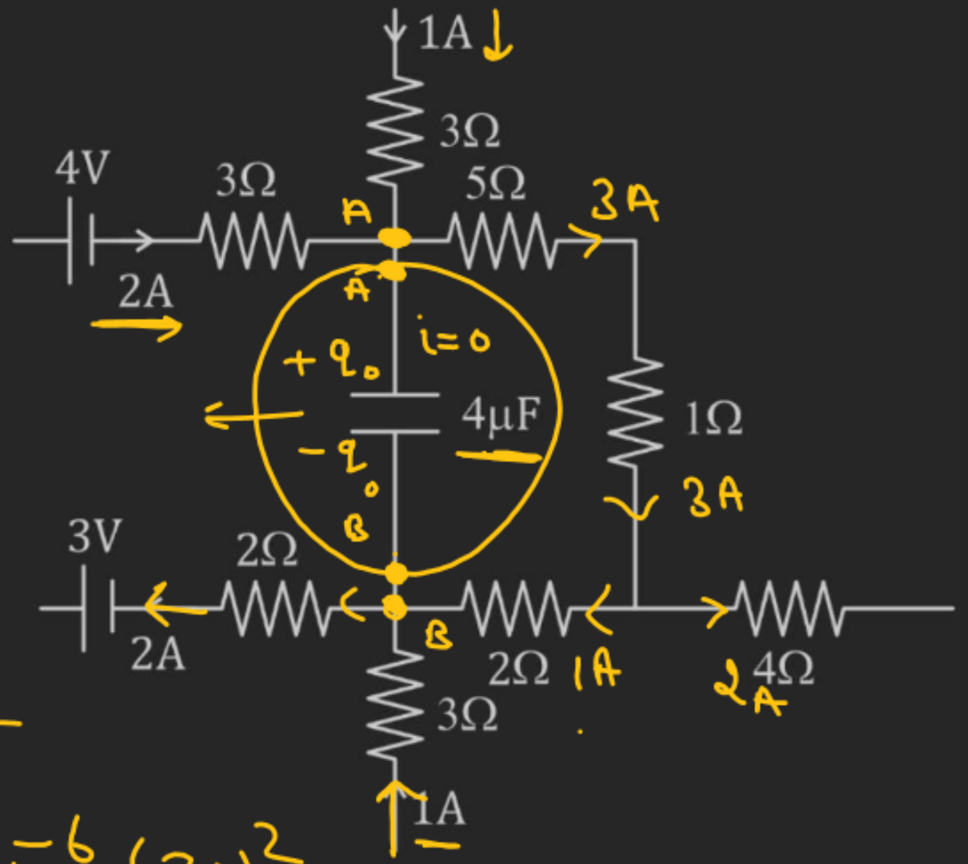
H.W

CURRENT ELECTRICITY

Q.4 Calculate the steady state current in the 2ohm resistor shown in the circuit in the figure. The internal resistance of the battery is negligible and the capacitance of the condenser C is 0.2 microfarad. (1982)



Q.5 A part of circuit in a steady state along with the currents flowing in the branches, the values of resistances etc., is shown in the figure. Calculate the energy stored in the capacitor C(4μF) **(1986)**



Sol^n

$U_{4\mu F} = ??$

At Steady state Capacitor behave as open ckt.

Potential difference across the Capacitor at Steady state $V = |V_A - V_B|$

$V_A - (5\times3) - (1\times3) - (1\times2) = V_B$

$V_A - V_B = \underline{20}$ volt

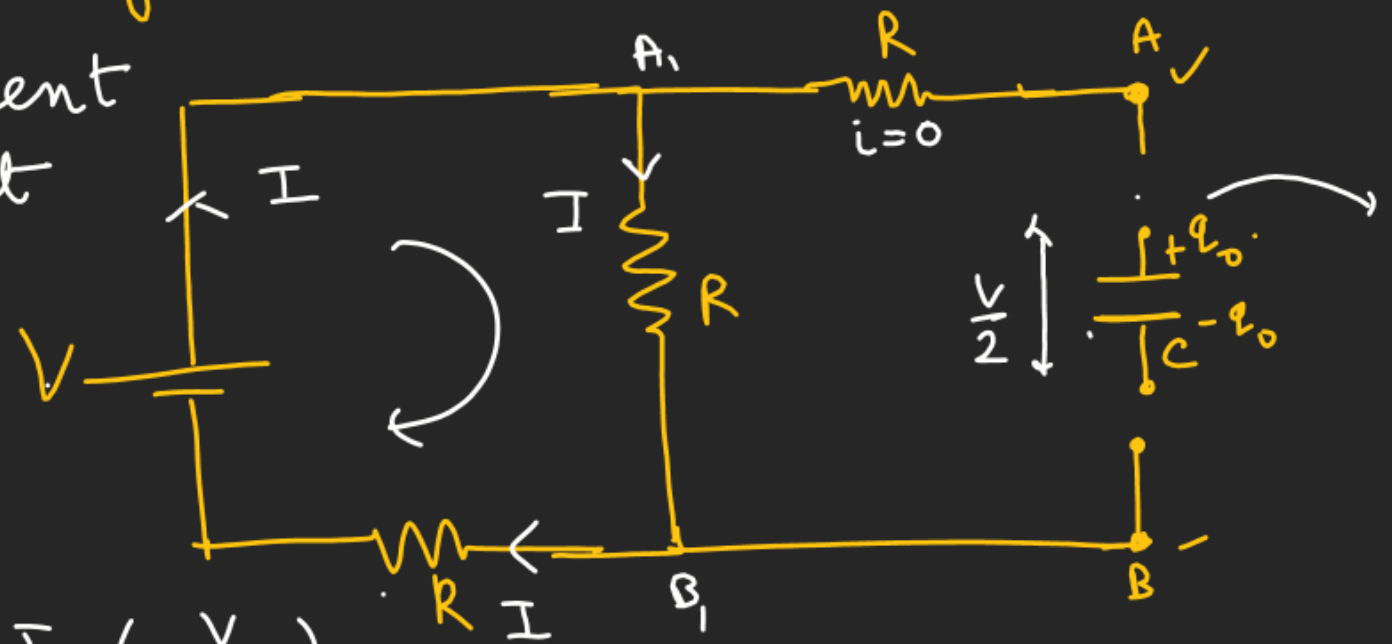
$U = \frac{1}{2}CV^2$

$U = \frac{1}{2}\times 4\times10^{-6}\times(20)^2$

$U = 8\times10^{-6}\times10^2 = 800\,\mu J$

At Steady state Capacitor is fully Charged acts as a open ckt.

I = Current in the Ckt at Steady State.



$I = \left(\frac{V}{2R}\right)$

$V_{AB} = V_{A_1B_1}$

$V_{AB} = I \cdot R$

$= \frac{V}{2R} \times R = \left(\frac{V}{2}\right)$

$q_0 = \left(\frac{CV}{2}\right)$

$q = q_0(1 - e^{-t/\tau})$

$$\boxed{q = \frac{CV}{2}\left[1 - e^{-2t/3RC}\right]}$$

CURRENT ELECTRICITY

Q.7 In the circuit shown in figure, the battery is an ideal one, with emf V. The capacitor is initially uncharged. **(1988)**

The switch S is closed at time $t = 0$.

(a) Find the charge Q on the capacitor at time t. $\rightarrow Q \rightarrow f(t)$.

(b) Find the current in AB at time t. What is its limiting value at $t \rightarrow \infty$. $i_{AB} = f(t)$

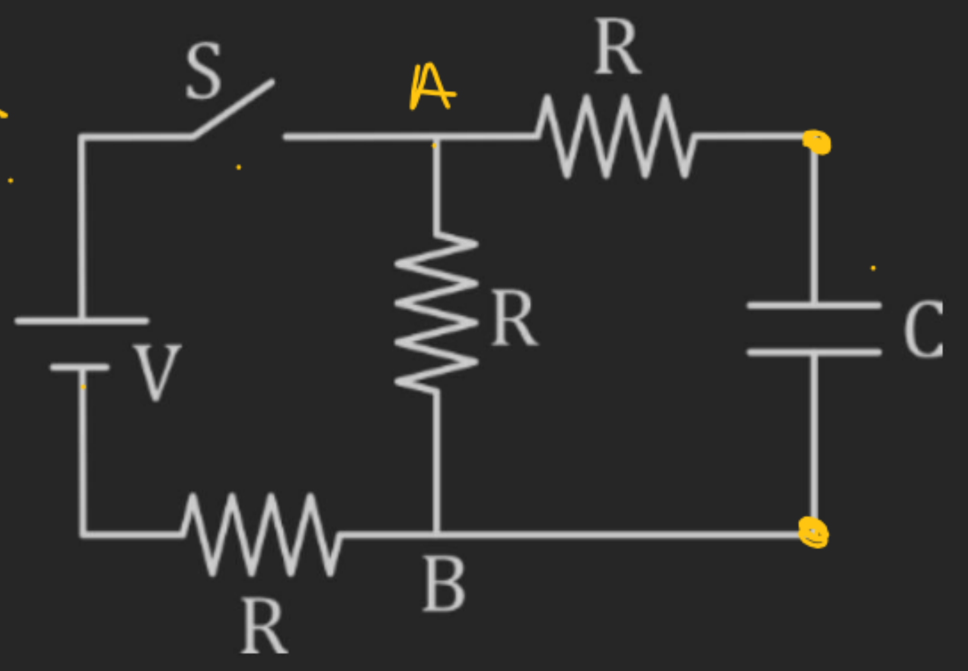
a) $q = q_0(1 - e^{-t/\tau})$

$\tau = R_{eq} \cdot C$

$R_{eq} = ??$

$\Rightarrow R_{eq} = \frac{3R}{2}$

$\boxed{\tau = \frac{3RC}{2}}$



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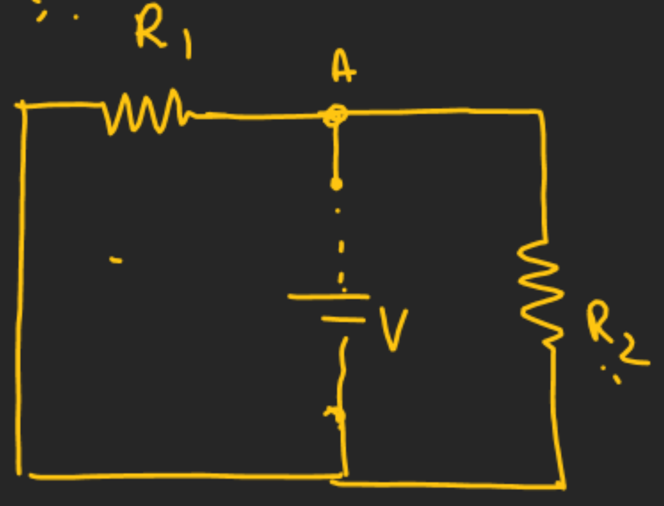
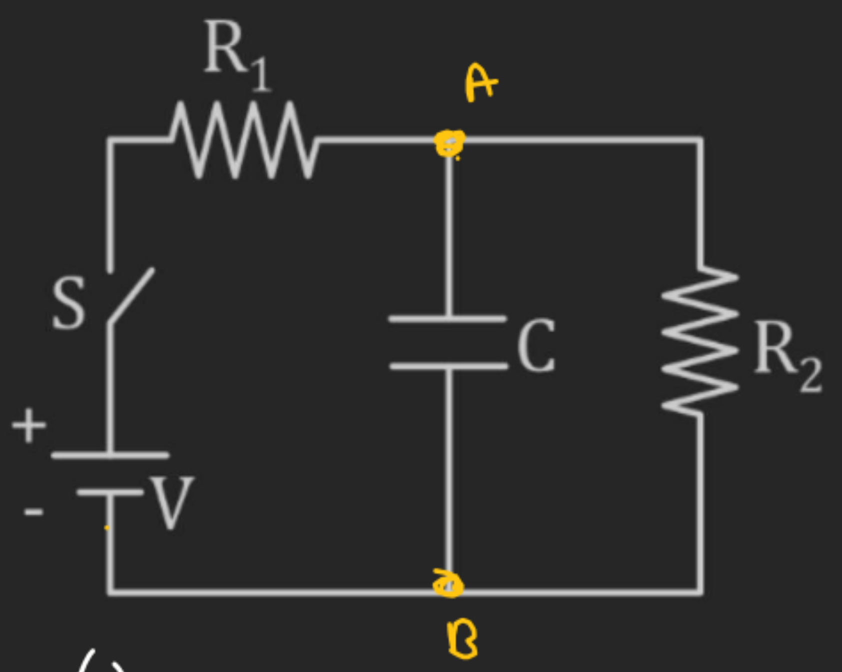
CURRENT ELECTRICITY

Q.8 In the given circuit, the switch S is closed at time $t = 0$. The charge Q on the capacitor at any instant t is given by $\boxed{Q(t) = Q_0(1 - e^{-\alpha t})}$. Find the value of Q_0 and α in terms of given parameters as shown in the circuit. **(2005)**

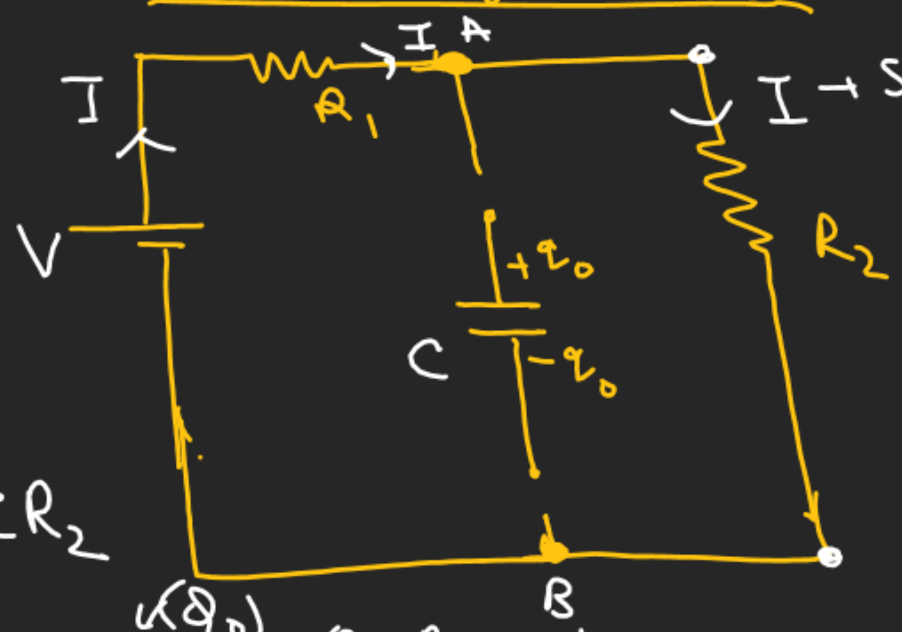
$R_{eq} = ??$





$Q_0 = ??$ $\alpha = ??$

At the time of steady state



$I \rightarrow$ Steady State.

$$(R_{eq})_{AB} = \left(\frac{R_1R_2}{R_1+R_2}\right)$$

$$\tau = \left(\frac{R_1R_2C}{R_1+R_2}\right)$$

$$I = \left(\frac{V}{R_1+R_2}\right)$$

$$\alpha = \frac{1}{\tau}$$

$$\alpha = \left[\frac{R_1+R_2}{R_1R_2C}\right] \text{ Ans}$$

$$V_{AB} = V_{R_2} = IR_2$$

$$V_{AB} = \left(\frac{VR_2}{R_1+R_2}\right)$$

$$q_0\,(Q_0) = \left(\frac{CVR_2}{R_1+R_2}\right) - \text{Ans}$$

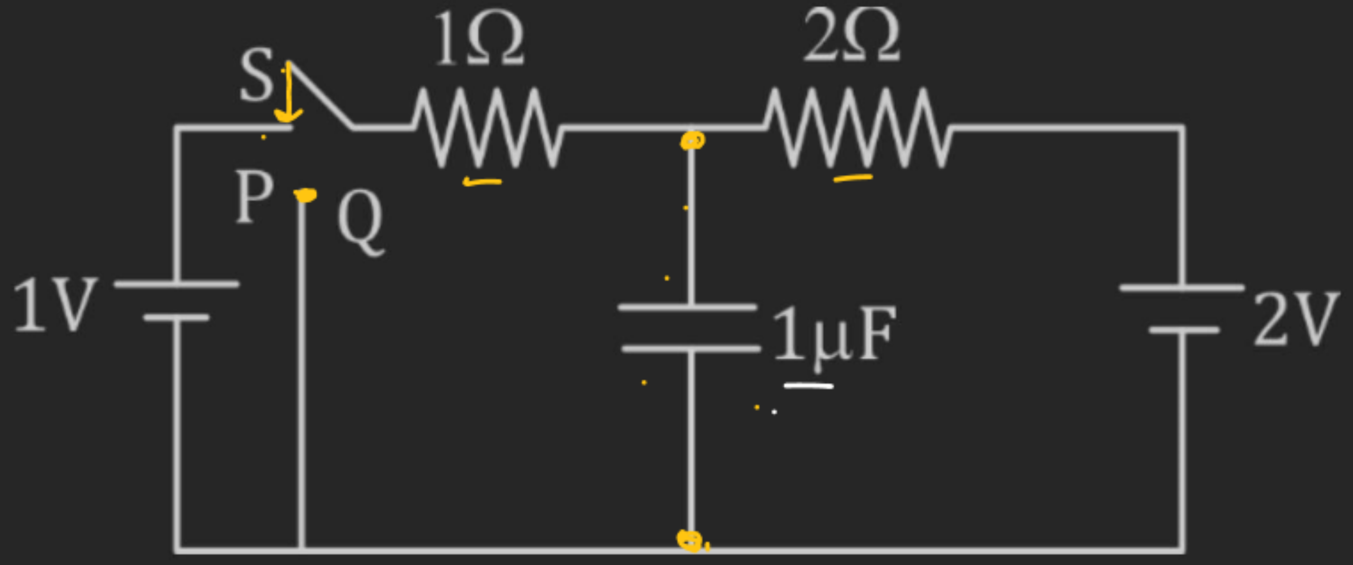
Maximum Charge on the Capacitor

CURRENT ELECTRICITY

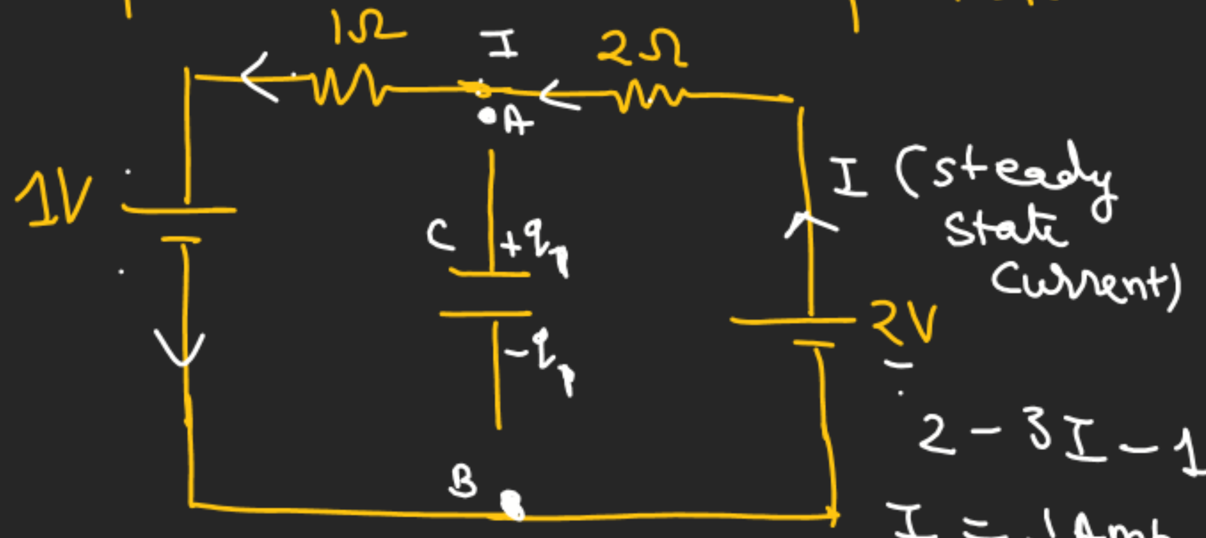
Q.9 In the circuit shown below, the switch S is connected to position P for a long time so that the charge on the capacitor becomes q_1 μC. Then S is switched to position Q. After a long time, the charge on the capacitor is q_2 μC. **(2021)**

(a) The magnitude of q_1 is 1.33.

(b) The magnitude of q_2 is ____.



a) At the time of steady state Capacitor behave as open ckt.



$2 - 3I - 1 = 0$

$I = \frac{1}{3}$ Amp

$V_B + 2 - 2 \times \frac{1}{3} = V_A$

$V_A - V_B = 2 - \frac{2}{3}$

$= \frac{4}{3}$ volt

$q_1 = (1 \times 10^{-6}) \times \frac{4}{3}$

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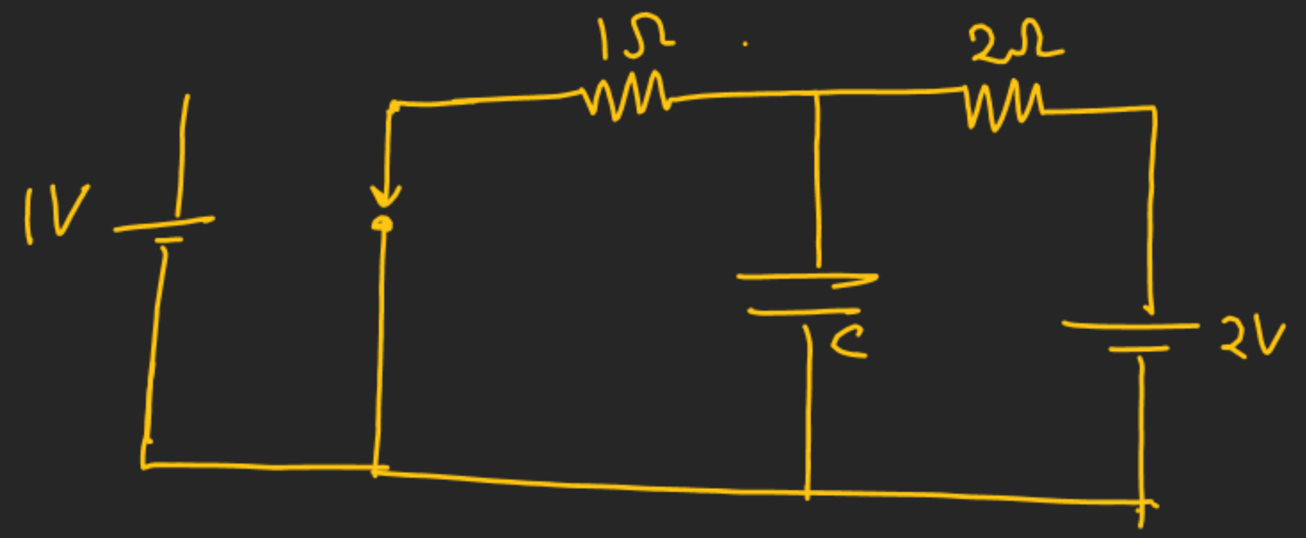
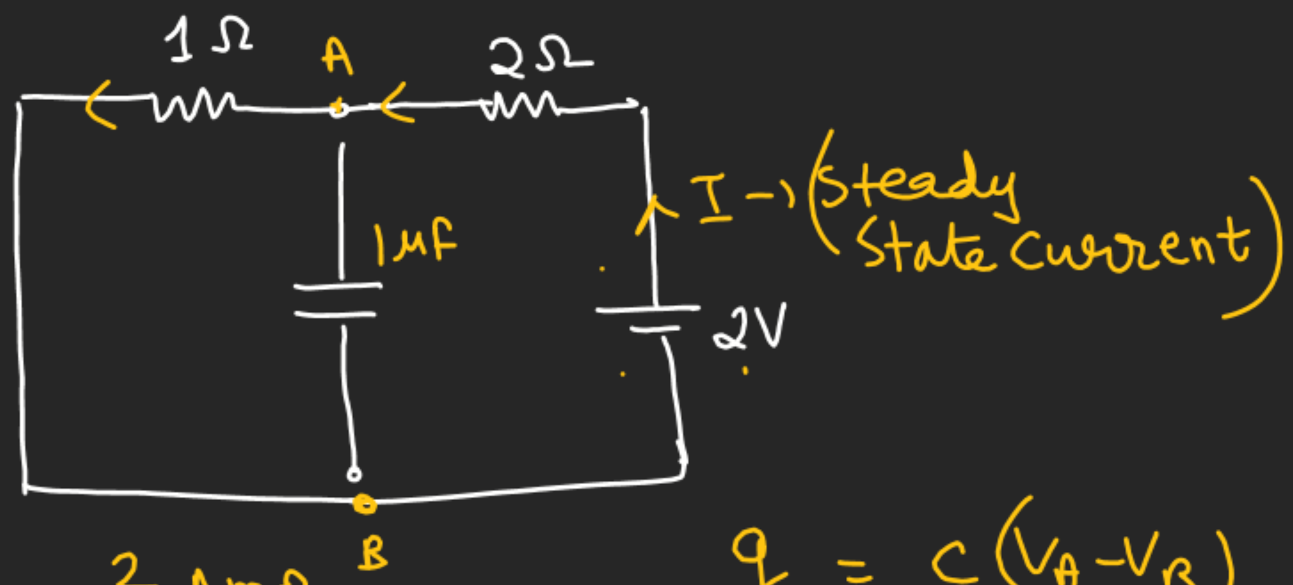
CURRENT ELECTRICITY

(b) $q_2 = ??$



At the time of steady state.



$I = \frac{2}{3}$ Amp

$V_B + 2 - \frac{2}{3} \times 2 = V_A$

$V_A - V_B = 2 - \frac{4}{3} = \frac{2}{3}$

$q_2 = C(V_A - V_B)$

$= 1 \times 10^{-6} \times \left(\frac{2}{3}\right)$

$= \boxed{0.66 \mu C}$