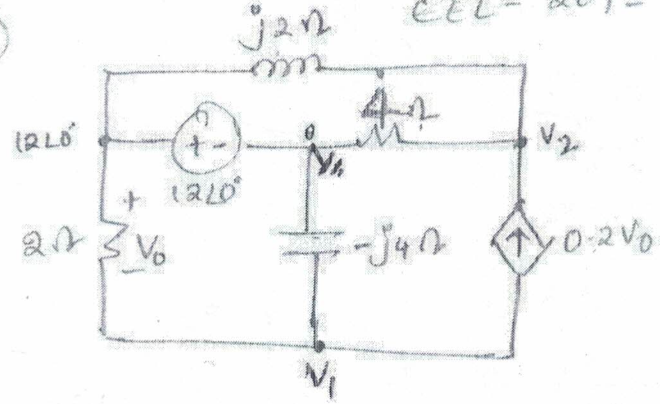
EEL- 209- LNT (END-EXAM)

1



$V_0 = 12\angle 0° - V_1 \rightarrow (1)$ $\Rightarrow$ ~~from (1)~~

Apply nodal analysis at "V_1"

$\frac{V_1 - 12\angle 0°}{2} + \frac{V_1}{-j4} = -0.2V_0, \rightarrow (2)$ $\Rightarrow \frac{2(V_1 - 12\angle 0°)}{2 \times 2} + \frac{V_1 j}{-j4(j)} = -0.2V_0$

$\frac{V_2 - 12\angle 0°}{j2} + \frac{V_2}{4} = 0.2V_0 \rightarrow (3)$ $\quad \frac{2V_1 - 24\angle 0°}{4} + \frac{V_1 j}{4} = -0.2V_0 \rightarrow (2(a))$

1M

From (2(a)) $2V_1 - 24 + jV_1 = -0.8V_0 \rightarrow (4)$

Sub (1) in (4) $(2+j)V_1 = -0.8(12 - V_1) + 24$

$(2+j)V_1 = -9.6 + 0.8V_1 + 24$

$V_1(1.2+j) = 14.4$

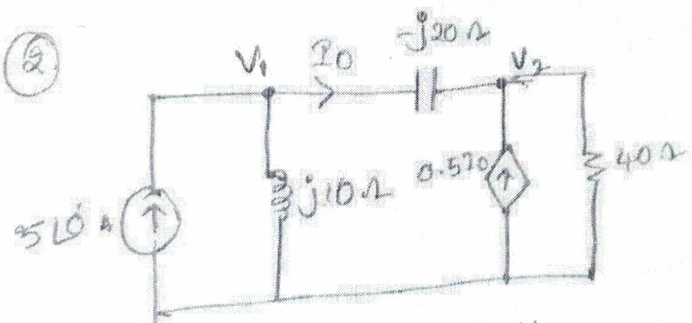
$V_1 = \frac{14.4}{1.2+j} = 7.081 - 5.901j \rightarrow (5)$ 1M

From (1), sub (5) in (1) $V_0 = 12\angle 0° - 7.081 + 5.901j$

$V_0 = 4.918 + 5.901j$

$V_0 = 7.682\angle 50.194$ 1M

2



Nodal at V_1

$\frac{V_1 - V_2}{-j20} + \frac{V_1}{j10} = 5\angle 0°$

$jV_1 - jV_2 - 2jV_1 = 100$

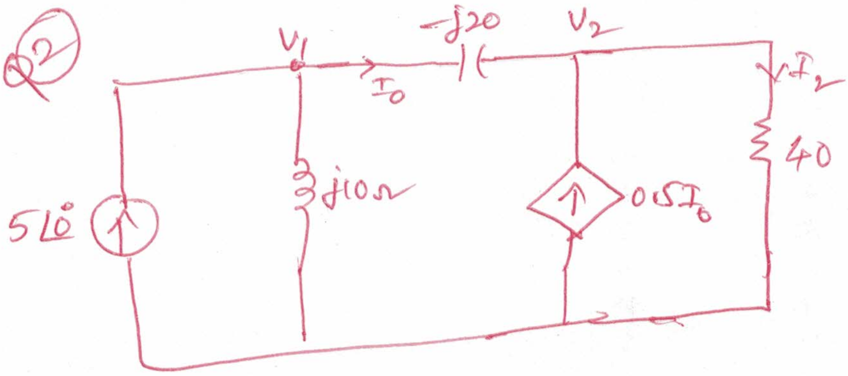
$V_1 = j100 - V_2 \rightarrow (1)$

Nodal at V_2

$\frac{V_2}{40} + \frac{V_2 - V_1}{-j20} = 0.5I_0, \rightarrow (2)$ $\quad \frac{V_1 - V_2}{-j20} = I_0 \rightarrow (3)$

1M

Q2



At node 1

$$\frac{V_1}{j10} + \frac{V_1 - V_2}{-j20} = 5$$

$$V_1 = 100j - V_2 \quad \text{— ① 1M}$$

At node 2:

$$0.5I_0 + I_0 = \frac{V_2}{40}, \text{ but } I_0 = \frac{V_1 - V_2}{-j20}; \text{ hence}$$

$$1.5\left(\frac{V_1 - V_2}{-j20}\right) = \frac{V_2}{40} \Rightarrow 3V_1 = (3 - j)V_2 \quad \text{— ② — 1M}$$

Substituting ① in ②

$$300j - 3V_2 = 3V_2 - jV_2 \Rightarrow 300j = V_2(6 - j)$$

$$\therefore V_2 = \frac{300j}{6 - j} = -8.1 + j48.6 \text{ or } 49.32\angle 99.46$$

↳ 1M

$$I_2 = \frac{49.32}{40} = 1.23A.$$

$$P_{avg} = \frac{1}{2}\left|\frac{V^2}{R}\right| \text{ or } \frac{1}{2}|I_2^2|R. = 30.25W \rightarrow 2M$$

From (2) $\frac{V_2}{40} + \frac{2j(V_2 - V_1)}{40} = 0.5\left(\frac{V_1 - V_2}{-j20}\right)$

$\boxed{j^2 = -1}$

$V_2 + 2jV_2 - 2jV_1 = \frac{V_1 - V_2}{-j}$

$-V_2 j + 2V_2 - 2V_1 = V_1 - V_2$

$-3V_1 = -V_2 - 2V_2 + V_2 j$

$-3V_1 = -V_2(3-j) \Rightarrow V_1 = V_2\left(\frac{3-j}{3}\right) \to (4) \to 1M$

From (1) $V_1 = 100j - V_2$

Sub (1) in (4) $100j - V_2 = V_2\left(\frac{3-j}{3}\right)$

$300j - 3V_2 = 3V_2 - 3jV_2$

$\cancel{300j + 3j = 6V_2 \Rightarrow}$ $\cancel{V_2 = 50j \pm 0.5j}$

$\cancel{V_2 = 50 + 5j}$

$3V_2 - 3jV_2 + 3V_2 = 300j$

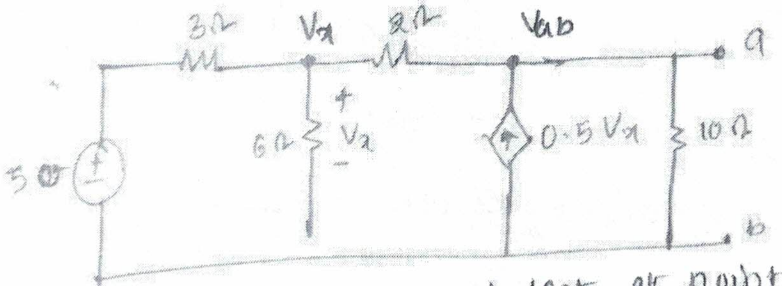
$V_2 = \frac{300j}{6-3j} = \frac{100j}{2-j}$

$I_2 = \frac{V_2}{40} = \frac{2.5j}{2-j}$ → 1M

$P_{avg} = \frac{1}{2}|I_2|^2 R = \frac{1}{2}\left(\frac{2.5}{\sqrt{5}}\right)^2 (40) = \cancel{25}$ Watt → 2M

30.25

(3)



Thevenin's equivalent at point "ab". ⇒ ($V_{ab} = V_{th}$)

$\frac{V_x - 50}{3} + \frac{V_x - V_{ab}}{2} + \frac{V_x}{6} = 0$

$2V_x - 100 + 3V_x - 3V_{ab} + V_x = 0$

$6V_x - 3V_{ab} = 100 \to (1)$

$\frac{V_{ab}}{10} + \frac{V_{ab} - V_x}{2} = 0.5V_x \Rightarrow V_{ab} + 5V_{ab} - 5V_x = 5V_x$

$6V_{ab} = 10V_x \Rightarrow V_x = 0.6V_{ab} \to (2)$

Sub (2) in (1).

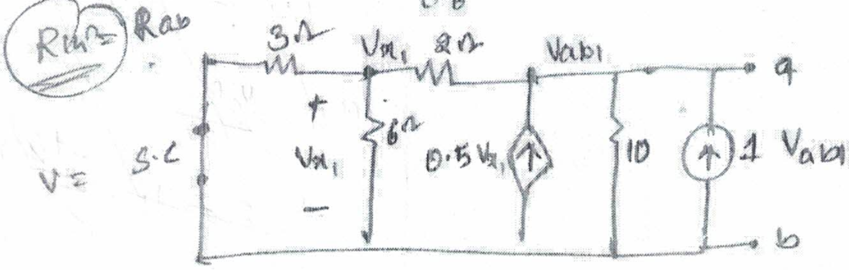
$$6(0.6\,V_{ab}) - 3\,V_{ab} = 100$$

$$3.6\,V_{ab} - 3\,V_{ab} = 100$$

$$V_{ab} = \frac{100}{0.6} = 166.67 \text{ volt}$$ — 2M

R_{th} = R_{ab}

1-V method



$$R_{th} = R_{ab} = \frac{V_{ab_1}}{1} \rightarrow (5)$$

calculate V_{ab_1}

$$\frac{V_{x_1}}{3} + \frac{V_{x_1}}{6} + \frac{V_{x_1} - V_{ab_1}}{2} = 0$$

$$2V_{x_1} + V_{x_1} + 3V_{x_1} - 3V_{ab_1} = 0$$

$$6V_{x_1} = 3V_{ab_1} \rightarrow (3) \Rightarrow V_{x_1} = 0.5\,V_{ab_1}$$

$$\frac{V_{ab_1} - V_{x_1}}{2} + \frac{V_{ab_1}}{10} = 1 + 0.5\,V_{x_1}$$

$$5V_{ab_1} - 5V_{x_1} + V_{ab_1} = 10 + 5V_{x_1}$$

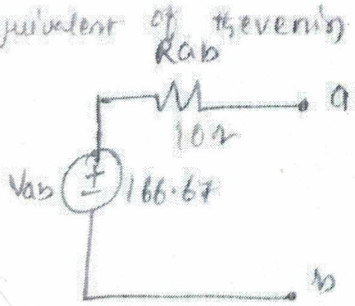
$$6V_{ab_1} = 10 + 10V_{x_1} \rightarrow (4)$$

Sub (3) in (4) $\quad 6V_{ab_1} = 10 + 5V_{ab_1}$

$$V_{ab_1} = 10$$

Sub V_{ab_1} in (5) $\quad R_{th} = R_{ab} = \frac{10}{1} = 10\Omega$ → 2M

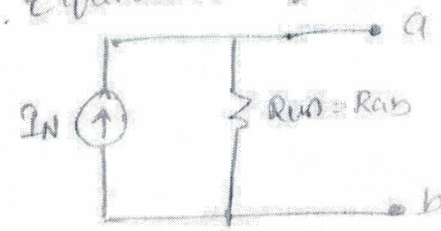
Equivalent of thevenin



↓

1M

Equivalent of Norton

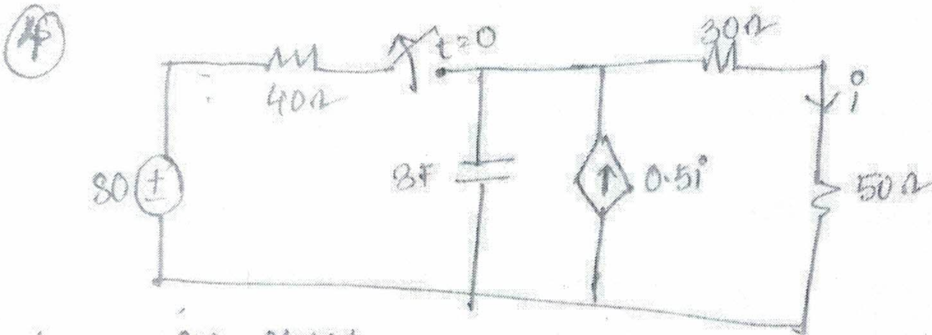


→ 1M

$$I_N = \frac{V_{th} = V_{ab}}{R_{th} = R_{ab}} = \frac{166.67}{10}$$

$$I_N = 16.667 \text{ Amp}$$

(4)



~~$v_c(t) = v(\infty) - [v(\infty) - v(0)]e^{-t}$~~

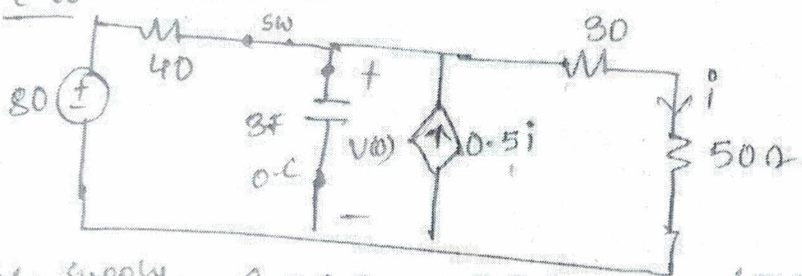
~~S-S Transient~~

~~$= 160 - 96 \cdot e^{-t/480}$~~

~~$i(t) = \frac{v_c(t)}{80}$~~

~~$= 2 - 1.2 e^{-t/480}$~~

t<0 SW = Closed



DC supply, C = O.C, cal initial value V(0)

$$\frac{V(0)-80}{40} + \frac{V(0)}{80} = 0.5i \rightarrow (1) \qquad i = \frac{V(0)}{80} \rightarrow (2)$$

$$\frac{2V(0)-160}{80} + \frac{V(0)}{80} = \frac{0.5 \cdot V(0)}{80}$$

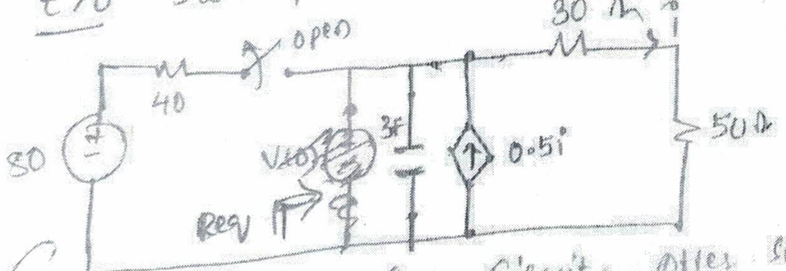
$$2V(0) + V(0) - 0.5\,V(0) = 160$$

$$2.5\,V(0) = 160$$

$$V(0) = 64 \text{ volt}, \leftarrow 1M$$

from (2), sub V(0) = 64 ⇒ $i(0) = \frac{64}{80} = 0.8$ Amp ⇒ 1M

t>0 SW = Open

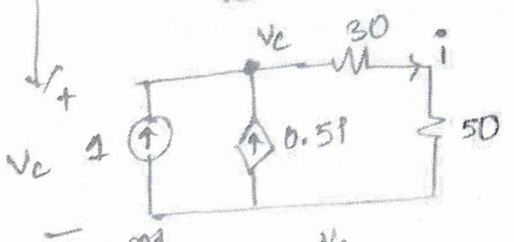


$$i(t) = i(0)e^{-t/\tau}$$

After SW operation T.S occur

The ckt is source free circuit.

RC circuit, $\tau = R_{eq}C$



1-V method $R_{eq} = \frac{V_c}{1}$

$$\frac{V_c}{80} = 1 + 0.5i, \qquad i = \frac{V_c}{80}$$

$$V_c = 80 + 0.5\,V_c$$

$$V_c = 160$$

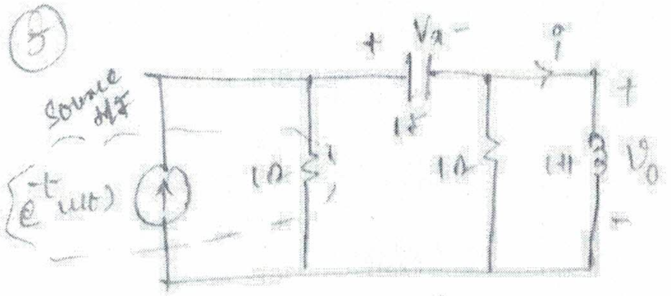
$$R_{eq} = \frac{160}{1} = 160$$

$$\tau = R_{eq} \cdot C = 160 \times 3 = 480 \text{ sec} \nearrow 1M$$

$$\boxed{i(t) = 0.8\,e^{-t/480} \text{ Amp}}$$

↳ 2M

(5)

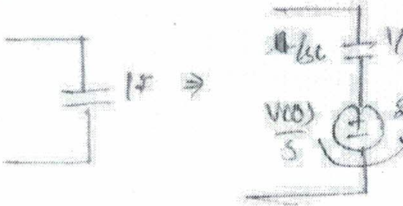


Assume

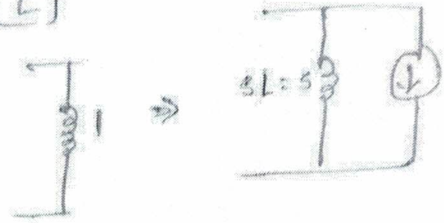
$V_x(0) = 2$ volt

$i(0) = 1$ Amp

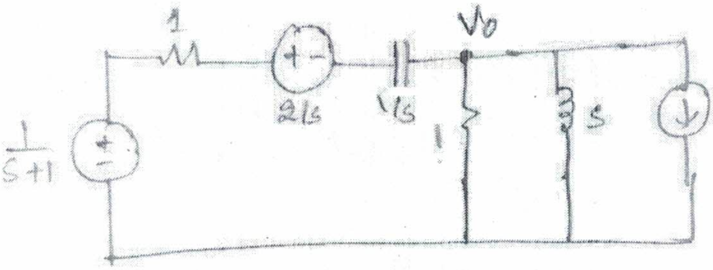
using Initial condition $\boxed{C}$, $\boxed{L}$



→ 1M



→ 1M



$$\frac{V_0}{1} + \frac{V_0}{s} + \frac{(1/(s+1)) - 2/s - V_0}{1 + 1/s} = \frac{-1}{s} \Rightarrow \frac{s}{s+1} - 2 - sV_0 = (s+1)(s+1/s)V_0 + \frac{s+1}{s}$$

$$\frac{s}{s+1} - \frac{s+1}{s} - 2 = (2s+2+1/s)V_0$$

$$V_0 = \frac{-2s^2-4s-1}{(s+1)(2s^2+2s+1)}$$ → 1M

$$V_0 = \frac{-s^2-2s-0.5}{(s+1)(s^2+s+0.5)} = \frac{A}{s+1} + \frac{Bs+C}{s^2+s+0.5}$$

sub $s=-1$, ⇒ $-s^2-2s-0.5 = A(s^2+s+0.5) + B(s^2+s) + C(s+1)$

→ $A = 1$

Equating coeff

$s^2 \Rightarrow -1 = A+B \Rightarrow B = -2$

$s^1 \Rightarrow -2 = A+B+C \Rightarrow C = -1$

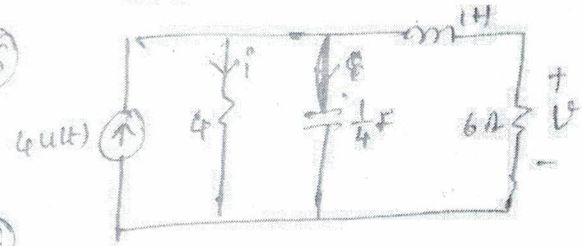
$$V_0 = \frac{-s^2-2s-0.5}{(s+1)(s^2+s+0.5)} = \frac{1}{s+1} - \frac{2(s+0.5)}{(s+0.5)^2+(0.5)^2}$$

$$V_0(s) = \left[e^{-t} - 2e^{-t/2}\cos(t/2)\right]u(t) \text{ volt}$$ → 2M

(3) & (4)

4.23

6



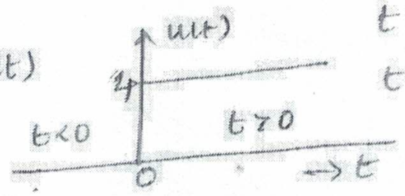
(a) $i(0^+)$, $v(0^+)$

(b) $i(\infty)$, $v(\infty)$

(c) $di(0^+)/dt$, $dv(0^+)/dt$

(a)

for $t<0$, $4u(t)=0$ so that the circuit is not active.



$t<0 = 0$

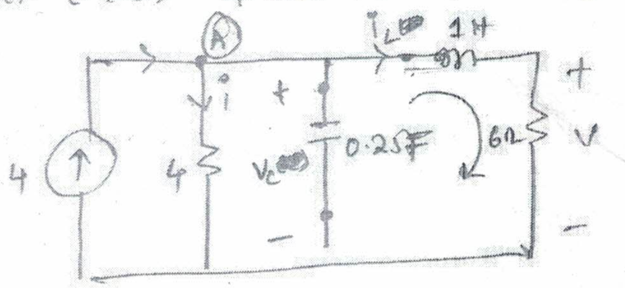
$t>0 = 4$

Initial conditions = 0.

$i_L(0^-) = i_L(0^+) = 0 \Rightarrow i(0^+)$

$V_C(0^-) = V_C(0^+) = 0 \Rightarrow v(0^+)$ } ← 1M

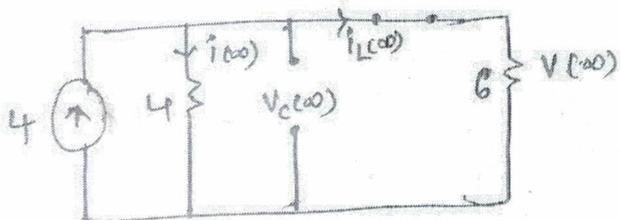
for $t>0$, $4u(t) \rightarrow 4$ (supply). ckt is active



$di(0^+)/dt = 4$ Amp/sec

$dv(0^+)/dt = 0$ volt/sec

(b) for $t>0$, sw is closed for long time $t \to \infty$, $C \to$ O.C, $L \to$ S.C



Current division

$i(\infty) = \frac{4 * 6}{10} = 2.4$ Amp.

$i_L(\infty) = \frac{4*4}{10} = 1.6$ Amp → 1M

$V(\infty) = i_L(\infty) * 6$

$V(\infty) = 1.6 * 6 = 9.6$ volt → 1M

$V_C(\infty) = i(\infty) * 4 = 9.6$ volts.

(c) We know that

$C\frac{dV_C(0^+)}{dt} = i_C(0^+) \Rightarrow \frac{dV_C(0^+)}{dt} = \frac{i_C(0^+)}{C} = \frac{0}{C} = 0$ volt/sec (O.C).

$L\frac{di_L(0^+)}{dt} = V_C(0^+) \Rightarrow \frac{di_L(0^+)}{dt} = \frac{V_C(0^+)}{L} = \frac{0}{L} = 0$ Amp/sec (S.C) → (1)

$V(0^+) = i_L(0^+)\cdot(6) \Rightarrow$ diff $\Rightarrow \frac{dV(0^+)}{dt} = \frac{di_L(0^+)}{dt}(6) = 0\,(6)$

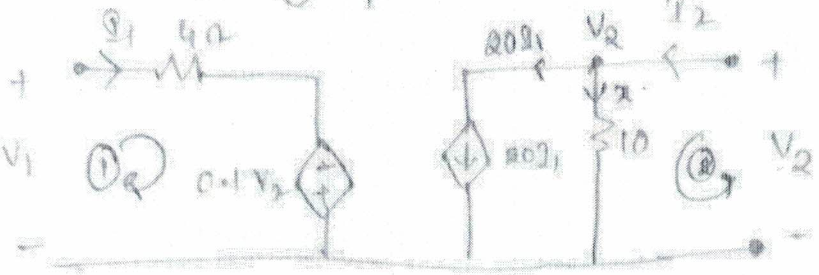
$\frac{dV(0^+)}{dt} = 0$ volt/sec → 1M

At point (A) apply KCL:

$4 = i + i_L$ $\quad \frac{di(0^+)}{dt} + \frac{di_L(0^+)}{dt} = 4$ from (1)

$\frac{di(0^+)}{dt} = 4$ Amp/sec → 1M

(d) Z & g- parameters



$20I_1 + x = I_2$

$x = I_2 - 20I_1$

Apply loop (1)

$4I_1 - 0.1V_2 - V_1 = 0 \rightarrow (1)$

loop (2)

$-V_2 + (I_2 - 20I_1)10 = 0$

$\cancel{V_2 = 20I_1 - I_2} \rightarrow (2)$

$I_2 = 20I_1 + \frac{V_2}{10} \quad - (2)$

from (2),

$V_1 = 4I_1 - 0.1(20I_1 - I_2)$

$\cancel{V_1 = 4I_1 - 2I_1 + 0.1I_2} \Rightarrow V_1 = \cancel{2I_1 + 0.1I_2} \rightarrow (3)$

$\cancel{V_1 = 24I_1 - I_2} \rightarrow (3)$

1 M

Z- parameters

$V_1 = I_1 Z_{11} + I_2 Z_{12}$

$V_2 = I_1 Z_{21} + I_2 Z_{22}$

$v_2 = -200I_1 + 10I_2 \quad -(4)$

From (1) & (4)

$$[Z] \Rightarrow \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 24 & \cancel{0.1} \\ -200 & +10 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} \rightarrow 2M$$

g- parameters

$I_1 = g_{11}V_1 + g_{12}I_2$

$V_2 = g_{21}V_1 + g_{22}I_2$

from (3)

$V_1 - 0.1I_2 = 2I_1$

$I_1 = \frac{1}{2}V_1 - \frac{0.1}{2}I_2 \rightarrow (4)$ 0.05

$V_2 = 20I_1 - I_2 \rightarrow (2)$

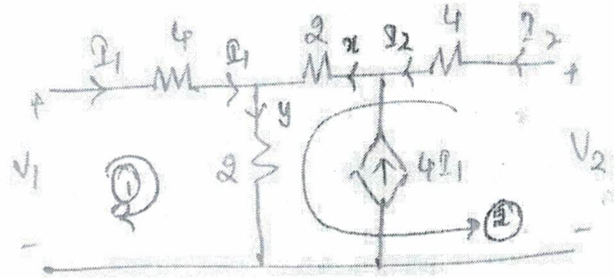
$$\cancel{(g) \Rightarrow \begin{bmatrix} I_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 0.5 & -0.05 \\ 20 & -1 \end{bmatrix} \begin{bmatrix} V_1 \\ I_2 \end{bmatrix}} \rightarrow 2M$$

From (2) & (3)

$$h = \begin{bmatrix} 4 & -0.1 \\ 20 & 0.1 \end{bmatrix} \Rightarrow g = \begin{bmatrix} \frac{1}{24} & \frac{1}{24} \\ \frac{-25}{3} & \frac{5}{3} \end{bmatrix}$$

(8)

8



$x = I_2 + 4I_1, \quad y = I_1 + x = I_2 + 5I_1$

Y - parameters

$I_1 = Y_{11} V_1 + Y_{12} V_2$

$I_2 = Y_{21} V_1 + Y_{22} V_2$

loop (1)

$4I_1 + 2(I_2 + 5I_1) - V_1 = 0$

$9I_1 + 2I_2 = V_1 \rightarrow (2)$ → 0.5 M

loop (2)

$4I_2 + 2(I_2 + 4I_1) + 2(I_2 + 5I_1) - V_2 = 0$

$4I_2 + 2I_2 + 8I_1 + 2I_2 + 10I_1 = V_2$

$18I_1 + 8I_2 = V_2 \rightarrow (3)$ → 0.5 M

$Z = Y^{-1}$ (or) $Y = Z^{-1}$

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 9 & 2 \\ 18 & 8 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

$$Y = Z^{-1} = \begin{bmatrix} 8 & -2 \\ -18 & 9 \end{bmatrix} \cdot \frac{1}{9 \times 8 - 2 \times 18} \quad \downarrow \ 1/36$$

$$Y = \begin{bmatrix} 0.22 & -0.055 \\ -0.5 & 0.25 \end{bmatrix} = \begin{bmatrix} 2/9 & -1/18 \\ -1/2 & 1/4 \end{bmatrix}$$ → 2M

h - parameters

$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix} \Rightarrow \quad \begin{aligned} V_1 &= h_{11} I_1 + h_{12} V_2 \\ I_2 &= h_{21} I_1 + h_{22} V_2 \end{aligned}$$

from (3) $\quad I_2 = \frac{1}{8} V_2 - \frac{18}{8} I_1 \rightarrow (4)$

sub (4) in (2). $\quad 9I_1 + \frac{2}{8} V_2 - \frac{2}{8} \cdot 18 I_1 = V_1 \Rightarrow V_1 = 4.5 I_1 + 0.25 V_2 \rightarrow (5)$

from (4) $\quad I_2 = -2.25 I_1 + 0.125 V_2 \rightarrow (6)$

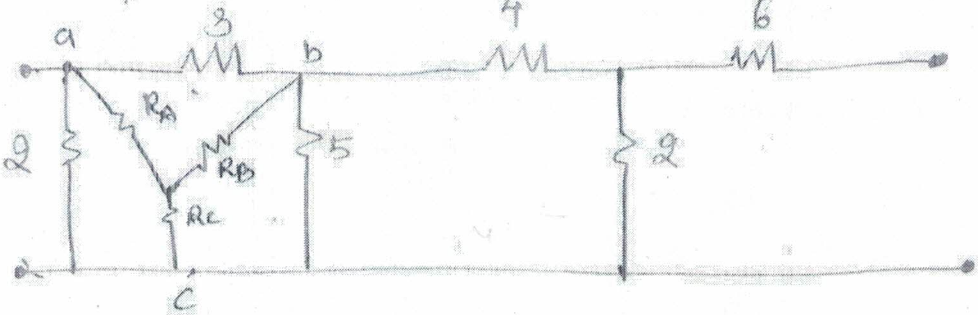
$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 4.5 & 0.25 \\ -2.25 & 0.125 \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$ → 2M

$\frac{\ }{I_1 2} \geq \frac{1}{\ }$ const

9

9

P- parameters.

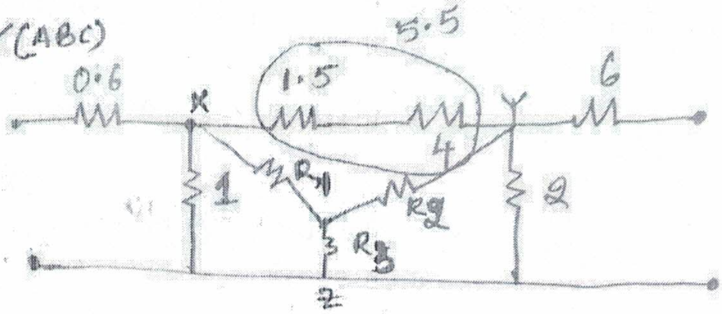


Convert Δ (abc) to Y(ABC)

$R_A = \frac{3\times2}{10} = 0.6\,\Omega$

$R_B = \frac{15}{10} = 1.5\,\Omega$

$R_C = \frac{10}{10} = 1\,\Omega$

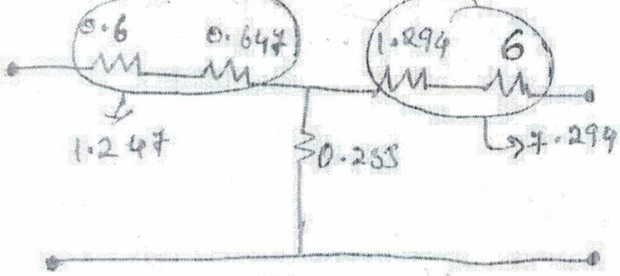


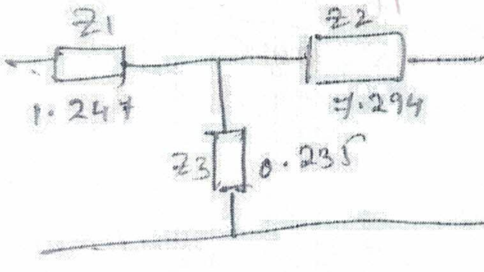
Convert XYZ (Δ) to Y(123)

$R_1 = \frac{5.5*1}{8.5} = 0.647\,\Omega$

$R_2 = \frac{5.5*2}{8.5} = 1.294\,\Omega$

$R_3 = \frac{1*2}{8.5} = 0.235\,\Omega$





$$[Z] = \begin{bmatrix} Z_1+Z_3 & Z_3 \\ Z_3 & Z_2+Z_3 \end{bmatrix}$$

$$[Z] = \begin{bmatrix} 1.482 & 0.235 \\ 0.235 & 7.529 \end{bmatrix} \rightarrow 2M$$

T- parameters

$$\left.\begin{aligned} V_1 &= AV_2 - BI_2 \\ I_1 &= CV_2 - DI_2 \end{aligned}\right\} 1M$$

$V_1 = 1.482\, I_1 + 0.235\, I_2 \rightarrow (1)$

$V_2 = 0.235\, I_1 + 7.529\, I_2 \rightarrow (2)$

$I_1 = \frac{1}{0.235} V_2 - \frac{7.529}{0.235} I_2$

$I_1 = 4.25\, V_2 - 32.03\, I_2 \rightarrow (3) \rightarrow 1M$

from (3) sub I_1 in (1)

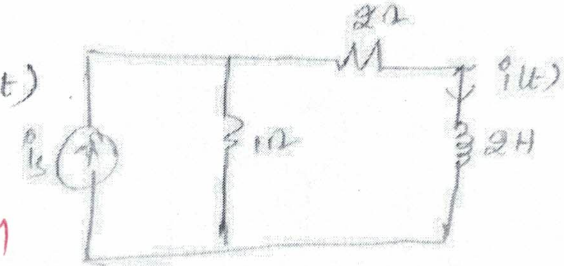
$V_1 = 1.482\,(4.25)\,V_2 - (1.482)(32.03)\,I_2 + 0.235\, I_2$

$V_1 = 6.306\, V_2 - 47.24\, I_2 \rightarrow (4)$

Based on (3) & (4)

$$[T] = \begin{bmatrix} 6.306 & 47.24 \\ 4.25 & 32.03 \end{bmatrix} \rightarrow 2M$$

(10) $i_s(t) = 2 - \frac{16}{\pi^2}\sum_{k=1}^{\infty}\frac{1}{n^2}\cos nt, \quad n = 2k-1$



$f(t) = a_0 + \sum_{n=1}^{\infty}(a_n\cos n\omega_0 t + b_n \sin n\omega_0 t)$

$a_0 = 2, \quad a_n = -\frac{16}{\pi^2 n^2}, \quad \omega_n = n\omega_0, \quad \omega_0 = 1, \quad \boxed{\omega_n = n} \rightarrow$ 1M

$|A_n| = \sqrt{a_n^2 + b_n^2}, \quad \phi_n = -\tan^{-1}(b_n/a_n)$

$L \to sL = 2s$
$R \to R$
$i(t) \to I(s) \to I(\omega)$
$i_s(t) \to I_s(\omega)$

$|A_n| = \frac{16}{\pi^2 n^2}, \quad \phi_n = -\tan^{-1}(0/a_n) = 0$

$I_s(\omega_n) = |i_s(\omega_n)| \angle \theta_n = \frac{16}{\pi^2 n^2}(\angle 0)$

from circuit find $I(\omega_n)$ (for AC supply).

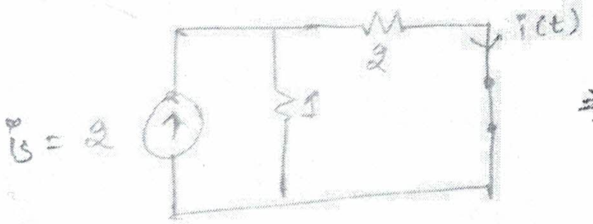
Current division Rule.

$I(\omega_n) = \frac{I_s(s) * 1}{1 + 2 + 2s} = \frac{1}{3 + j2\omega_n} I_s(\omega_n) \rightarrow$ 1M

$I(\omega) = \frac{1}{\sqrt{9 + 4\omega_n^2}} \angle -\tan^{-1}\left(\frac{2\omega_n}{3}\right) * \frac{16}{\pi^2 n^2}\angle 0$

~~$I(\omega) = \frac{1}{2\sqrt{(1+\omega_n^2)}} \cdot \frac{16}{\pi^2 n^2}$~~ $-\tan^{-1}\left(\frac{2\omega_n}{3}\right) = \underbrace{\frac{16}{\pi^2 n^2 \sqrt{(9 + 4\omega_n^2)}}}_{A_n} \underbrace{-\tan^{-1}\left(\frac{2\omega_n}{3}\right)}_{\phi_n} \rightarrow$ 1M

For DC supply.



1M

$\Rightarrow i_{DC}(t) = \frac{2 * 1}{2 + 1} = 2/3 = \underbrace{0.66}_{a_0}$ Amp. $\rightarrow$ 1M

Amplitude - phase form

$f(t) = \underset{\substack{\uparrow \\ DC}}{a_0} + \underbrace{\sum_{n=1}^{\infty} A_n \cos(n\omega_0 t + \phi_n)}_{A \cdot C}$

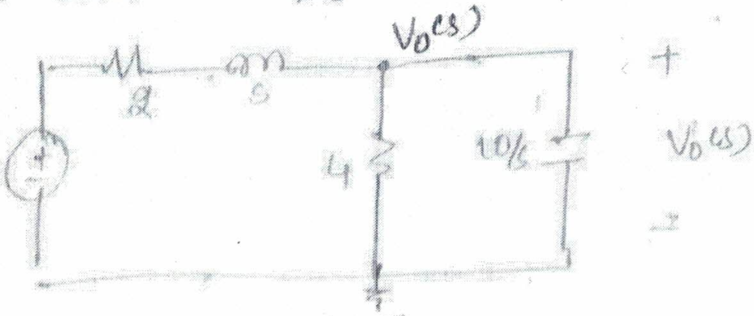
$i(t) = 0.66 + \sum_{n=1}^{\infty} \frac{8}{\pi^2 n^2 \sqrt{(1 + \omega_n^2)}} \cos(nt + \tan^{-1}(\omega_n))$

$n = 2k-1$

$\omega_n = n$

$i(t) = 0.66 + \sum_{n=1}^{\infty} \frac{16}{\pi^2 n^2 \sqrt{9 + 4n^2}} \cos\left(nt - \tan^{-1}\frac{2n}{3}\right) \rightarrow$ 2M

(11) Evaluate the $H(s) = V_0(s)/V_s(s)$ (11)



$L \to sL$

$C \to 1/sC$

$R \to R$

$V_s \to V_s(s)$

$V_0 \to V_0(s)$

10, 2+s, 4

using nodal analysis

$$\frac{V_0(s) - V_s(s)}{2+s} + \frac{V_0(s)}{4} + \frac{V_0(s)}{10/s} = 0$$

$$40\,V_0(s) - 40\,V_s(s) + 10(2+s)\,V_0(s) + V_0(s)\,s\,(2+s)\,4 = 0$$ ~~10, 2+s, 4~~

$$40\,V_0(s) + (20 + 10s)\,V_0(s) + (8s + 4s^2)\,V_0(s) = 40\,V_s(s)$$

$$(40 + 20 + 10s + 8s + 4s^2)\,V_0(s) = 40\,V_s(s)$$

$$\frac{V_0(s)}{V_s(s)} = \frac{40}{4s^2 + 18s + 60} = \frac{20}{2s^2 + 9s + 30}$$

$$H(s) = \frac{V_0(s)}{V_s(s)} = \frac{20}{2s^2 + 9s + 30} \longrightarrow 1M$$

$s = j\omega$

$$H(j\omega) = \frac{20}{2(j\omega)^2 + 9(j\omega) + 30} = \frac{20}{(30 - 2\omega^2) + j9\omega}$$

$$|H(\omega)| = \frac{20}{\sqrt{(30 - 2\omega^2)^2 + (9\omega)^2}}$$

$$|H(0)| = \frac{20}{\sqrt{(30)^2}} = \frac{20}{30} = 2/3 = 0.66 \simeq 0$$ 1M

$$|H(\infty)| = \frac{20}{\sqrt{(30 - \infty)^2 + 9(\infty)^2}} = 0$$

Filter is Band pass. $\longrightarrow$ 1M

$$1 = \frac{20^2}{(30 - 2\omega_c^2)^2 + (9\omega_c)^2} \Rightarrow 900 + 4\omega_c^4 - 120\omega_c^2 + 81\omega_c^2 = 400$$

$$4\omega_c^4 - 39\omega_c^2 + 500 = 0$$

$$\omega_c^2 = 4.878 \pm 10.06j$$