Basic Electrical Technology

CLASS 11 – 01 DECEMBER 2021

Charging of a Capacitor through a Resistor

Applying KVL,

$$V - Ri - v_c = 0$$

where, $i = C\frac{dv_c}{dt}$

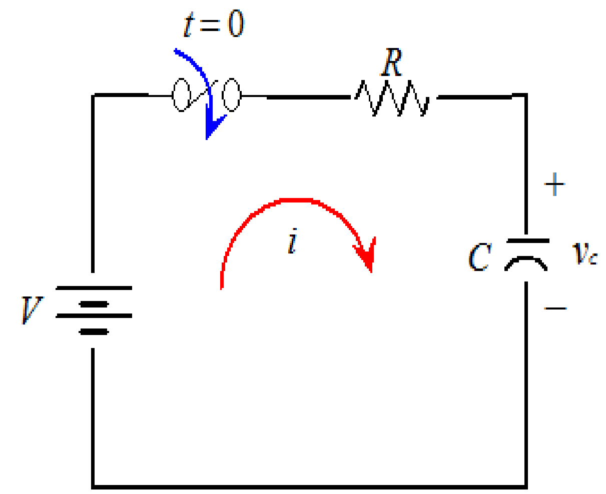
Initial Conditions,

$$At\ t = 0\ sec, V_c = 0\ V$$

Final current & voltage equation,

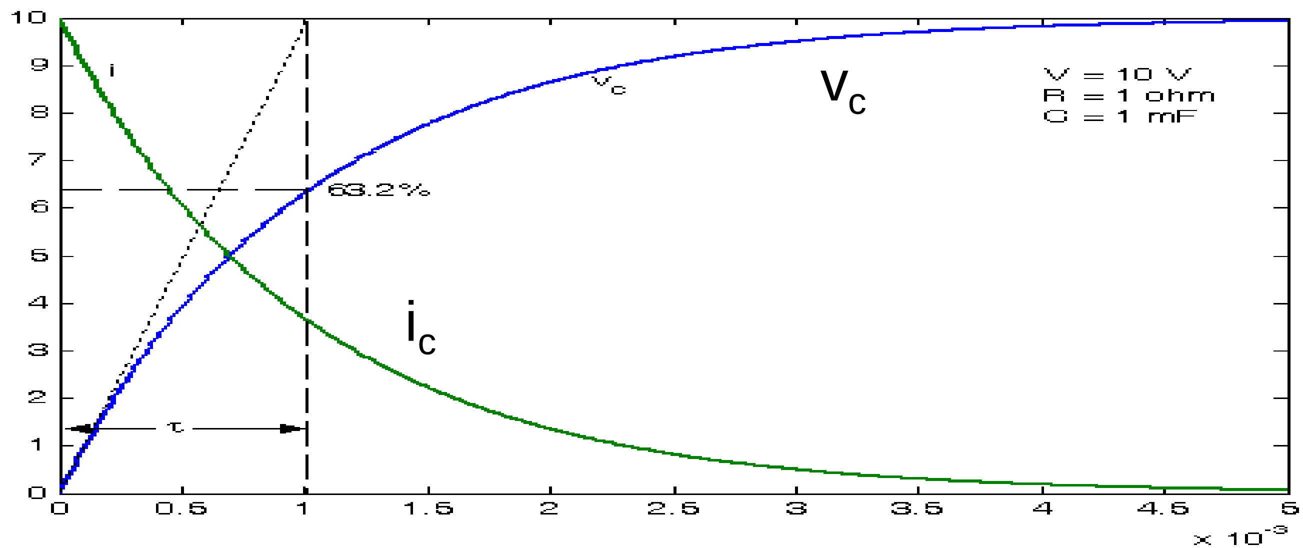
$$v_c = V\left(1 - e^{-\frac{1}{RC}t}\right)$$

$$i_c = \left(\frac{V}{R}\right) e^{-\left(\frac{1}{RC}\right)t}$$



Time Constant (τ): Time taken by the voltage of the capacitor to reach its final steady state value, had the initial rate of rise been maintained constant

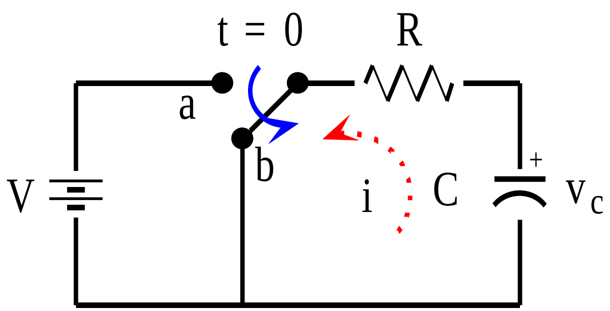
$$\tau = RC$$



Discharging of a Capacitor through a Resistor

- Capacitor is initially charged to a voltage $\boldsymbol{V}$

- At $\boldsymbol{t = 0}$, switch is moved from position ***a*** to ***b***



Applying KVL,

$$\boldsymbol{v_c - Ri = 0}$$

Where, $\boldsymbol{i = -C\frac{dv_c}{dt}}$

Using initial conditions and then solving

$$\boldsymbol{v_c = V\, e^{-(\frac{1}{RC})t}}$$

$$\boldsymbol{i_c = -I\, e^{-(\frac{1}{RC})t}}$$

Discharging of a Capacitor through a Resistor

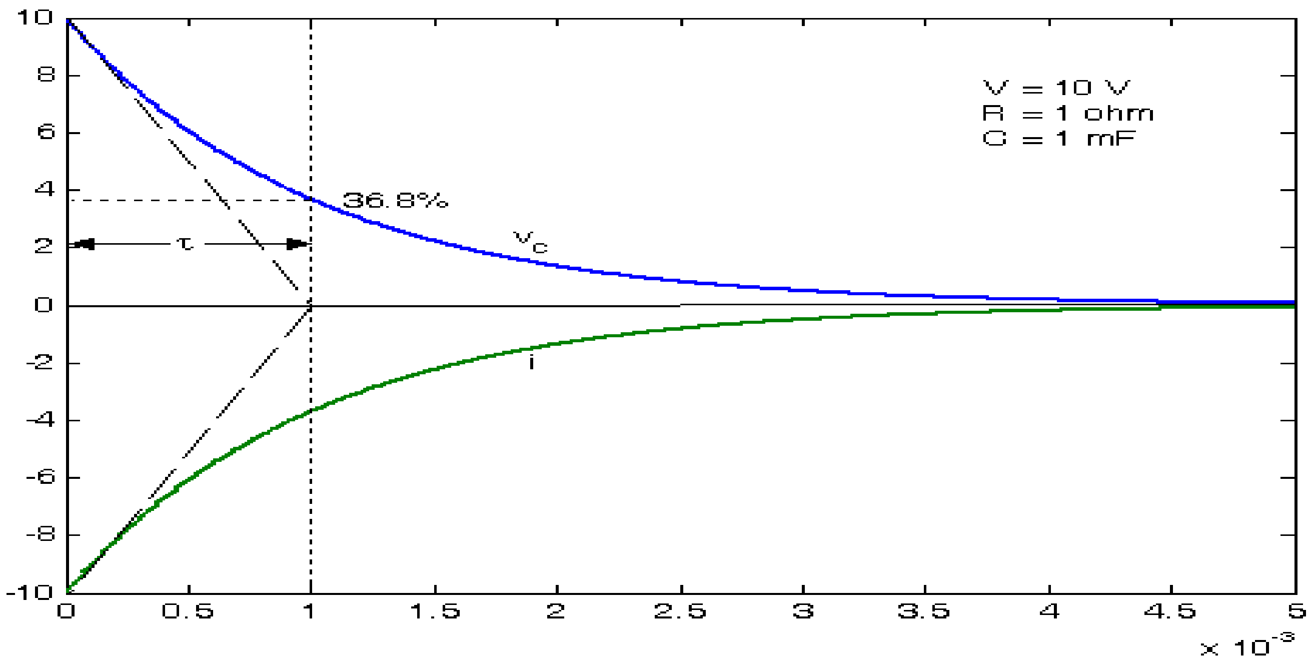


Illustration 1

An 8 μF capacitor is connected in series with a 0.5 MΩ resistor, across a 200 V dc supply through a switch. At t=0 sec, the switch is turned on. Calculate

i. Time constant of the circuit
ii. Initial charging current.
iii. Time taken for the potential difference across the capacitor to grow to 160 V.
iv. Current & potential difference across the capacitor 4.0 seconds after the switch is turned on.

Ans: (i) 4 seconds, (ii) 400 μA , (iii) 6.44 seconds (iv) 126.42 V & 147.15 μA

Illustration 2

A 15 μF uncharged capacitor is connected in series with a 47 kΩ resistor across a 120 V, d.c. supply.

a) Determine the capacitor voltage at a time equal to one time constant after being connected to the supply and also two seconds after being connected to the supply.

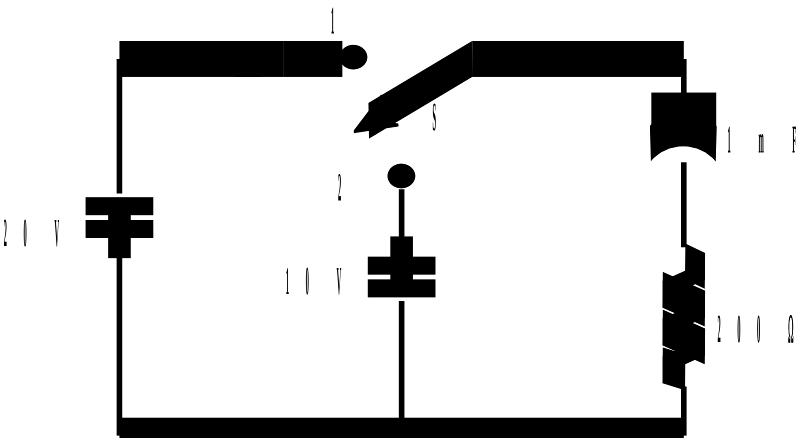
b)Find the time for the capacitor voltage to reach one half of its steady state value. Draw the capacitor voltage waveform.

Ans: a) 75.84 V, 112.97 V b) 0.49 s.

Illustration 3

In the network shown below, the switch is closed to position 1 at t = 0 & is moved to position 2 at t = 0.4 sec. Determine the voltage across the capacitor $v_c(t)$ & sketch it for 0 ≤ t ≤1 sec

Also find the value of 't' for which $v_c(t) = 0$

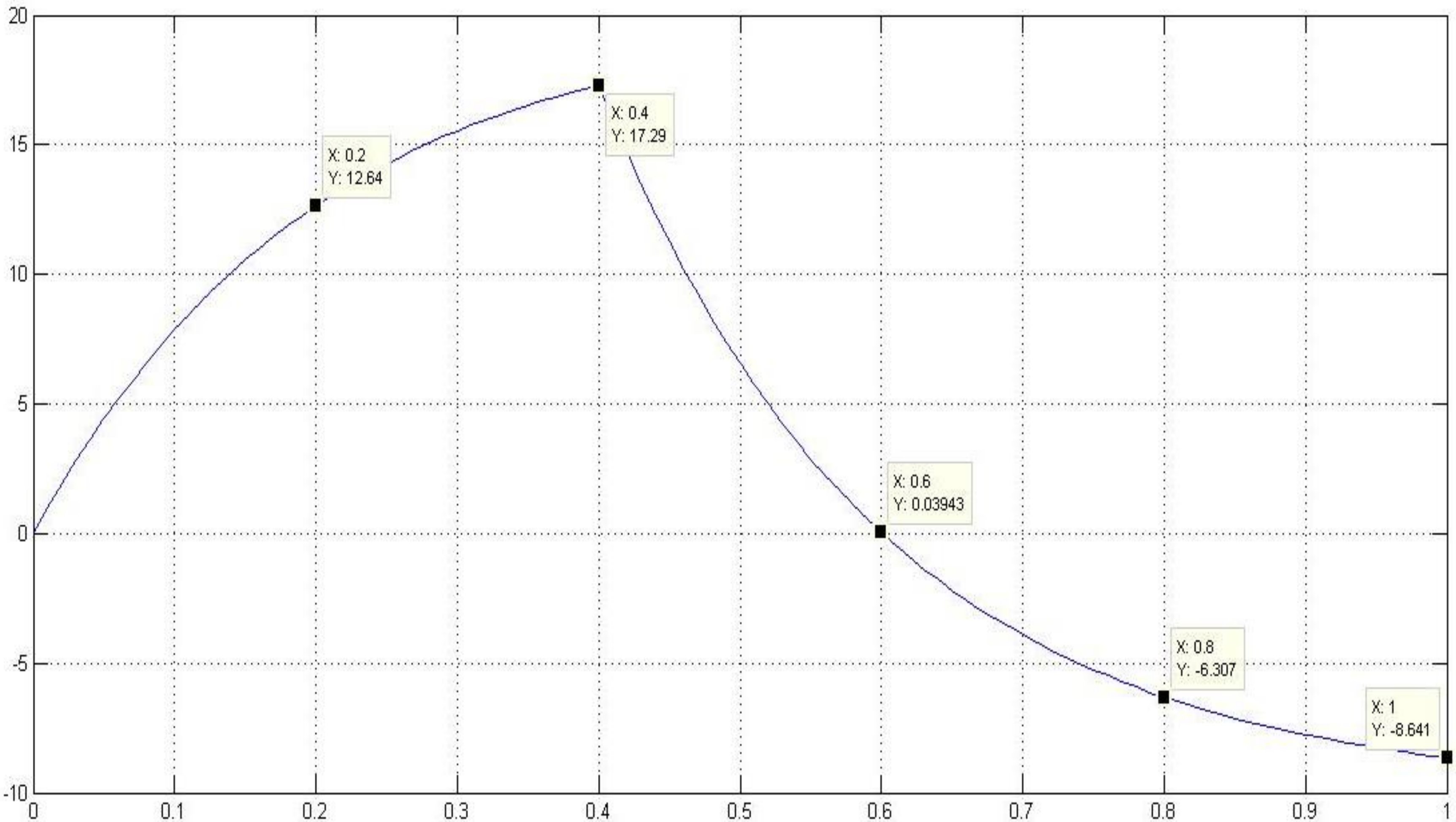


$\boldsymbol{Ans: At\ t = 0.6\ sec, v_c = 0\ V}$

$v_c = 20(1 - e^{-t/0.2})$
$At\ t = 0.4\ sec, v_c = 17.29\ V$

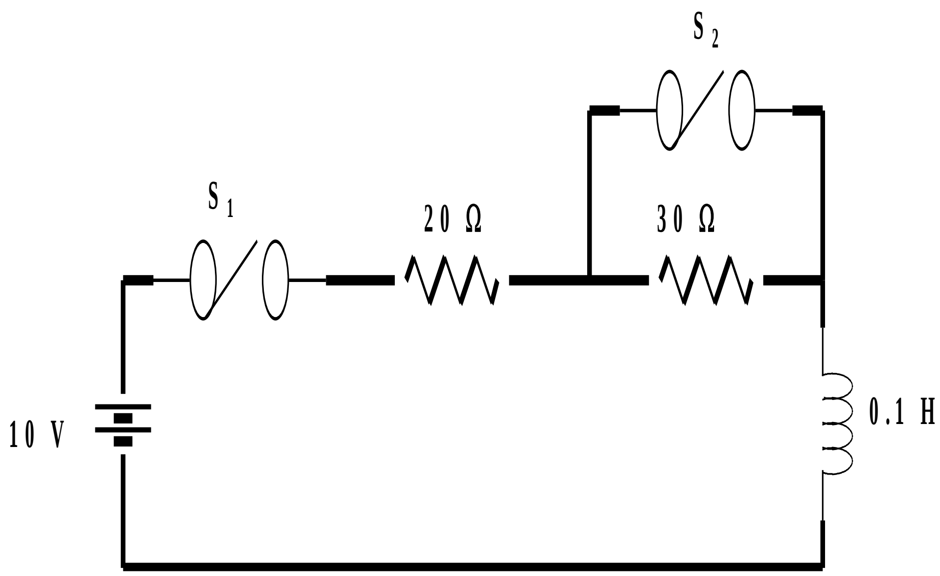
$After\ 0.4\ second, the\ switch\ is\ in\ postion\ 2$
$v_c = -10 + 27.29e^{-(t-0.4)/0.2}$
$At\ t = 1\ sec, v_c = -8.64\ V$

Solution

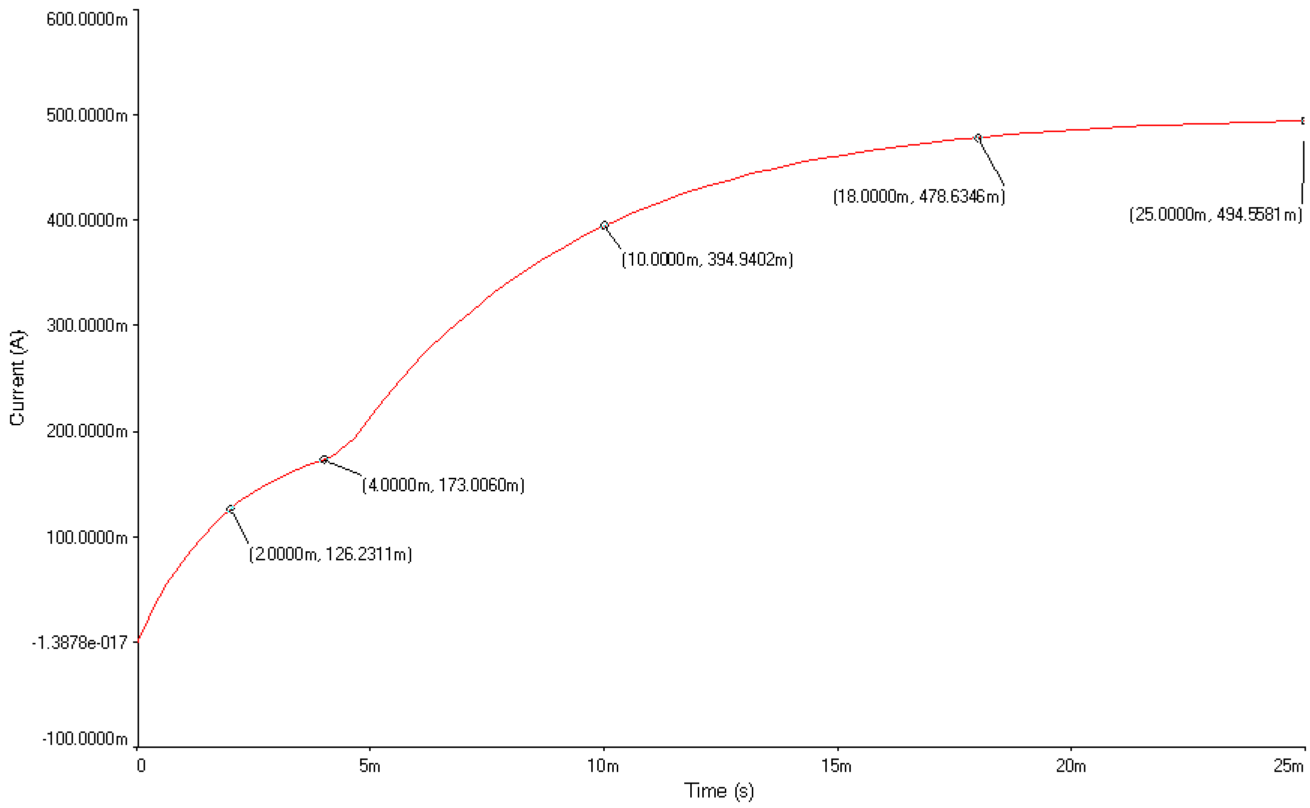

X: 0.2
Y: 12.64
X: 0.4
Y: 17.29
X: 0.6
Y: 0.03943
X: 0.8
Y: -6.307
X: 1
Y: -8.641
20
15
10
5
0
-5
-10
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Question 01

In the circuit shown below, both the switches, S_1 & S_2 are open initially. At t = 0 sec, S_1 is closed (& S_2 remains open). At t = 4 ms S_2 is closed. Sketch the inductor current $\boldsymbol{i(t)}$ for 0 ≤ t ≤ 25 ms.



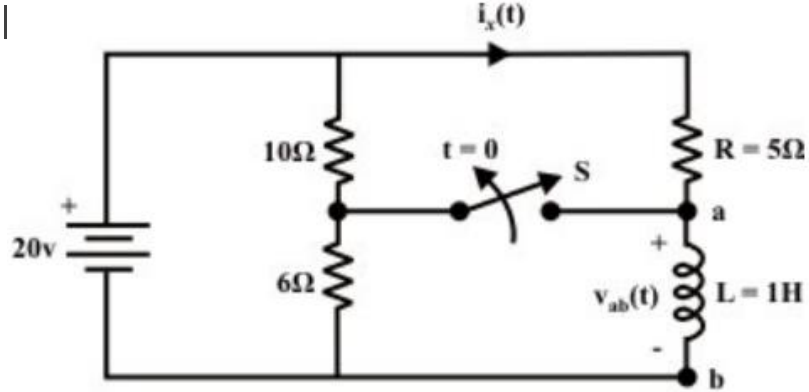
Solution



600.0000m
500.0000m
400.0000m
300.0000m
200.0000m
100.0000m
-1.3878e-017
-100.0000m
Current (A)
0
5m
10m
15m
20m
25m
Time (s)
(2.0000m, 126.2311m)
(4.0000m, 173.0060m)
(10.0000m, 394.9402m)
(18.0000m, 478.6346m)
(25.0000m, 494.5581m)

Question 02

For the circuit shown in figure below, the switch **S** has been closed for a long time and then o|



Find,

i. $v_{ab}(0^-)$

ii. $i_x(0^-)$

iii. $i_L(0^-)$

iv. $i_x(0^+)$

v. $v_{ab}(0^+)$

vi. $i_x(t=\infty)$

vii. $v_{ab}(t=\infty)$

viii. $i_x(t)$, for $t > 0$

Answers:

i. $= 0\ \mathrm{V}$

ii. $= 4\ \mathrm{A}$

iii. $= 6\ \mathrm{A}$

iv. $= 6\ \mathrm{A}$

v. $= -10\ \mathrm{V}$

vi. $= 4\ \mathrm{A}$

vii. $= 0\ \mathrm{V}$

viii. $20 - 5\, i_x - \frac{di_x}{dt} = 0 \Rightarrow$ $i_x(t) = 4 + 2e^{-5t}$ .... Initial condition: At t = 0, $i_x = 6\ \mathrm{A}$

Question 03

For the circuit shown in figure below, the switch **S** has been kept open for a long time and then it is closed

Find,

i. $v_c(0^-)$

ii. $v_c(0^+)$

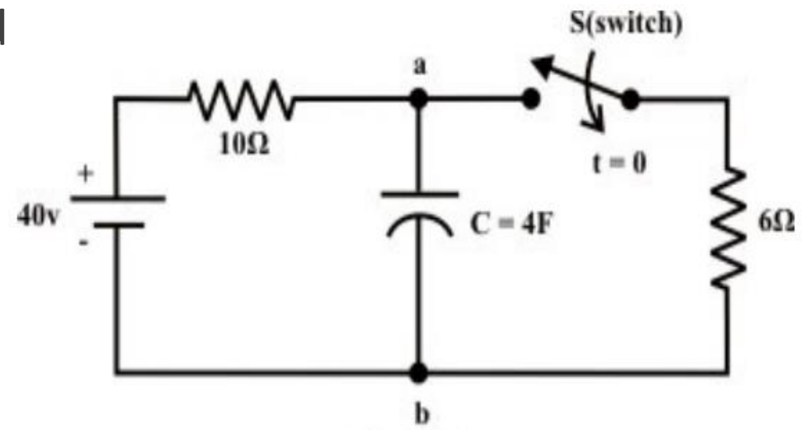
iii. $i_c(0^-)$

iv. $i_c(0^+)$

v. $\left.\frac{dv_c}{dt}\right|_{t=0^+}$

vi. $v_c(t=\infty)$

vii. find the time constants of the circuit before and after



Answers:

i. $= 40\text{ V}$

ii. $= 40\text{ V}$

iii. $= 0\text{ A}$

iv. $= \frac{20}{3}\text{ A}$

v. $= \frac{5}{3}\text{V/s}$

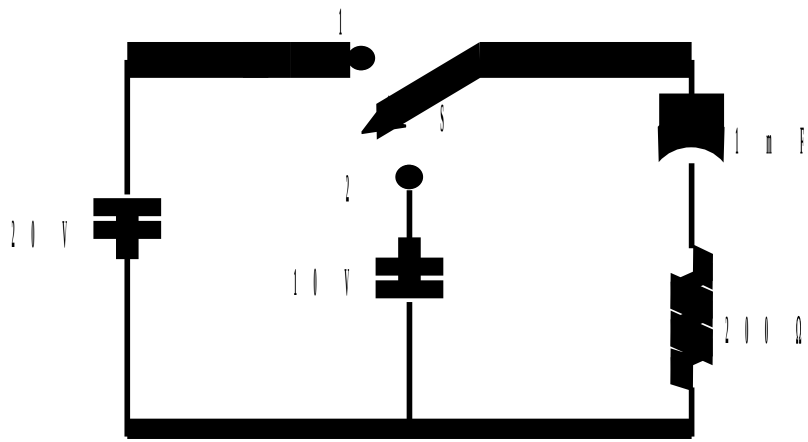
vi. $= 15\text{ V}$

vii. $\tau_1 = 40\text{ s}$, $\tau_2 = 15\text{ s}$ (To find τ_2 find the Thevenin's equivalent resistance)

Question 04

In the network shown below, the switch is closed to position 1 at t = 0 & is moved to position 2 at t = 0.4 sec. Determine the voltage across the capacitor $v_c(t)$ & sketch it for $0 \leq t \leq 1$ sec

Also find the value of 't' for which $v_c(t) = 0$



Solution

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