NORTH SOUTH UNIVERSITY

Department of Mathematics & Physics

Assignment –

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Ans. to the ques.no. 57

Let,

Voltage accross the resistor, $V_R = IR$

and Voltage accross the capacitor, $V(t) = \epsilon(1-e^{-t/RC})$

We know,

$$I \text{ during charging} = \frac{\epsilon}{R} \cdot e^{-t/RC}$$

Therefore,

$$V(t) = V_R$$

$$\Rightarrow V(t) = IR$$

$$\Rightarrow \epsilon(1-e^{-t/RC}) = \frac{\epsilon}{R} \cdot e^{-t/RC} \cdot R$$

$$\Rightarrow 1-e^{-t/RC} = e^{-t/RC}$$

$$\Rightarrow 1 = 2e^{-t/RC}$$

$$\Rightarrow e^{-t/RC} = \frac{1}{2}$$

$$\Rightarrow \frac{-t}{RC} = \ln\left(\frac{1}{2}\right)$$

$$\therefore t = -RC\ln\left(\frac{1}{2}\right)$$

$$\therefore t = -20 \times 15 \times 10^{-6} \times \ln\left(\frac{1}{2}\right) = \cancel{0.208\text{ sec}}\ 207.94 \times 10^{-6}\text{ sec}$$

An

Ans. to the ques. no. 58

Given,

$\epsilon = 12.0 \text{ V}$

$R = 1.40 \text{ M}\Omega = 1400000 \ \Omega$

$C = 1.80 \mu F = 1.8 \times 10^{-6} \text{ F}$

a)

Time constant $= RC$

$= (1400000 \times 1.8 \times 10^{-6}) \text{ sec}$

$= 2.520 \text{ sec}$

Ans

b)

We know,

maximum change on capacitor during charging

is $= \epsilon C$

$= (12.0 \times 1.8 \times 10^{-6}) \text{ Coul.}$

$= \cancel{0.0216 \text{ coul.}}$

$= 21.6 \times 10^{-6} \text{ Coul}$

c)

We know,

During charging,

$$q = \epsilon C\left(1 - e^{-t/RC}\right)$$

$$\Rightarrow q = \epsilon C - \epsilon C e^{-t/RC}$$

$$\Rightarrow e^{-t/RC} = \frac{\epsilon C - q}{\epsilon C}$$

$$\Rightarrow \frac{-t}{RC} = \ln\left(\frac{\epsilon C - q}{\epsilon C}\right)$$

$$\Rightarrow t = -RC \ln\left(1 - \frac{q}{\epsilon C}\right)$$

$$= -2.520 \times \ln\left(1 - \frac{16 \times 10^{-\cancel{3}6}}{\cancel{0.0}21.6 \times 10^{-6}}\right)$$

$$\cancel{= 3401.82 \text{ sec}}$$

$$= 3.40 \text{ sec}$$

Ans

Ans. to the ques. no. 59

We know,

Time constant $\tau = RC$

During charging, charge, $q = \epsilon C(1 - e^{-t/RC})$

Maximum charge, $q_{max} = \epsilon C$

Therefore,

$$\frac{99.0}{100} \times q_{max} = q$$

$$\Rightarrow 0.99\,\epsilon C = \epsilon C(1 - e^{-t/RC})$$

$$\Rightarrow 0.99 = 1 - e^{-t/RC}$$

$$\Rightarrow e^{-t/RC} = 0.01$$

$$\Rightarrow \frac{-t}{RC} = \ln(0.01)$$

$$\Rightarrow t = -RC\ln(0.01)$$

$$= 4.61\,RC$$

$$= 4.61\,\tau \text{ Ans}$$

Therefore, in $4.61\,\tau$, the capacitor will be charged to 99.0% of its final charge.

Ans. to the ques. no. 60

Given,

initial charge, q_0

We know,

During discharging,

$$q = q_0 e^{-t/RC}$$

Time constant, $\tau = RC$

a)

One third of its charge $= \frac{q_0}{3}$

Therefore,

$$q = \frac{q_0}{3}$$

$$\Rightarrow q_0 e^{-t/RC} = \frac{q_0}{3}$$

$$\Rightarrow e^{-t/RC} = \frac{1}{3}$$

$$\Rightarrow \frac{-t}{RC} = \ln\left(\frac{1}{3}\right)$$

$$\Rightarrow t = -RC \ln\left(\frac{1}{3}\right)$$

$$= 1.10\ RC$$

$$= 1.10\ \tau$$

Ans

b)

two - third of its charge $= \frac{2q_0}{3}$

Therefore,

$$q = \frac{2}{3} q_0$$

$$\Rightarrow q_0 e^{-t/RC} = \frac{2}{3} q_0$$

$$\Rightarrow t = -RC \ln\left(\frac{2}{3}\right) \quad \text{[as same as (a)]}$$

$$= 0.41\, RC$$

$$= 0.41\, \tau$$

Ans

Ans. to the ques. no. 61

Given,

Resistor, $R = 15\ k\Omega = 15000\ \Omega$

Source, $\mathcal{E} = 12\ V$

a)

During charging, we know,

Voltage between two plates of the capacitor,

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

$$\Rightarrow \cancel{5000}\ V_c = \epsilon - \epsilon e^{-t/RC}$$

$$\Rightarrow e^{-t/RC} = \frac{\epsilon - V_c}{\epsilon}$$

$$\Rightarrow \frac{-t}{RC} = \ln\left(\frac{\epsilon - V_c}{\epsilon}\right)$$

$$\Rightarrow RC = -\frac{t}{\ln\left(1 - \frac{V_c}{\epsilon}\right)}$$

$$= -\frac{1.30\times10^{-6}}{\ln\left(1 - \frac{5}{12}\right)}$$

$$\cancel{= 0.002411\ sec}$$

$$= 2.41\times10^{-6}\ sec$$

Therefore, time constant, $\tau = RC = \cancel{0.002411\ sec}\ 2.41\times10^{-6}$ sec b)

From (a),

Time constant,

$$\tau = \cancel{0.00}\,2.411 \times 10^{-9} sec$$

$$\Rightarrow RC = \cancel{0.00}2411 \times 10^{-6}$$

$$\Rightarrow C = \frac{\cancel{0.00}2411 \times 10^{-6}}{R}$$

$$= \frac{\cancel{0.00}2.411 \times 10^{-6}}{15000} F$$

$$= \cancel{160.73 \times 10^{-9} F}$$

$$= 0.16 \times 10^{-9} F$$ Ans

Ans. to the ques. no. 68

Given,

Capacitance, $C = 1.0\ \mu F = 1 \times 10^{-6} F$

Stored energy, $U_c = 0.50\ J$

Resistor, $R = 1.0\ M\Omega = 1 \times 10^{6}\ \Omega$

a)

We know,

stored energy on a capacitor,

$$U_c = \frac{Q^2}{2C}$$

$$\Rightarrow Q^2 = 2C U_c$$

$$\Rightarrow Q = \sqrt{2C U_c}$$

$$= \sqrt{2 \times 1 \times 10^{-6} \times 0.50}$$

$$= 0.001 \text{ Coul.}$$

Therefore,

initial charge on the capacitor is, $q_0 = 0.001$ Coul.

b)

From (a),

initial charge, $q_0 = 0.001$ Coul.

During discharging, we know,

charge, $q = q_0 e^{-t/RC}$

We know,

$$\text{current, } i = \frac{dq}{dt}$$

$$= \frac{d}{dt}\left(q_0 \, e^{-t/RC}\right)$$

$$= -\frac{q_0 \, e^{-t/RC}}{RC}$$

$$= -\frac{0.001}{1\times10^{6} \times 1\times10^{-6}} \cdot e^{-t/RC}$$

$$= -0.001 \, e^{-t}$$

Ans

c)

We know,

Puttential difference between the plates of the capacitor,

$$V_c = \frac{q}{c} = \frac{q_0}{c}$$

$$= \frac{0.001}{1\times10^{-6}} \text{ V}$$

$$= 1000 \text{ V}$$

Ans

d)

We know, the pottential differenee accross a resistors

$$V_R = iR$$

$$= (-0.001\, e^{-t}).(1\times 10^{6})\ V$$

$$= -1000\, e^{-t}\ V$$

An

e)

Time constant, $\tau = RC$

$$= 1\times 10^{6} \times 1\times 10^{-6}$$

$$= 1\ \text{sec}$$

initial stored energy, $U_c = 0.50\ J$

After 1 time constant,

$$U_c = \frac{q^2}{2C} = \frac{(q_0 e^{-t/RC})^2}{2C}$$

$$= \frac{(0.001\times e^{-1})^2}{2\times 1\times 10^{-6}}$$

$$= \cancel{0.068\ J}\ 0.0677\ J$$

$\therefore$ energy loss $= (0.50 - 0.0677)\,J$

$= 0.4323\ J$

$\therefore$ Rate of change in percentage $= \dfrac{0.4323}{0.50} \times 100\%$

$= 86.46\%$

Therefore,

in every time constant resistor will produce 86.46% thermal energy of the remaining stored energy in the capacitor.