DPP – 4 (Capacitor)

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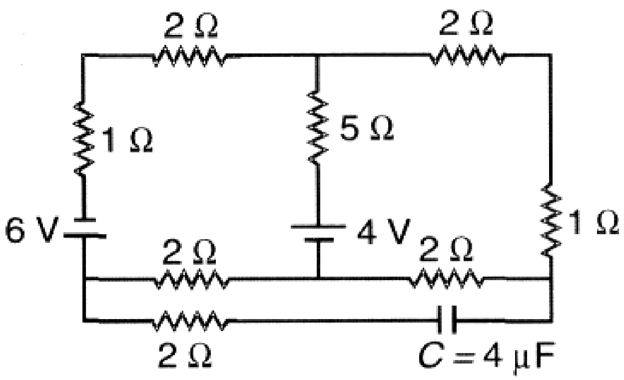
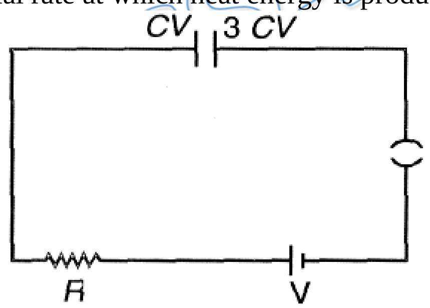
Q 1. Find charge on capacitor in steady state of given circuit



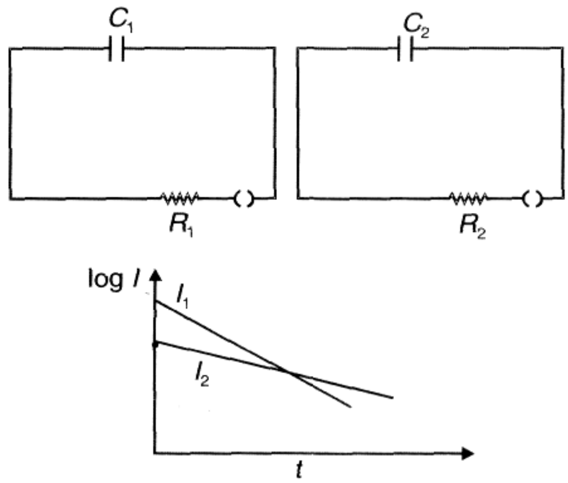
(a) 9.6 μC (b) 7.2 μC
(c) 4.8 μC (d) 2.4 μC

Q 2. Plates of a parallel plate capacitor C have charges CV and 3 CV on it's plate. If switch is closed at t = 0. Then initial rate at which heat energy is produced in resistane R is



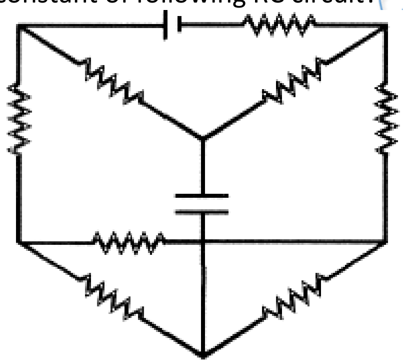
(a) $\frac{V^2}{R}$
(b) $4\frac{V^2}{R}$
(c) $9\frac{V^2}{R}$
(d) $16\frac{V^2}{R}$

Q 3. Two capacitors of capacitance C_1 and C_2 are charged to a potential difference V and connected in series with resistance R_1 and R_2 at t = 0. Both keys are closed. Graph of current I_1 & I_2 in two circuits are as shown here. Which of the following must be incorrect?



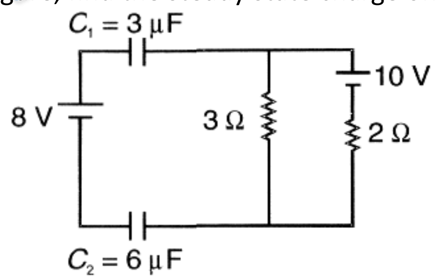
(a) $R_1>R_2$ (b) $R_1<R_2$ (c) $C_1>C_2$ (d) $C_1<C_2$

Q 4. What is equivalent time constant of following RC circuit?



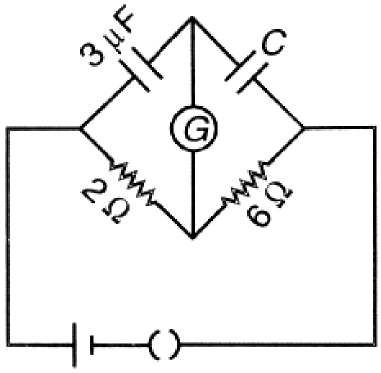
(A)1.5 RC
(B) 3RC
(C) 2 RC
(D) RC/2

Q 5. In the circuit shown in figure, find the steady state charge on C, capacitor



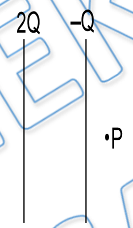
(a) 2μC
(b) 3μC
(c) 4μC
(d) Zero

Q 6. If key K, is closed in circuit shown in figure and galvanometer doesn't give deflection at any time, then value of C is



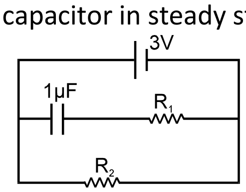
(a) 3μF
(b) 9μF
(c) 4 μF
(d) 1 μF

Q 7. In the figure shown the plates of a parallel plate capacitor have unequal charges. Its capacitance is 'C'. P is a point outside the capacitor and close to the plate of charge –Q. The distance between the plates is 'd'.



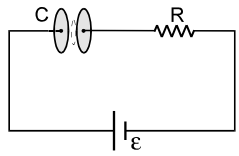
(A) A point charge at point 'P' will experience electric force due to capacitor
(B) The potential difference between the plates will be $\frac{3Q}{2C}$
(C) The energy stored in the electric field in the region between the plates is $\frac{9Q^2}{8C}$
(D) The force on one plate due to the other plate is $\frac{Q^2}{2\pi\epsilon_0 d^2}$

Q 8. A 1 μF capacitor is connected in the circuit shown below. The e.m.f. of the cell is 3 volts and internal resistance is 0.5 ohms. The resistors R_1 and R_2 have values 4 ohms and 1 ohm respectively. The charge on the capacitor in steady state must be :



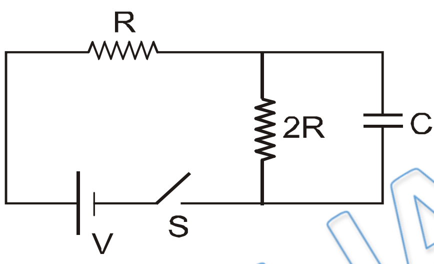
(A) 2 μ C (B) 1 μ C
(C) 1.33 μ C (D) zero

Q 9. In the circuit shown the capacitor of capacitance C is initially uncharged. Now the capacitor is connected in the circuit as shown. The charge passed through an imaginary circular loop parallel to the plates (also circular) and having the area equal to half of the area of the plates, in one time constant is:



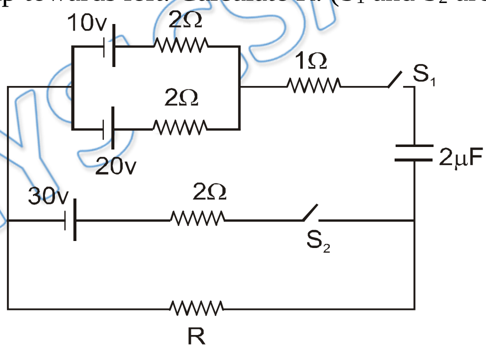
(A) $C\epsilon\left(1-\frac{1}{e}\right)$
(B) $\frac{C\varepsilon}{2}\left(1-\frac{1}{e}\right)$
(C) $\frac{C\varepsilon}{4}$
(D) zero

Q 10. Consider the circuit shown, capacitor is uncharged initially. Switch is closed at t = 0, then select correct alternative/s :



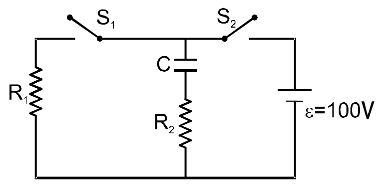
(A) charge on the capacitor as function of time is $q=\frac{2CV}{3}\left(1-e^{-\frac{3t}{2RC}}\right)$
(B) current in the resistance 2R on function of time will be $i=\frac{V}{3R}\left(1-e^{-\frac{3t}{2RC}}\right)$
(C) current in the resistance 2R on function of time will be$i=\frac{V}{3R}\left(1-e^{\frac{3t}{2RC}}\right)$
(D) charge on the capacitor on function of time will be $q=\frac{2CV}{3}\left(1-e^{\frac{t}{2RC}}\right)$

Q 11. Some ideal batteries and an unknown resistance are connected as shown in the circuit. At t = 0, current in R is 1 amp towards left. Calculate R. (S_1 and S_2 are closed at t = 0)



(A) 20.5 Ω (B) 21.5 Ω (C) 20 Ω (D) None of these

Comprehension (Q.12 TO Q.14)
In the circuit shown in the figure the capacitor is initially uncharged



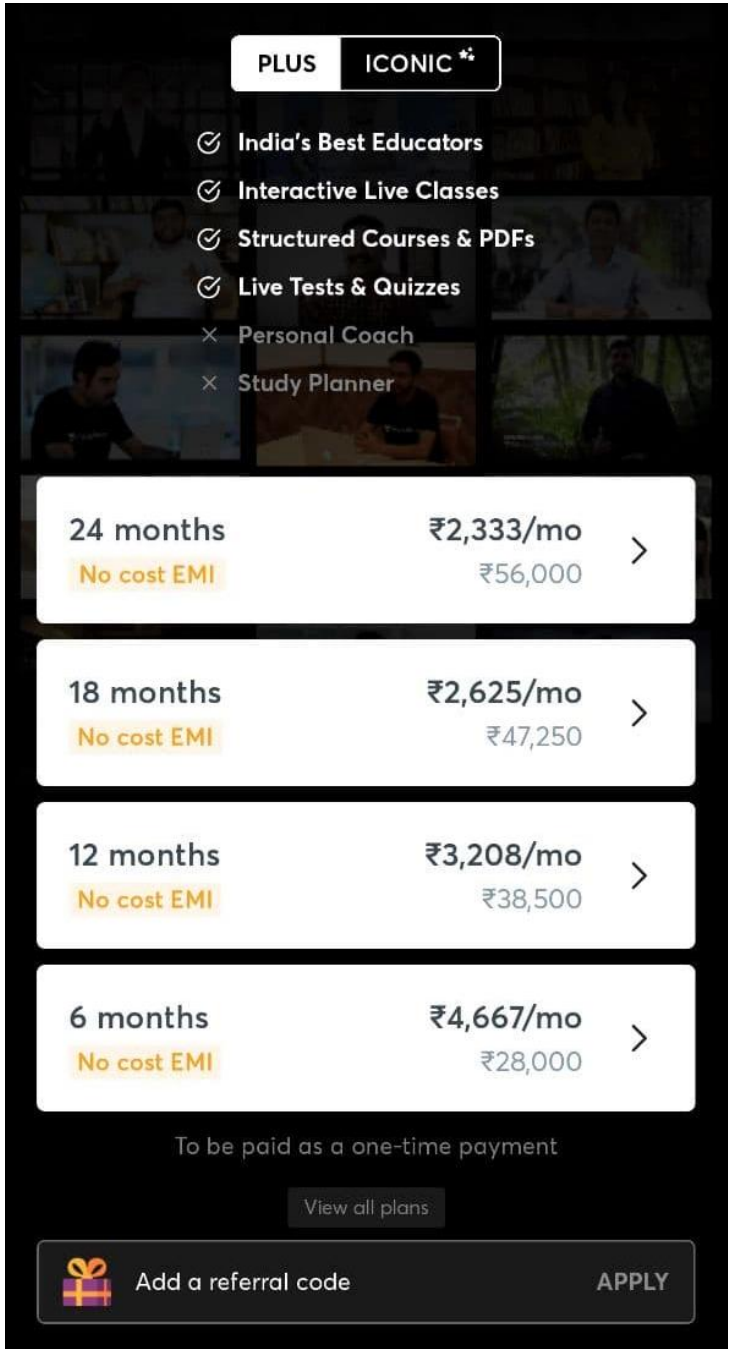
Q 12. S_1 and S_2 are simultaneously closed at t = 0. Power dissipated in the resistor R_1 is 0.2 W and initial current through R_2 is 10 mA. Choose the correct option :
(A) $R_1 = 50k\,\Omega$, $R_2 = 10\,M\,\Omega$
(B) $R_1 = 50k\,\Omega$, $R_2 = 10\,k\,\Omega$
(C) $R_1 = R_2 = 50k\,\Omega$
(D) $R_1 = 10k\,\Omega$, $R_2 = 50\,k\,\Omega$

Q 13. When the capacitor gets fully charging switch S_2 is opened. It is observed that after 5 sec, the current in R_1 is 0.74 mA. [ln(2.25) = 0.812]. Choose the correct option :
(A) C = 100 mF approximately
(B) C = 50 mF approximately
(C) The charge on the capacitor at the instant mentioned in the question is approximately equal to 2 mC
(D) Both (A) and (C) are correct

Q 14. At the instant mentioned in the previous question S_1 is opened and S_2 is closed simultaneously. Taking this instant is t = 0, the charge on the capacitor as a function of time is best represented by
(A) $q = (4.4\,e^{-t})$mC
(B) $q = (10 + 5.6\,e^{-t})$mC
(C) $q = (10 - 5.6\,e^{-t})$mC
(D) $q = (5.6\,e^{-t} - 1.2)$mC

Answer Key

Q.1 a	Q.2 b	Q.3 a	Q.4 a	Q.5 c
Q.6 d	Q.7 a, b, c	Q.8 a	Q.9 d	Q.10 a, b
Q.11 b	Q.12 b	Q.13 a	Q.14 c	



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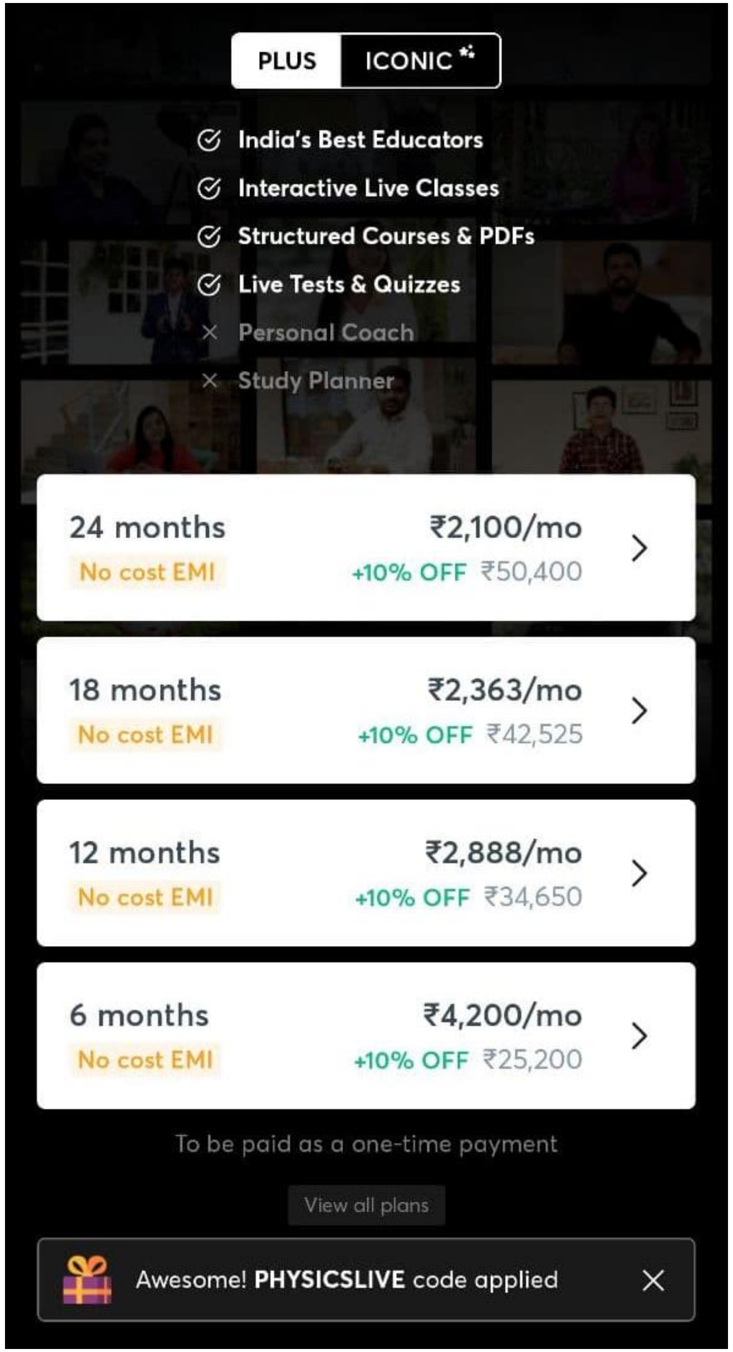

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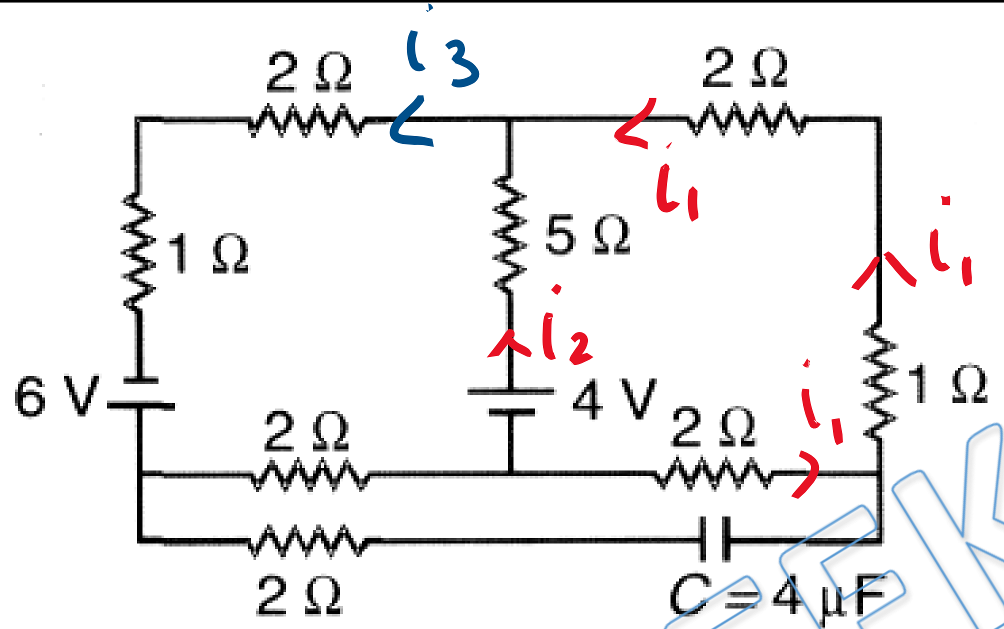
Written Solution

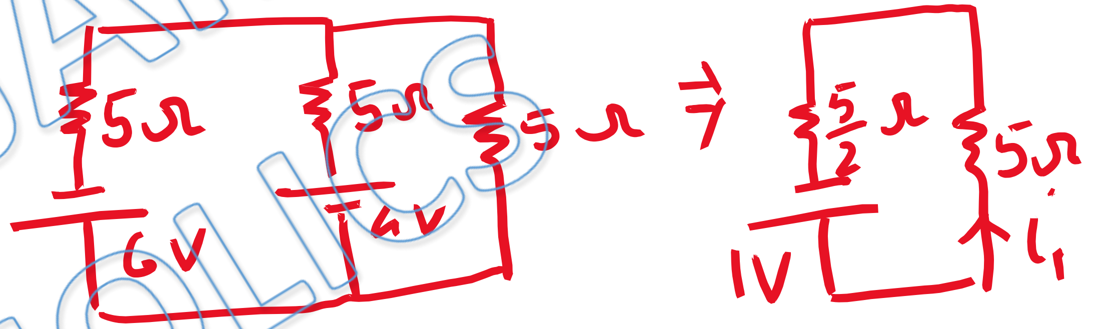
DPP-4 Capacitor- Energy in Capacitor, R-C Circuit, Energy stored in Electric Field & Electrostatic Pressure

By Physicsaholics Team

1)



Steady state current in Capacitor = 0



$i_1 = \frac{1}{7.5} = \frac{2}{15}$ A.

by using KVL → $4 - 5i_2 + 5\times\frac{2}{15} = 0$

⇒ $5i_2 = 4 + 2/3 = 14/3$ ⇒ $i_2 = \frac{14}{15}$

⇒ $i_3 = i_1 + i_2 = \frac{2}{15} + \frac{14}{15} = \frac{16}{15}$ A

Voltage across capacitor $= 2i_1 + 2i_3$

$= 2\left(\frac{2}{15} + \frac{16}{15}\right) = \frac{36}{15} = \frac{12}{5} = 2.4\,V$

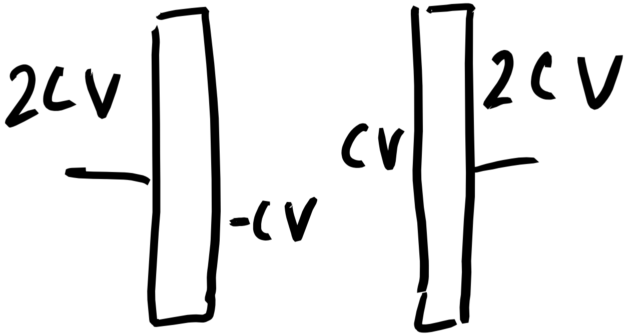
Charge on capacitor $= CV$

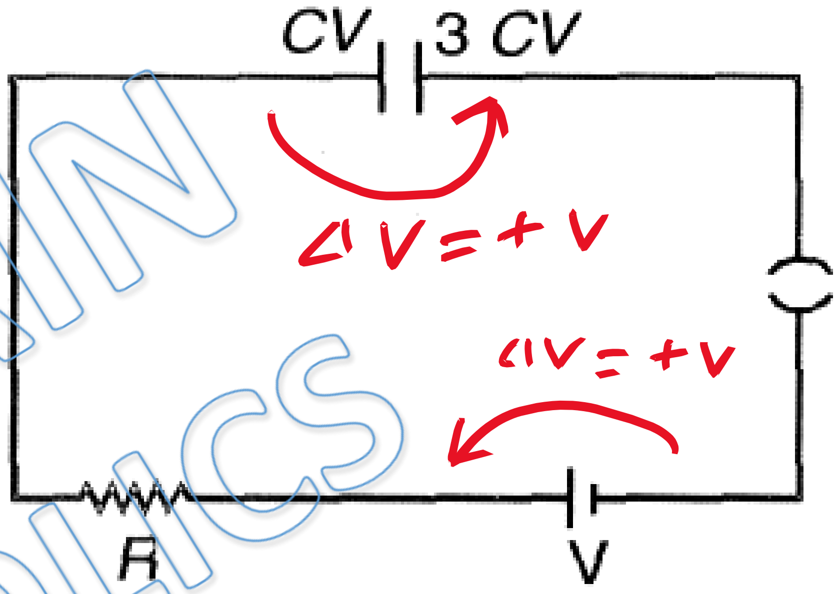
$= 4\mu \times 2.4$

$= 9.6\,\mu C$

Ans (a)

2)





Potential difference across capacitor $= \frac{CV}{V} = V$

Potential difference across resistance $= V + V = 2V$

Power of resistance $= (2V)^2/R = \frac{4V^2}{R}$

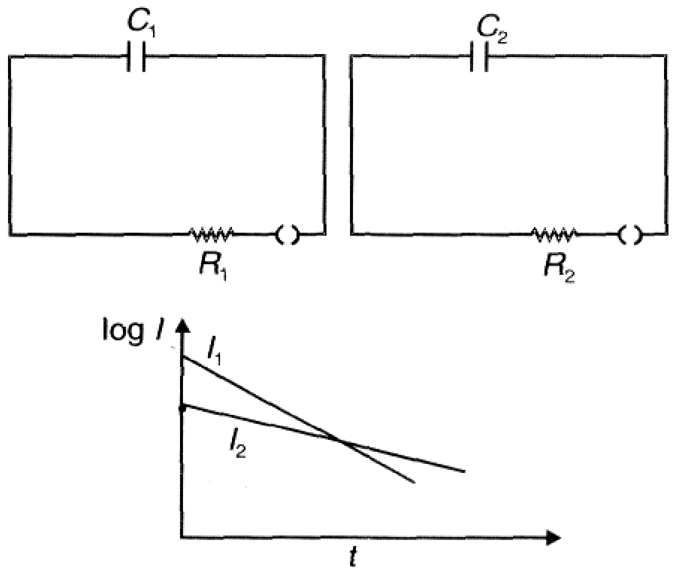
Ans (b)

3) for Discharging RC circuit →

$$i = i_0 e^{-t/RC} \Rightarrow i = \frac{V}{R} e^{-t/RC}$$

$$\Rightarrow \ln i = -\frac{t}{RC} + \ln(V/R)$$

$$\Rightarrow |\text{Slope}| = \frac{1}{RC}, \text{ intercept} = \ln(V/R)$$



$$\Rightarrow \ln(V/R_1) > \ln(V/R_2)$$

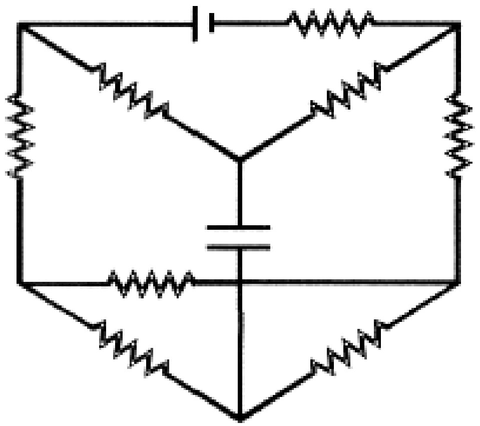
$$\Rightarrow R_1 < R_2$$ → option (a) is not possible.

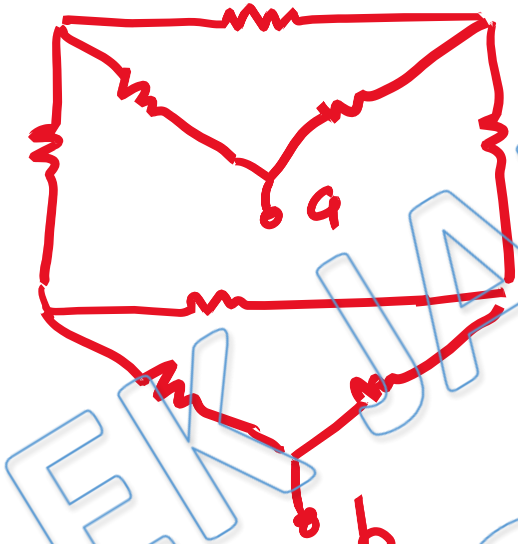
$$\frac{1}{R_1C_1} > \frac{1}{R_2C_2} \Rightarrow \frac{C_1}{C_2} < \frac{R_2}{R_1} > 1$$

⇒ c_1 may be greater & may be smaller than c_2.

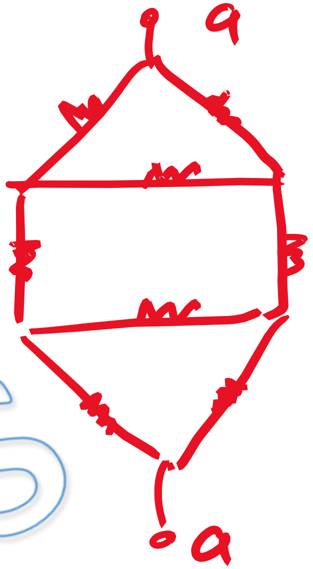
Ans (a)

4)





$\Rightarrow$



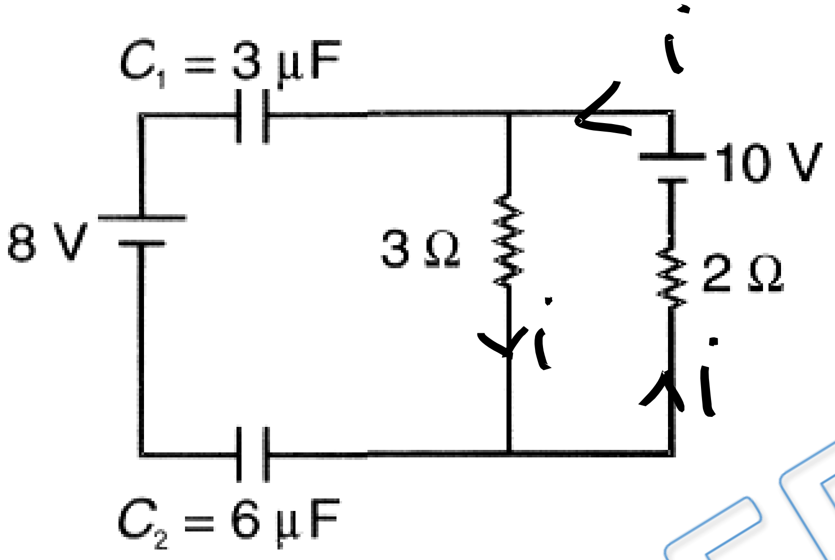
$R_{ab} = \frac{3R}{2}$

$\tau = R_{eff} C$ where R_{eff} is effective resistance between a & b.

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

Ans (a)

5)



In steady state current in capacitor $= 0$

$\Rightarrow$ Current in $3\,\Omega$ resistance $= \frac{10}{3+2} = 2$ A.

Voltage across $3\Omega = 3i = 6V$

Voltage across combination of C_1 & $C_2 = 8 - 6 = 2V$

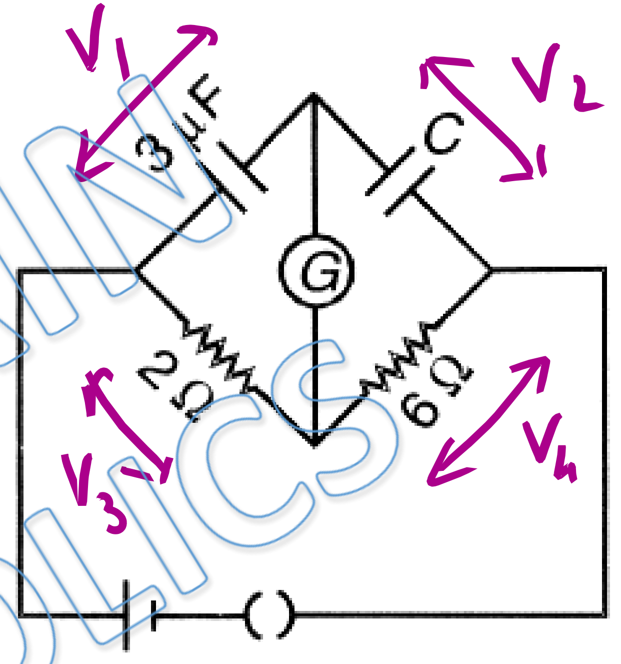
effective Capacitance of C_1 & $C_2 = \frac{3\mu \times 6\mu}{9\mu} = 2\mu F$

Charge on C_1 = charge on effective $= 2 \times 2\mu = 4\mu C$

ANS(C)

6) Since reading of galvanometer is zero.

$3\mu F$ & C are in series and 2Ω and 6Ω are in series.



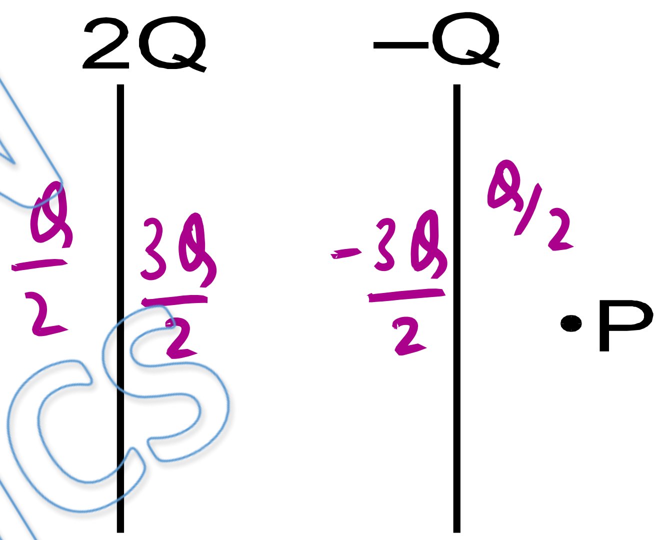
$$\frac{V_1}{V_2} = \frac{V_3}{V_4}$$

$$\Rightarrow \frac{C}{3\mu} = \frac{2}{6} \Rightarrow C = 1\mu F$$

Ans(d)

7) Electric field at $P = \dfrac{(Q/2)}{A\epsilon_0}$

$\Rightarrow$ charge at P will experience force.



P.D. b/w plates $= \dfrac{(3Q/2)}{C} = \dfrac{3Q}{2C}$

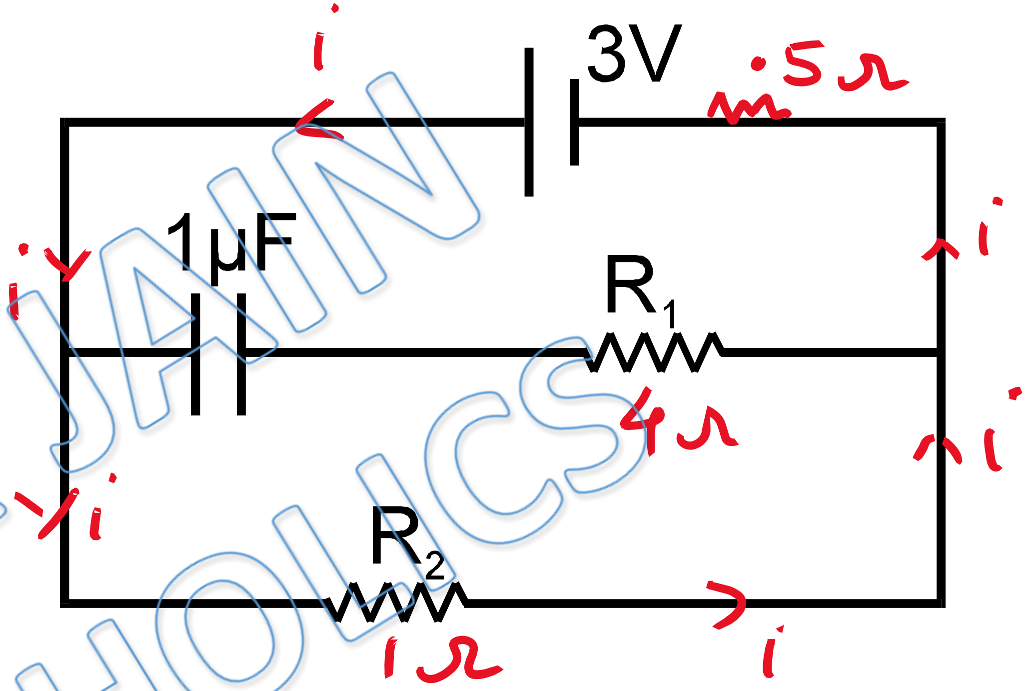
Energy stored b/w plates $= \dfrac{(3Q/2)^2}{2C} = 9Q^2/8C$

field of 2Q on -ve plate $= \dfrac{2Q}{2A\epsilon_0} = \dfrac{Q}{A\epsilon_0}$

force on -ve plate $= QE = \dfrac{Q^2}{A\epsilon_0}$

Ans (a, b, c)

8) $i = \frac{3}{1+.5} = 2A.$



Voltage across capacitor

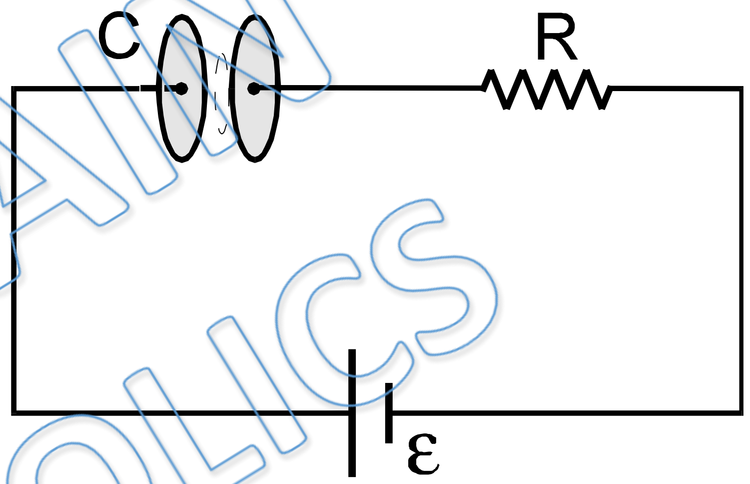
= " " R_2

= $2 \times 1 = 2V$

Charge on capacitor = $1\mu \times 2 = 2\mu C$

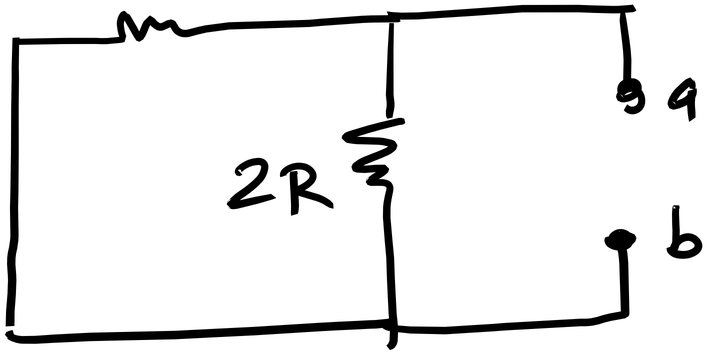
Ans (a)

9) During charging of Capacitor no Current flows in space between plates.

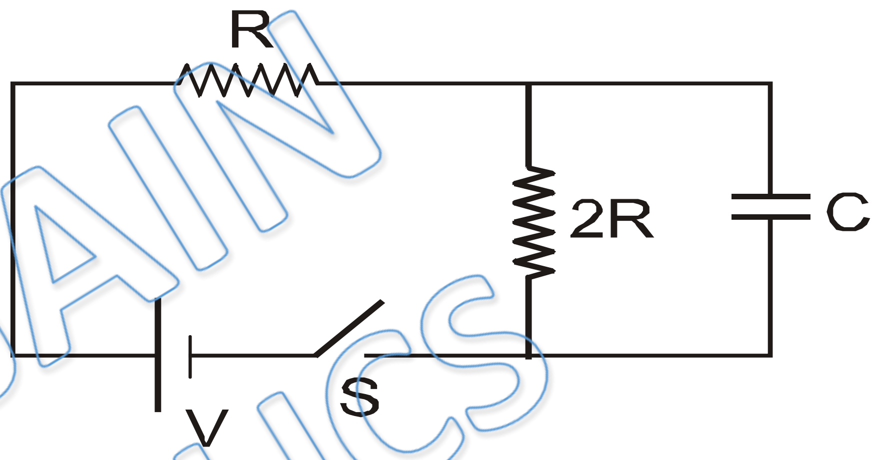


Ans(d)

10)



$$R_{eff} = \frac{2R \times R}{2R + R} = \frac{2R}{3}$$



$$\tau = R_{eff} C = \frac{2RC}{3}$$

steady state voltage across C

= " " " 2R = $2V/3$

steady state charge on C = $2CV/3$

Charge on capacitor at $t = t$

$$q = q_0\left(1 - e^{-t/\tau}\right) = \frac{2CV}{3}\left(1 - e^{-3t/2RC}\right)$$

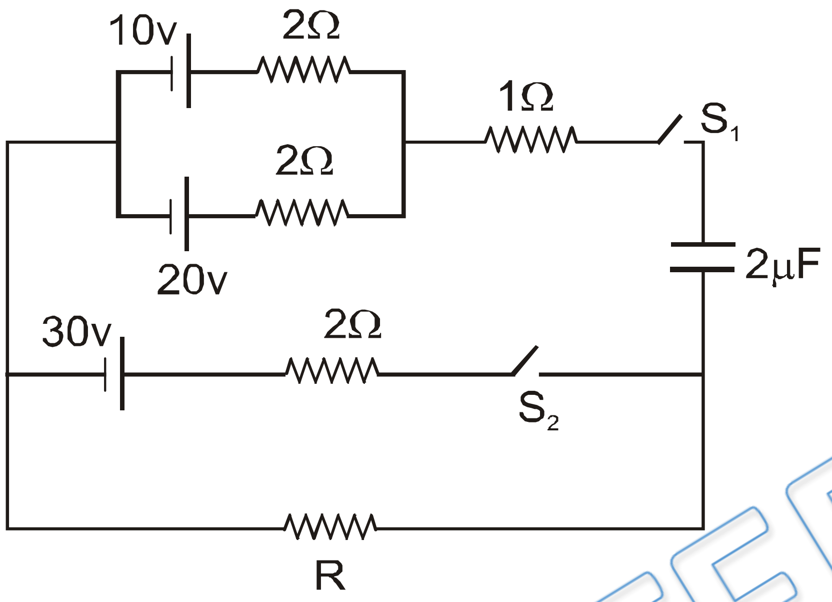
If i is current in $3R$ at $t = t$.

$$2iR = q/C \Rightarrow i = \frac{q}{2RC}$$

$$\Rightarrow i = \frac{V}{3R}\left(1 - e^{-3t/2RC}\right)$$

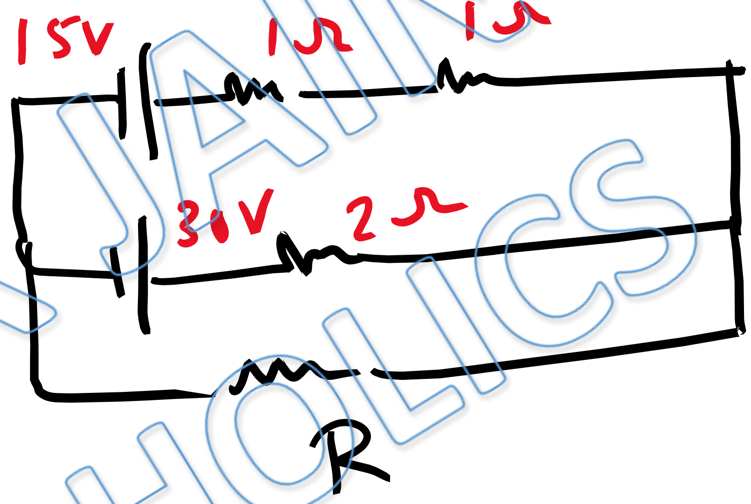
Ans(a, b)

11)

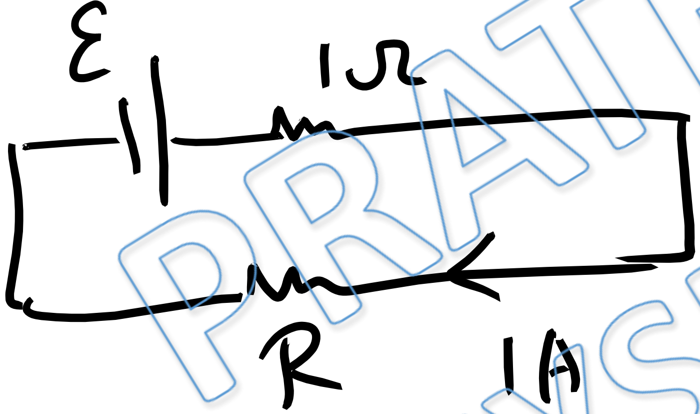


at $t=0$, Capacitor behaves as simple wire.

$\Rightarrow$



$\Rightarrow$



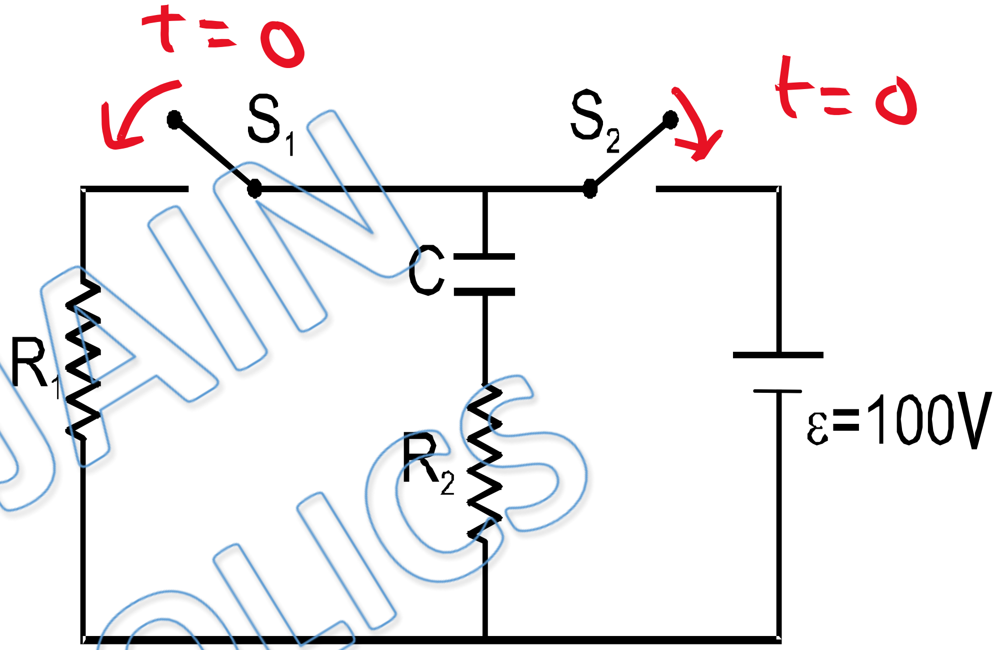
$$\varepsilon = \frac{30 \times 2 + 15 \times 2}{2+2} = \frac{90}{4} = 22.5\,V$$

$$\varepsilon = i(R+r) \Rightarrow 22.5 = 1(R+1)$$

$$\Rightarrow R = 21.5\,\Omega$$

Ans(b)

12)



Power of R_1 = .2 W

$$\frac{(100)^2}{R_1} = .2$$

$$\Rightarrow R_1 = 50\ k\Omega$$

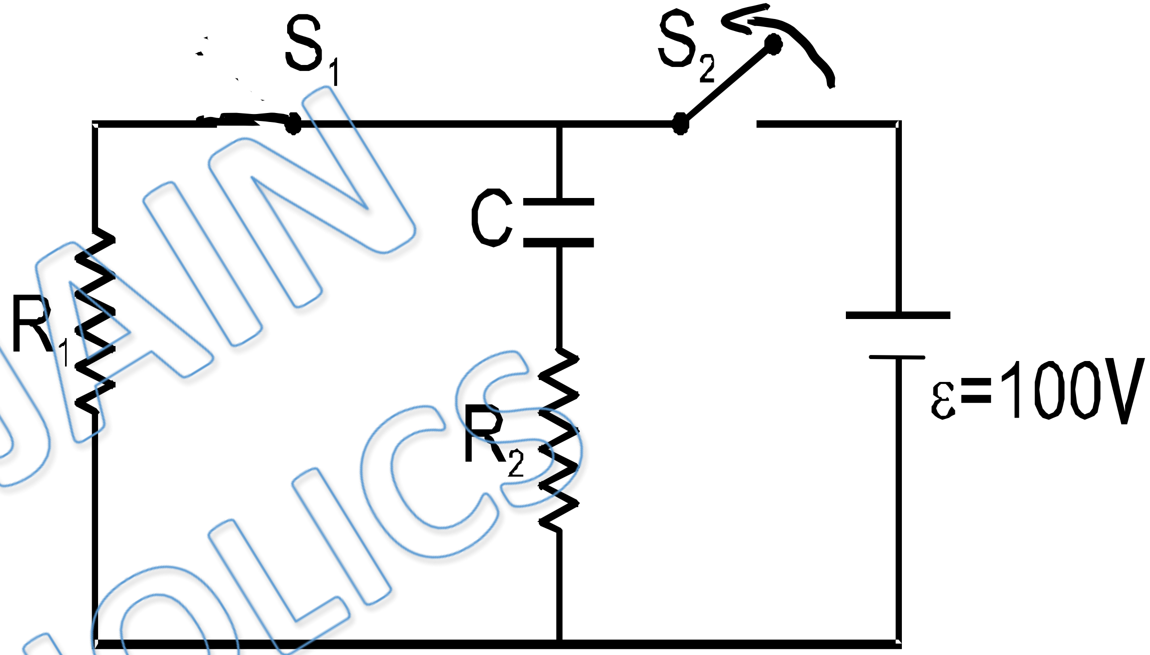
Current in R_2 = 10 mA

$$\frac{100}{R_2} = 10\ mA$$

$$R_2 = 10\ k\Omega$$

Ans (b)

(3) At the instant of opening S_2



Voltage across C = 100V

Voltage across C after 5 Sec

$= 100\, e^{-t/60kC}$

Current in R_1 after 5 Sec

$.74\, mA = \dfrac{100\, e^{-t/60kC}}{60k}$

$e^{-t/60kC} = .444$

$e^{t/60kC} = \dfrac{1}{.444} = 2.25$

$$\frac{5}{60K\,C} = \ln(2.25) = .812$$

$$C = \frac{1}{12 \times .812\,K} = 100\,\mu F$$

Charge on capacitor at this instant

$= CV = 100\mu$ (Voltage across R_1 & R_2)

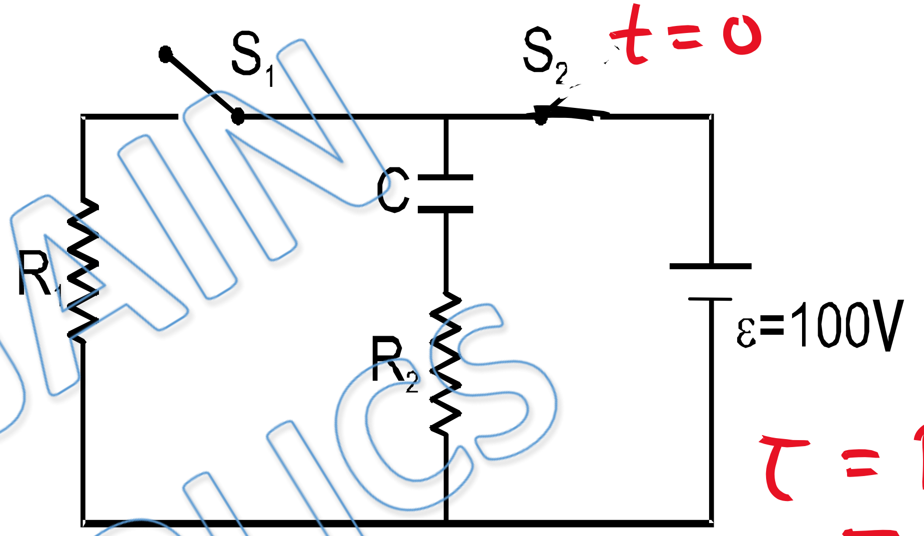
$= 100\mu \times .74m \times 60K$

$= 4.44\,\mu C$

Ans (a)

14) Charge on Capacitor at $t=0$

$$q_0 = 4.4\ \mu C$$



$$\tau = R_2 C = 1$$

Charge on Capacitor at $t=t$

$$q = \frac{100}{10k}\left(1 - e^{-t}\right) + 4.4\ \mu C\ e^{-t}$$

$$= \left(10 - 5.6 e^{-t}\right) mC$$

→ charge if there was no initial charge on capacitor

→ charge if there was no battery.

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