LNMIIT
The LNM Institute of Information Technology

Electronics I
Mid Term Exam

Date: 16th September 2016 **Time: 90 Minutes** **Max Marks. 30**

Notes: Attempt any 5 questions. Each question carries 6 marks.
Start every solution on fresh page.
Highlight your answers by inboxing or underlining them.
Assumptions made should be written clearly.

1: Using mesh analysis (loop analysis), calculate the values of loop current I_1, I_2, I_3, I_4 and Voltage V_o in Figure 1.

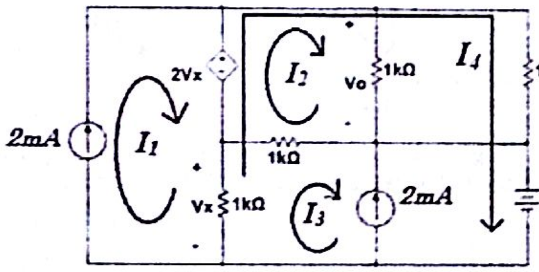

Figure 1

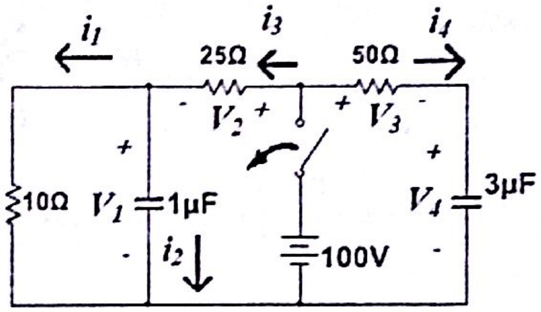

Figure 2

2: Assume that all capacitors were initially uncharged in Figure 2, and at time **t = 0** the switch was closed. Find the voltages (V_1, V_2, V_3 and V_4) and currents (i_1, i_2, i_3 and i_4) indicated in the circui:

a) Immediately after the switch closes (i.e. at $t = 0^+$ sec).
b) After the switch has been closed for a long time (i.e. $t >> 5\tau$).

3: For the circuit shown in Figure 3, calculate total circuit impedance **'Z'** and circuit current **'I '**. Also draw the voltage phasor diagram of circuit.

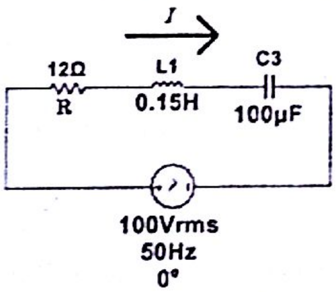

Figure 3

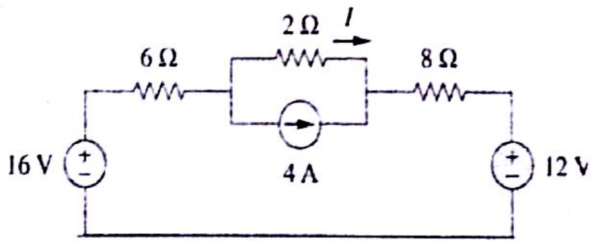

Figure 4

4: Determine the current flowing through 2Ω resistor in Figure 4, by building Thevenin's equivalent for the rest of the circuit.

5: Use Superposition theorem to solve for current *i* in the circuit shown in Figure 5.

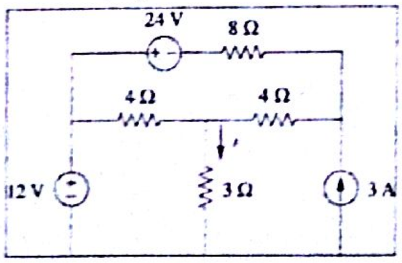

Figure 5

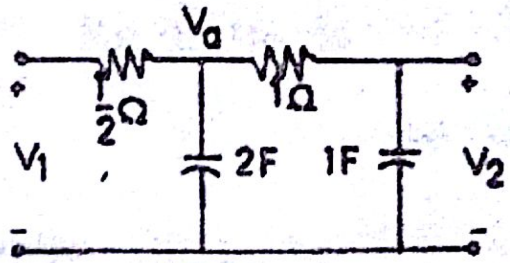

Figure 6

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6: Consider the circuit given in Figure 6. Express the transfer function $H(jw) = V_2(jw)/V_1(jw)$ in terms of R and C. Calculate and plot the amplitude Bode plot for the given values of the parameters.

7: Consider the circuit given in Figure 7. The switch opens at t =0s. Find the voltage across capacitor and current in inductor as a function of time.

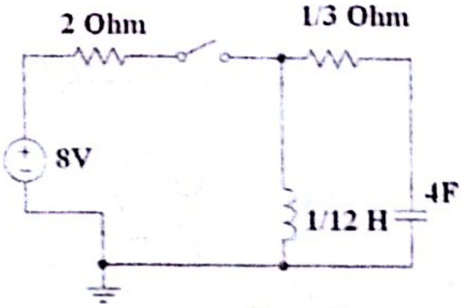


Figure 7.

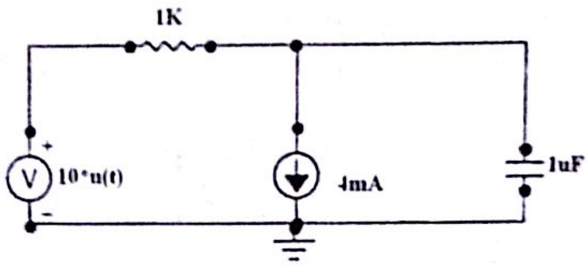
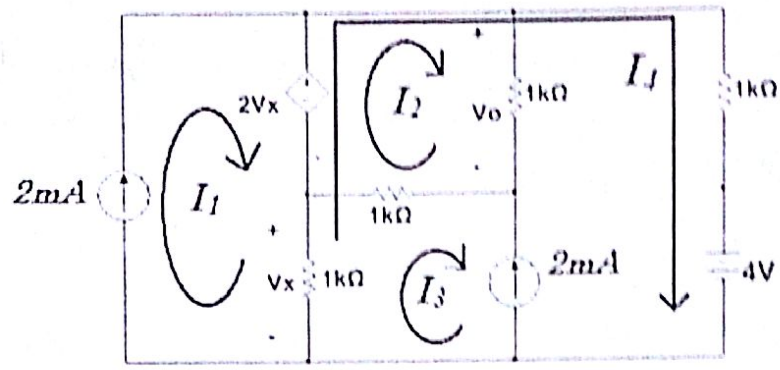


Figure 8

8: Find the voltage across capacitor, in Figure 8, as a function of time by using Laplace transform approach.

Q1. Using mesh analysis (loop analysis), calculate the values of current I_1, I_2, I_3, I_4 and Voltage V_o.



Sol 1:

Above network has 4 loops, and therefore four linearly independent equations are required to determine the loop currents. From the circuit provided, we can directly estimate the value of current I_1 and I_3 as:

$$I_1 = 2mA \quad (1)$$

and [2]

$$I_3 = -2mA \quad (2)$$

Applying KVL in loop 2 we get:

$$-2Vx + 10^3 I_2 + (I_2 - I_3)10^3 = 0 \quad (3)$$

Similarly, applying KVL in loop 3 we get:

$$[(I_4 + I_3 - I_1)\times 1k] - 2Vx + (1k \times I_4) + 4 = 0 \quad (4)$$

From loop 3 we can estimate Vx:

$$Vx = 1k \times (I_1 - I_2 - I_4) \quad (5)$$

Substituting equation (1), (2) and (5) into equation (4) gives:

$$2\times10^3 I_2 + 2\times10^3 I_4 = 6$$

$$4\times10^3 I_4 = 8$$

Hence

$$I_4 = 2mA \quad (6)$$

[2]

Substituting equation (2) and (5) in (3) yields:

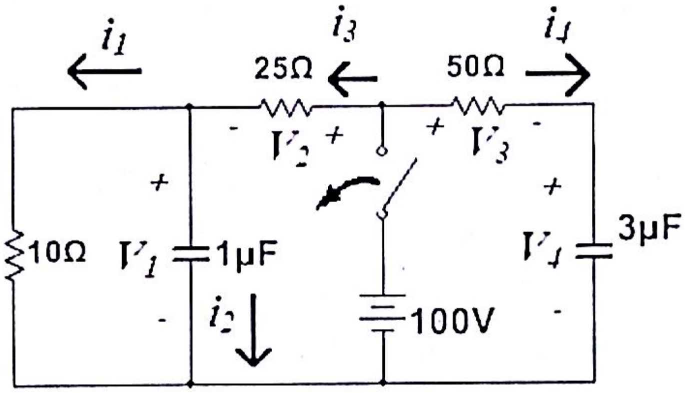
$$I_2 = 1mA$$ [1]

Therefore from loop 2 we can estimate V_0:

$$V_0 = I_2 \times 1k = 10^{-3} \times 10^3 = 1V$$ [1]

Q4. Assuming all the capacitors were initially uncharged, and at time $t = 0$ the switch was closed. Find the voltages (V_1, V_2, V_3 and V_4) and currents (i_1, i_2, i_3 and i_4) indicated in the circuit for:

a) Immediately after the switch closes (i.e. at $t = 0^+$ sec).
b) After the switch is closed for a long time (i.e. $t >> 5\tau$).



Ans-4

Sol: ***Step 1***

At time t = 0+ Secs, capacitors has 0V across them because the capacitor voltages cannot change abruptly.

Therefore, $V_1(0^+) = 0V$ and $V_4(0^+) = 0\,\text{V}$

Along with that, capacitor acts as short circuit at time t=0+, which results that 100V voltage source is across the resistances 25 Ω and 50 Ω.

Therefore, $V_2(0^+) = \text{V}_3(0^+) = 100\,\text{V}$

Three initial currents can be found from the voltages calculated above.

$i_1(0^+) = \dfrac{0}{10} = 0A$ $\quad$ $i_3(0^+) = \dfrac{100}{25} = 4A$ $\quad$ $i_4(0^+) = \dfrac{100}{50} = 2A$

[2]

Remaining initial currents can be found by applying KCL at the node at the top of $1\mu F$

$$i_2(0^+) = i_3(0^+) - i_1(0^+) = 4 - 0 = 4A$$ [1]

Step 2:

After the switch is closed for a long time (i.e., t>>5τ). The Capacitor voltages become constant and so the capacitor acts as open circuit.

Therefore, $i_2(\infty) = i_4(\infty) = 0A$

With $1\mu F$ capacitor acting as open circuit, the 10Ω and 25Ω resistors are in series across 100V voltage source.

Therefore, $i_1(\infty) = i_3(\infty) = \dfrac{100}{35} = 2.86A$

From the resistance and calculated currents, we can calculate the voltages:

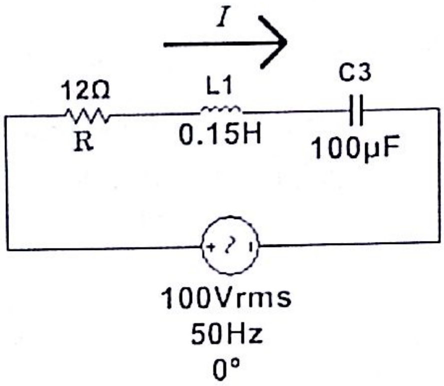
$$V_1(\infty) = 10 \times 2.86 = 28.6V$$
$$V_2(\infty) = 25 \times 2.86 = 71.4V$$
$$V_3(\infty) = 0 \times 50 = 0V$$

[2]

Now, from the right hand mesh

$$V_4(\infty) = 100 - V_3(\infty) = 100 - 0 = 100V$$ [1]

Q5. For the circuit shown below, calculate total circuit impedance '*Z*' and circuit current '*I* '. Also draw the voltage phasor diagram of circuit.



Am - 5

Sol: Voltage Source is provided in RMS, therefore student can either solve the circuit with RMS values or they can convert the Voltage to Voltage peak to peak (Vpp)

$$V_{pp} = V_{RMS} \times 2.83 = 100 \times 2.83 = 283V$$

Calculating the reactance of inductor and capacitor:

$$X_L = 2\pi fL = 2 \times 3.141 \times 50 \times 0.15 = 47.13\Omega$$

$$and$$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2 \times 3.141 \times 50 \times 100 \times 10^{-6}} = 31.83\Omega$$

Total circuit impedance is given by:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$Z = \sqrt{12^2 + (47.13 - 31.83)^2}$$

$$Z = \sqrt{144 + 234} = \underline{19.4\Omega} \quad [2]$$

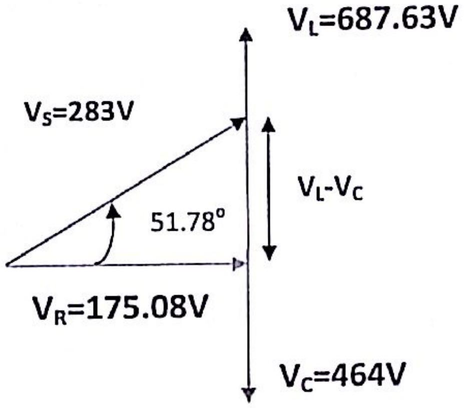
Current I in the circuit is given by:

$$I = \frac{V_S}{Z} = \frac{283}{19.4} = 14.59A \quad [1]$$

$$V_R = I \times R = 14.59 \times 12 = 175.08V$$
$$V_L = I \times X_L = 14.59 \times 47.13 = 687.63V$$
$$V_C = I \times X_C = 14.59 \times 31.83 = 464.39V$$

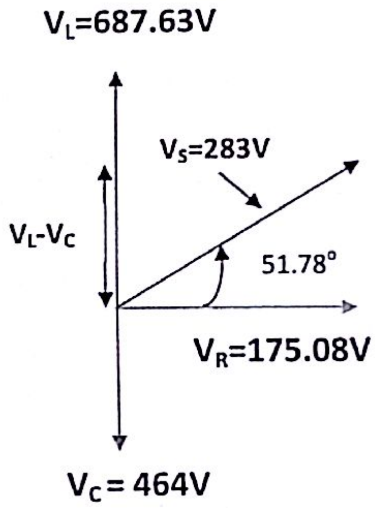
[1]

To plot the phasor diagram we take the current through the whole circuit as the reference, because current I is same through all components.



OR

[2]



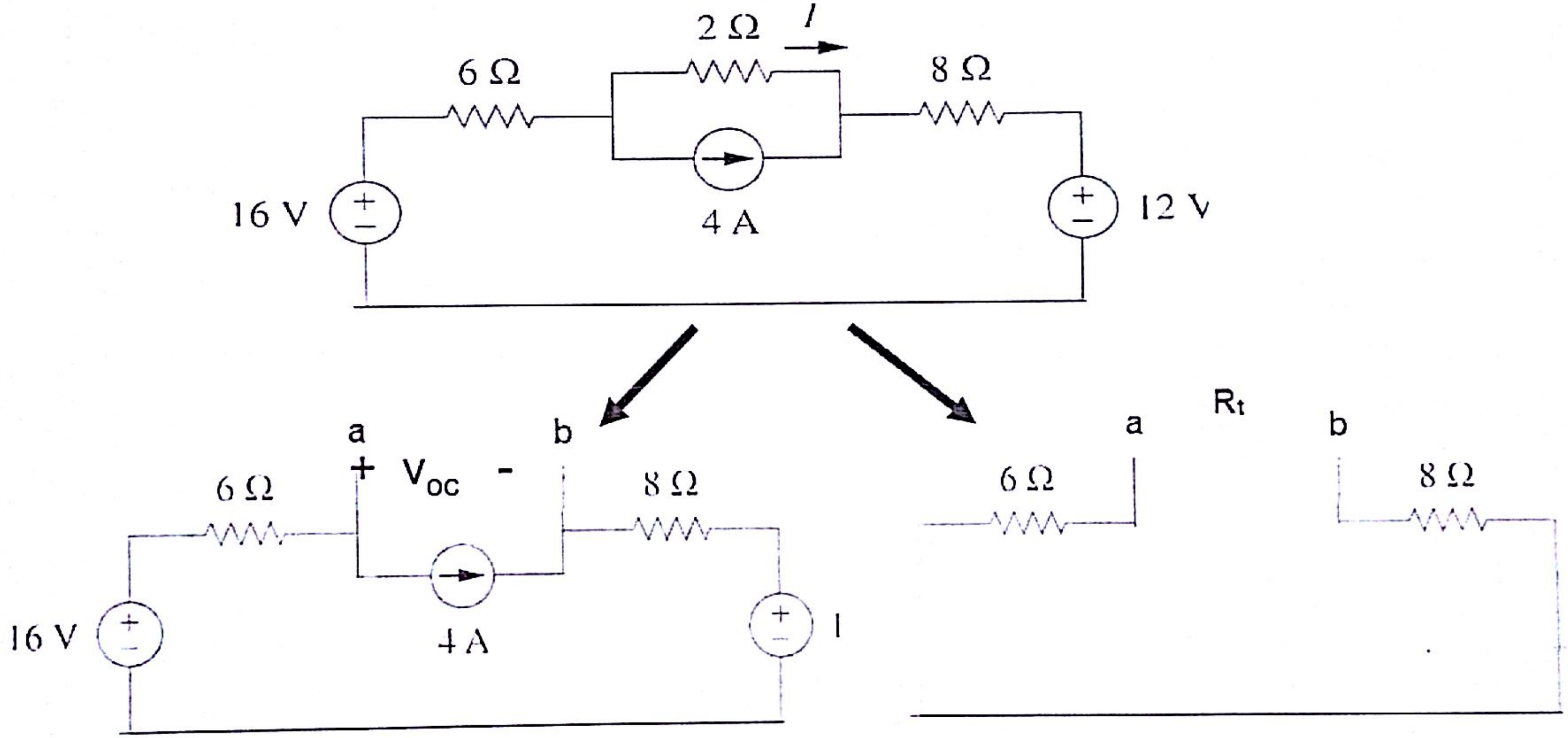
Phase angle between the Source voltage and Current is given by:

$$\cos\phi = \frac{R}{Z} = \frac{12}{19.4} = 0.618$$

or

$$\phi = \cos^{-1}(0.618) = 51.78$$

Q. 4 Determine current in 2Ω resistor by building Thevenin's equivalent for the rest of the circuit obtained by excluding it.

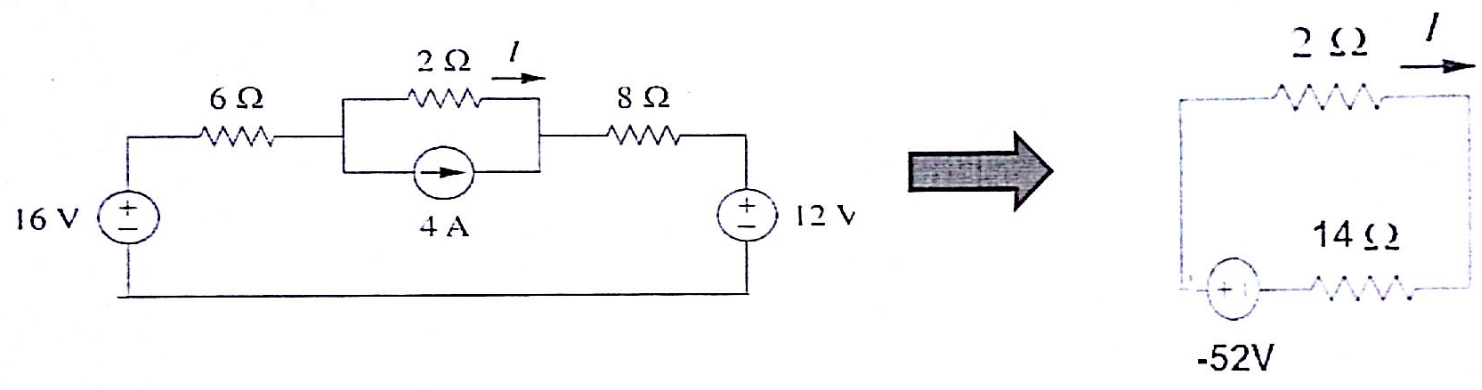


$$-16+4\times 6+v_{oc}+4\times 8+12=0$$

$$v_{oc}=-52V$$ [2]

$$R_t=14\Omega$$

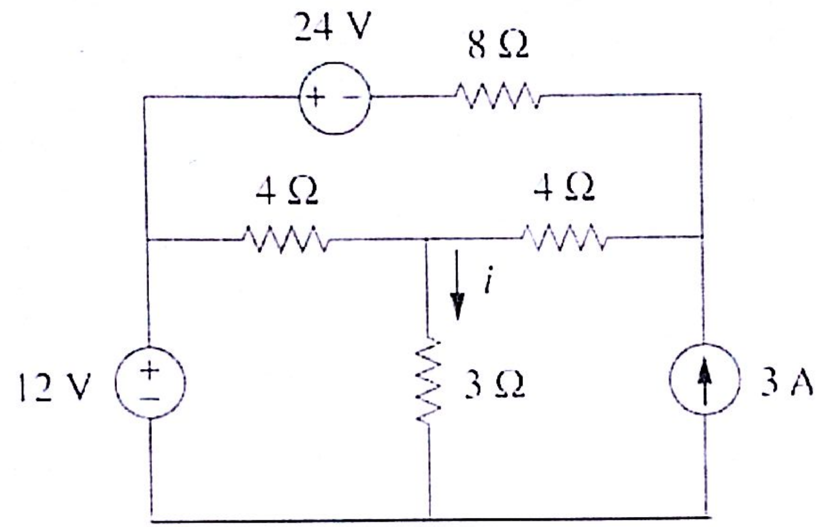
[2]



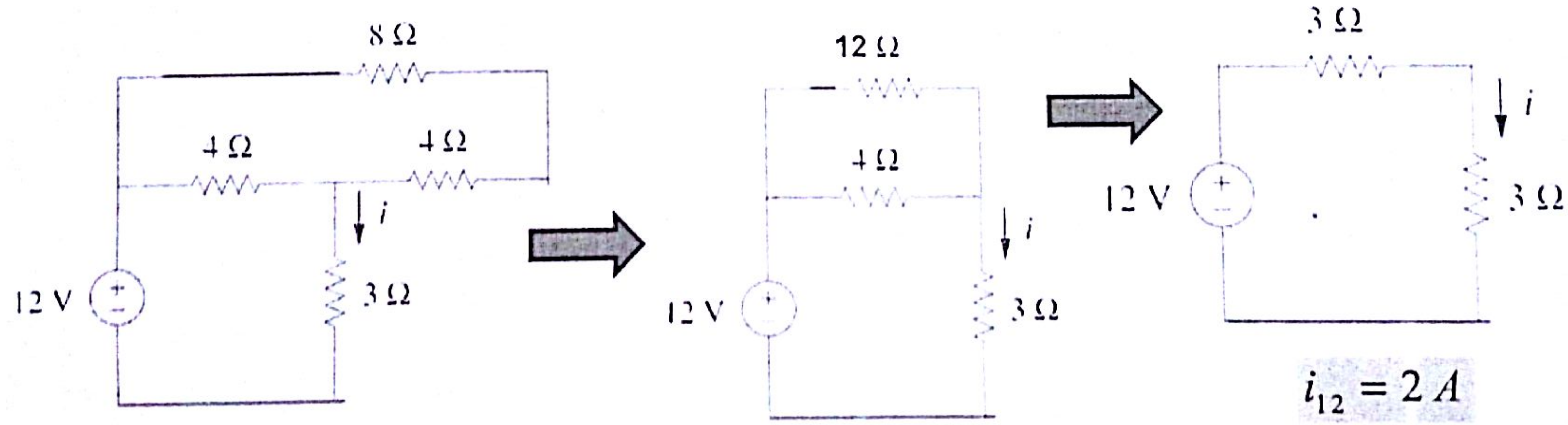
$$(2+14)I-(-52)=0$$

$$I = 3.25\,A \quad [2]$$

Q. 5 Use Superposition theorem to solve for current *i* in the following circuit:

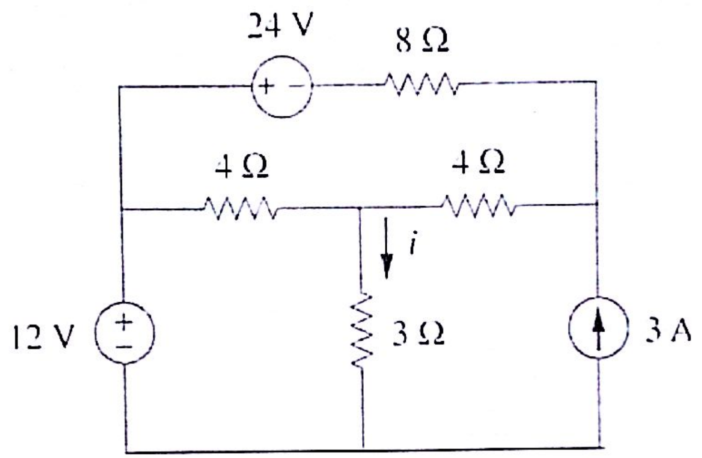


Find current due to 12V source only

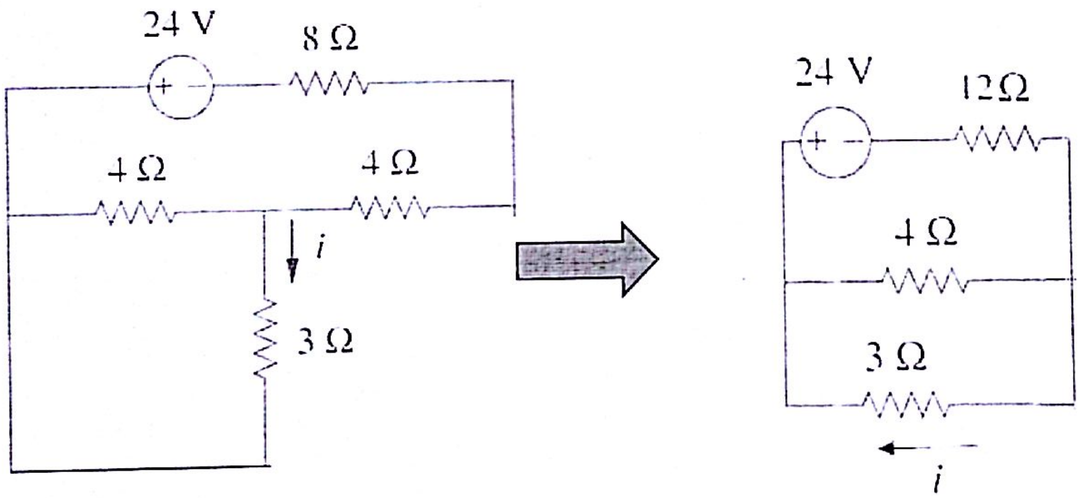


$i_{12} = 2\,A$

[2]

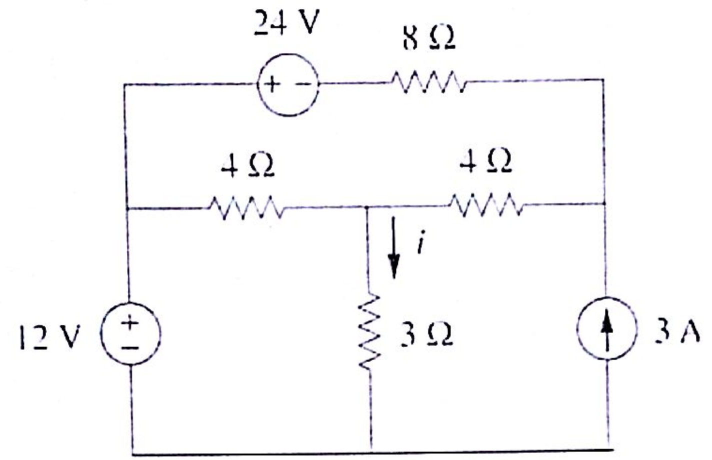


Find current due to 24V source only

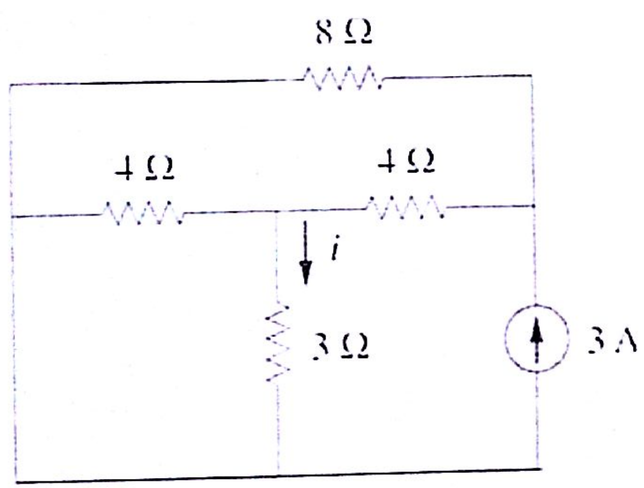


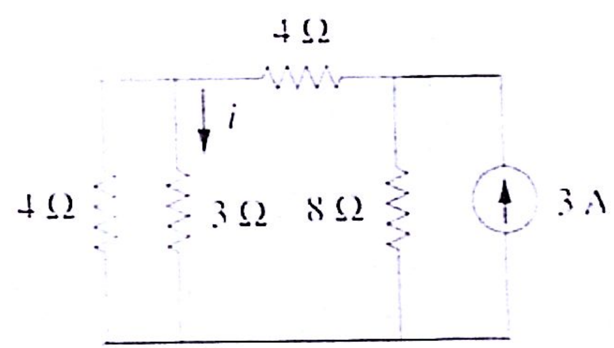
$i_{24} = -1A$

[2]



Find current due to 3A source only



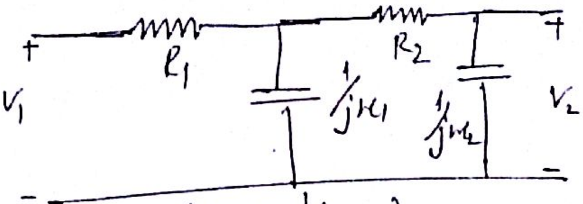


$i_3 = 1\,A$

[2]

Net current = $i_{12} + i_{24} + i_3 = 2\,A$

6



$$Z_{eq} = R_1 + \left(\frac{1}{j\omega C_1}\right) \parallel \left(R_2 + \frac{1}{j\omega C_2}\right) = R_1 + \frac{1/j\omega C_1 \times \left(R_2 + 1/j\omega C_2\right)}{1/j\omega C_1 + R_2 + \frac{1}{j\omega C_2}}$$

$$i = \frac{V_1}{Z_{eq}}$$

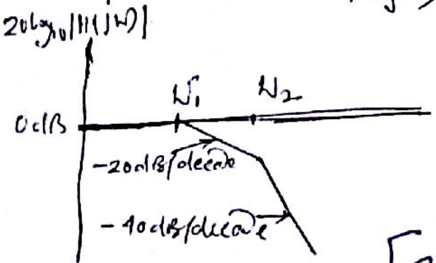
Current through output Capacitor, $i_c = i \times \dfrac{1/j\omega C_1}{R_2 + \frac{1}{j\omega C_1} + \frac{1}{j\omega C_2}}$

$$\therefore V_2 = i_c \times \frac{1}{j\omega C_2} = i \times \frac{1/j\omega C_1}{R_2 + \frac{1}{j\omega C_1} + \frac{1}{j\omega C_2}} \times \frac{1}{j\omega C_2}$$

[2]

$$= \frac{V_1}{Z_{eq}} \times \frac{1}{j\omega C_1} \times \frac{1}{j\omega C_2} \times \frac{1}{R_2 + \frac{1}{j\omega C_1} + \frac{1}{j\omega C_2}}$$

$$\therefore H(j\omega) = \frac{V_2(j\omega)}{V_1(j\omega)} = \frac{1}{Z_{eq}} \times \frac{1}{j\omega C_1} \times \frac{1}{j\omega C_2} \times \frac{1}{R_2 + \frac{1}{j\omega C_1} + \frac{1}{j\omega C_2}}$$



$$= \frac{\cancel{\left(1/j\omega C_1 + R_2 + 1/j\omega C_2\right)}}{R_1\left(1/j\omega C_1 + R_2 + 1/j\omega C_2\right) + 1/j\omega C_1\left(R_2 + 1/j\omega C_2\right)} \times \frac{1}{j\omega C_1} \times \frac{1}{j\omega C_2} \times \frac{1}{\cancel{}}$$

[2]

$$= \frac{1}{j\omega C_1 \times j\omega C_2 \times \left(\frac{R_1}{j\omega C_1} + R_1R_2 + \frac{R_1}{j\omega C_2}\right) + j\omega C_2\left(R_2 + 1/j\omega C_2\right)}$$

$R_1 = \frac{1}{2}$, $R_2 = 1$
$C_1 = 2$, $C_2 = 1$

$$= \frac{1}{j\omega C_2 R_1 + R_1R_2\left(-\omega^2 C_1C_2\right) + j\omega C_1 R_1 + j\omega C_2 R_2 + 1}$$

$$= \frac{1}{\left(1 - \omega^2 C_1C_2R_1R_2\right) + j\omega\left(C_1R_1 + C_2R_2 + C_2R_1\right)}$$

$$\therefore H(j\omega) = \frac{1}{\left(1 - \omega^2 \cdot 2 \cdot \frac{1}{2}\right) + j\omega\left(1 + 1 + \frac{1}{2}\right)} = \frac{1}{1 - \omega^2 + \frac{5}{2}\cdot j\omega}$$

[2]

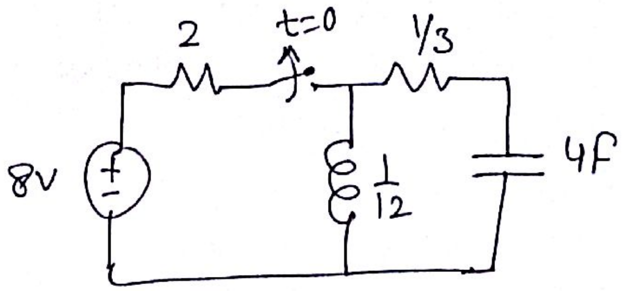
$$= \frac{2}{2 + 5j\omega - 2\omega^2}$$

$$= \frac{2}{(2 + j\omega)(1 + 2j\omega)}$$

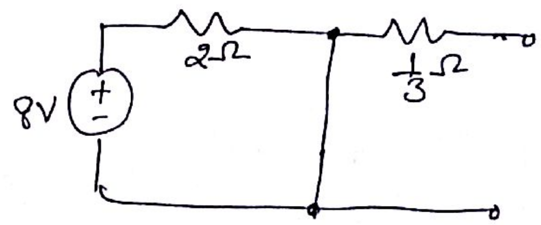
$$\therefore H(j\omega) = \frac{2}{2\left(1 + j\frac{\omega}{2}\right)\left(1 + j\frac{\omega}{1/2}\right)} = \frac{1}{\left(1 + j\frac{\omega}{\omega_1}\right)\left(1 + j\frac{\omega}{\omega_2}\right)}$$

$\omega_1 = \frac{1}{2}$, $\omega_2 = 2$

Q.7)



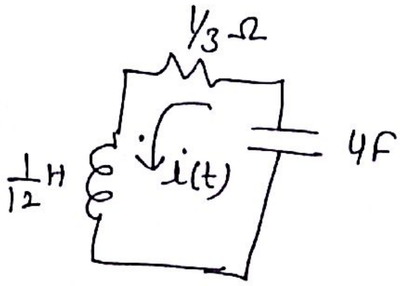
Before $t=0$ the equivalent ckt is $(t=0^-)$



$\therefore \; i_L(t) = \frac{8}{2} = 4\,A$ [1]

$v_C(t=0^-) = 0\,V$

After $t=0$ the equivalent ckt is



By KVL

$$\frac{1}{12}\frac{di}{dt} + \frac{1}{C}\int i\,dt + \frac{1}{3}i = 0$$

$$\frac{1}{12}\frac{d^2i}{dt^2} + \frac{i}{4} + \frac{1}{3}\frac{di}{dt} = 0$$

[1]

$$\Rightarrow \frac{d^2i}{dt^2} + \frac{4\,di}{dt} + 3i = 0 \quad \text{—(I)}$$

assuming $i = e^{st}$ is solution.

$$(s^2 + 4s + 3)e^{st} = 0$$

$$\therefore \; s^2 + 4s + 3 = 0 \quad \text{—(II)}$$

$$s_1 = -3, \quad s_2 = -1$$ [1]

$$\therefore \; i(t) = Ae^{-3t} + Be^{-t} \quad \text{—(III)}$$

at $t=0$

$$i(0) = Ae^{-3\times 0} + Be^{-0}$$

$$4 = A + B \quad \text{—(IV)}$$

Also $$V_R + V_L + V_C = 0$$

$$V_C = -V_R - V_L$$

at $t=0$ $$V_C(0^+) = -V_R(0^+) - V_L(0^+)$$

$$V_C(0^+) = R \cdot i(0^+) - L\frac{di(0^+)}{dt}$$

$$0 = -\frac{1}{3} \times 4 - \frac{1}{12}\left(\frac{d}{dt}(Ae^{-3t} + Be^{-t})\right)\Big|_{t=0}$$

$$0 = -\frac{4}{3} - \frac{1}{12}(-3A - B)$$

$$\cancel{-\frac{4}{3}} \quad \frac{4}{3} = \frac{1}{4}A + \frac{B}{12}$$

$$16 = 3A + B \quad \text{— (V)}$$

From (IV) and (V) $A = 6$, $B = -2$ [1]

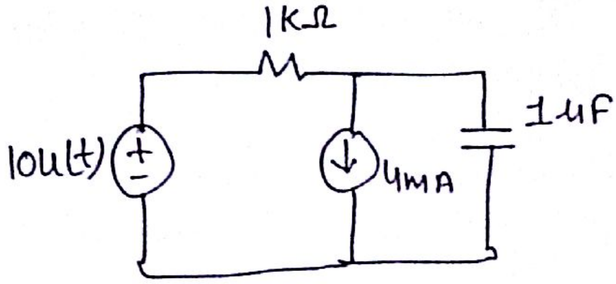
$$\therefore \boxed{i_L(t) = 6e^{-3t} - 2e^{-t}} \quad [1]$$

$$V_C(t) = \frac{1}{C}\int i\,dt = \frac{1}{12}\int_0^{\infty}(6e^{-3t} - 2e^{-t})\,dt$$

$$= \frac{1}{12}\left[\frac{6}{-3}e^{-3t} - \frac{2}{-1}e^{-t} + V_C(0^+)\right]$$

$$\boxed{V_C(t) = -\frac{1}{6}e^{-3t} + \frac{1}{6}e^{-t}} \quad [1]$$

Q.8)

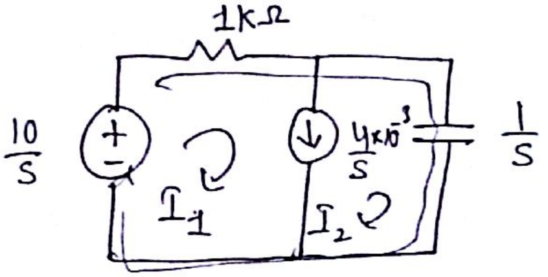


KVL in time domain

~~Laplace ckt~~

In loop. 1.

$$10^3 \times i_1(t) + V_c(t) = 10u(t) \quad (i)$$



$$i_1(t) - i_2(t) = 4\times10^{-3} \quad (ii)$$

$$i_2 = C\frac{dv_c}{dt}$$

[1]

$$i_2 = 10^{-6} \times \frac{dv_c}{dt} \quad (iii)$$

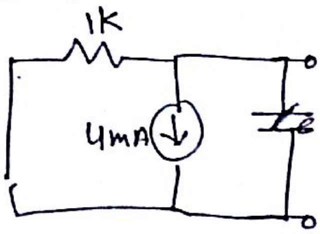
→ In Laplace domain

$$1000\, I_1(s) + V_c(s) = \frac{10}{s}$$

$$I_1(s) - I_2(s) = \frac{4\times10^{-3}}{s} \quad [1]$$

$$10^{-6}\left[s\,V_c(s) - V_c(0)\right] = I_2(s)$$

→ To get $V_c(0)$ the ckt before $t=0$ is



$$\therefore V_c(0^-) = -4V$$

$$\therefore \quad sV_c(s) + 4 = 10^6 \times I_2(s)$$

$$= 10^6\left(I_1(s) - \frac{4\times10^{-3}}{s}\right)$$

$$= 10^3\left(1000\, I_1(s) - \frac{4}{s}\right)$$

$$= 10^3\left(\frac{10}{s} - V_c(s) - \frac{4}{s}\right)$$

$$sV_c(s) + 4 = \frac{6000}{s} - 1000\, V_c(s)$$

$$s^2 V_c(s) + 4s = 6000 - 1000 . s V_c(s)$$

$$s^2 V_c(s) + 1000 . s V_c(s) = -4s + 6000$$

$$V_c(s)\left[s^2 + 1000s\right] = -4s + 6000$$

$$V_c(s) = \frac{-4s + 6000}{s(s+1000)} \quad [2]$$

$$= \frac{-4}{s+1000} + \frac{6000}{s(s+1000)} \quad [1]$$

taking inverse laplace transform.

$$V_c(t) = -4e^{-1000t} + 6(1 - e^{-1000t}) \quad [1]$$

$$V_c(t) = 6 - 10e^{-1000t} \text{ V}$$

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only Answers.

1) $I_1 = 2mA$, $I_2 = 1mA$ $I_3 = -2mA$ $I_4 = 2mA$

$V_0 = 1V$

2) a) $V_1 = 0$ $V_2 = 100$, $V_3 = 100$ $V_4 = 0$

$i_1 = 0$ $i_2 = 4A$, $i_3 = 4A$. $i_4 = 2A$

b) $V_1 = 28.6$ $V_2 = 71.4$, $V_3 = 0$. $V_4 = 100$

$i_1 = 2.86A$, $i_2 = 0$, $i_3 = 2.86A$, $i_4 = 0A$

3) $V_{pp} = 283V$ $I = 14.59A$

$Z = 19.4\Omega$

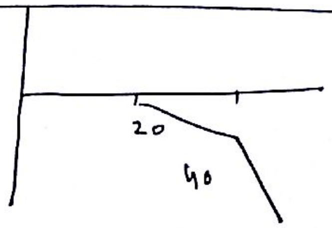
$V_R = 175.08V$, $V_L = 687.63V$ $V_c = 464.39V$

$\Phi = 51.78$

4) $V_{oc} = -52V$, $R_{TH} = 14\Omega$, $I = 3.25A$

5) $i = 2A$, $i = -1A$, $i = 1A$ $\therefore$ Total $= 2A$

6)



$$\frac{2}{(2+jw)(1+2jw)}$$

7) $S_1 = -3$, $S_2 = -1$, $\cancel{Ae^{3}}$

$i_L(t) = 6e^{-3t} - 2e^{-t}$

$V_C(t) = -\frac{1}{6}e^{-3t} + \frac{1}{6}e^{-t}$

8) $$V_C(s) = \frac{-4s+6000}{s(s+1000)} = \frac{-4}{s+1000} + \frac{6000}{s(s+1000)}$$

$$\therefore V_C(t) = -4e^{-1000t} + 6(1-e^{-1000t})$$

$$= 6 - 10e^{-1000t}$$