CLASS TEST

Sl. : 01SKEE-EFGHIJ-230723

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ELECTRIC CIRCUITS

ELECTRICAL ENGINEERING

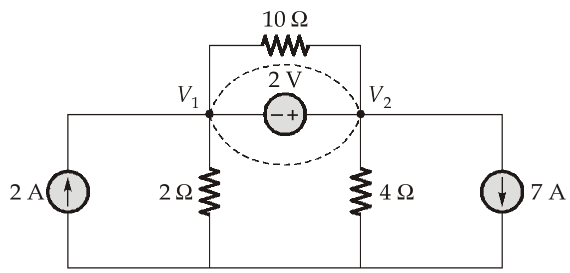
Date of Test : 23/07/2023

ANSWER KEY

1.	(c)	7.	(a)	13.	(d)	19.	(a)	25.	(b)
2.	(a)	8.	(a)	14.	(a)	20.	(a)	26.	(b)
3.	(b)	9.	(d)	15.	(b)	21.	(b)	27.	(b)
4.	(d)	10.	(b)	16.	(a)	22.	(c)	28.	(b)
5.	(a)	11.	(a)	17.	(c)	23.	(b)	29.	(c)
6.	(b)	12.	(a)	18.	(a)	24.	(a)	30.	(b)

DETAILED EXPLANATIONS

1. (c)



Using supernode method,

$$-2+\frac{V_1}{2}+\frac{V_2}{4}+7 = 0$$

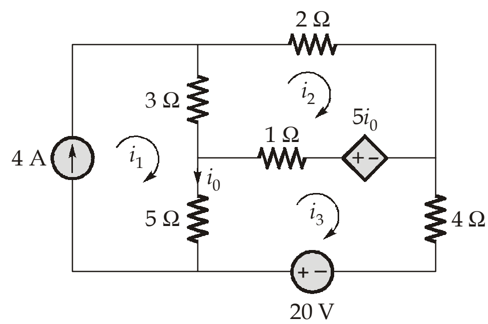
$$2V_1 + V_2 = -20$$

$$V_1 - V_2 = -2$$

$$V_1 = -7.33 \text{ V}$$

$$V_2 = -5.33 \text{ V}$$

2. (a)



Apply mesh analysis,

$$i_1 = 4$$

$$i_0 = (i_1 - i_3) = 4 - i_3$$

$$3(i_2 - i_1) + 2i_2 - 5i_0 + (i_2 - i_3) = 0$$

$$6i_2 + 4i_3 = 32 \quad \text{...(i)}$$

$$1(i_3 - i_2) + 5i_0 + 4i_3 - 20 - 5i_0 = 0$$

$$5i_3 - i_2 = 20 \quad \text{...(ii)}$$

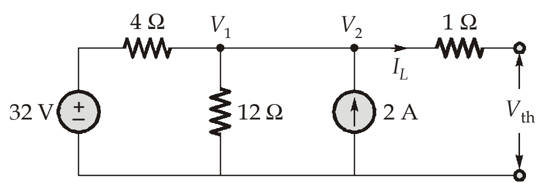
From equation (i) and (ii), we get

$$i_2 = 2.35 \text{ A;}$$

$$i_3 = 4.4705 \text{ A}$$

$$i_0 = 4 - i_3 = -0.4705 \text{ A}$$

3. (b)



Apply node analysis,

$$\frac{V_1 - 32}{4} + \frac{V_1}{12} - 2 = 0$$

$$V_1\left(\frac{1}{4} + \frac{1}{12}\right) = 10$$

$$V_1\left(\frac{4}{12}\right) = 10$$

$$V_1 = \frac{120}{4} = 30 \text{ V}$$

The thevenin across a, b it is open circuited,

$$\therefore \quad V_{th} = V_1 = 30 \text{ V}$$

4. (d)

$$i(t) = 10t\, e^{-5t}$$

$$\text{Energy stored, } E = \frac{1}{2}Li^2 = \frac{1}{2} \times 0.1 \times (10t\, e^{-5t})^2$$

$$= \frac{0.1}{2} \times 100t^2 e^{-10t} = 5t^2\, e^{-10t}$$

At $t = 1$ sec,

$$E_{1\text{ sec}} = 5 \times 1 \times e^{-10}$$

$$= \frac{5}{e^{10}} = 227 \times 10^{-6} = 227\ \mu\text{J}$$

5. (a)

$$Z_\Delta = (8 + 4j)\ \Omega$$

$$Z_Y = \frac{Z_\Delta}{3} = \left(\frac{8}{3} + \frac{4i}{3}\right)\Omega$$

$$V_{an} = 100\angle 10°\ \text{V}$$

$$V_{cn} = 100\angle 130°\ \text{V}$$

In star;

$$I_{c\text{ line}} = I_{c\text{ phase}} = \frac{100\angle 130°}{(8+4j)/3}$$

$$= 33.54\angle 103.43°\ \text{A}$$

6. (b)

y-parameters of 1 Ω resistor network are $\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}$

New y-parameter,

$$= \begin{bmatrix} 5 & 3 \\ 1 & 2 \end{bmatrix} + \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 6 & 2 \\ 0 & 3 \end{bmatrix} S$$

7. (a)

Let,

$$i_x = i_{xA} + i_{xB} + i_{xC}$$

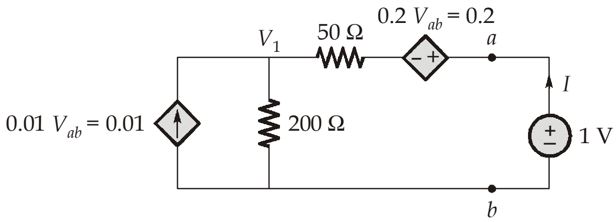
$$i_{xA} + i_{xB} = 20$$

$$i_{xA} + i_{xC} = -5$$
$$i_{xA} + i_{xB} + i_{xC} = 12$$
$$i_{xA} = 3 \text{ A};$$
$$i_{xB} = 17 \text{ A};$$
$$i_{xC} = -8 \text{ A}$$

$\therefore$ if only source V_B is operating,

then $i_x = i_{xB} = 17$ A

8. (a)



$$0.01 = \frac{V_1}{200} + \frac{V_1 - 1 + 0.2}{50}$$

$$0.01 = \frac{V_1}{200} + \frac{V_1}{50} - 0.016$$

$$V_1 = 0.026 \times 40 = 1.04 \text{ V}$$

$$I = \frac{1 - 0.2 - 1.04}{50} = -0.0048 \text{ A}$$

$$R_{th} = \frac{V}{I} = \frac{1}{-0.0048} = -208.33\ \Omega$$

9. (d)

$$C_{eq} = 1 \,||\, 4 = \frac{4}{5} = 0.8\ \mu\text{F}$$

$$i = C_{eq}\frac{dv}{dt} = 0.8\frac{d}{dt}(100e^{-80t}) \times 10^{-6}$$
$$= 0.8 \times 100 \times (-80)e^{-80t} \times 10^{-6}$$
$$= -6.4\, e^{-80t} \text{ mA}$$

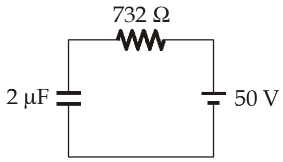
$$v_1(t) = \frac{1}{C_1}\int_0^t i\,dt + V_1(0)$$

$$= \frac{1}{1 \times 10^{-6}}\int_0^t -6.4e^{-80t}\,dt \times 10^{-3} + 20$$

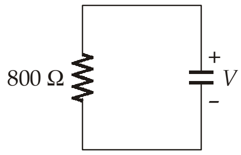
$$= \frac{-6.4}{10^{-3}} \times \frac{e^{-80t}}{-80}\Bigg|_0^t + 20$$

$$v_1(t) = 80(e^{-80t} - 1) + 20$$
$$= (80e^{-80t} - 60) \text{ V}$$

10. (b)

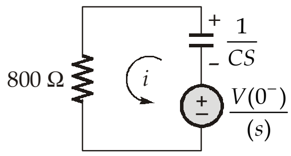


$$t \le 0$$
$$v(0^-) = 50\text{ V}$$
$$t \ge 0$$



$$i = \frac{50/s}{\left(R + \frac{1}{CS}\right)}$$

$$i = \frac{50C}{(1 + RCS)}$$



$$i(t) = \frac{50}{R} e^{-t/RC} A$$

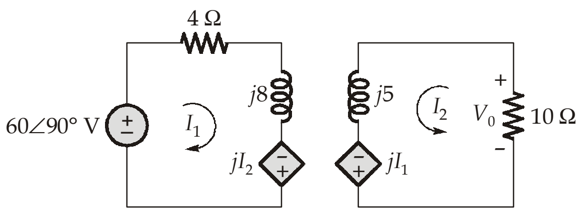
$$v = iR = 50e^{-t/RC}$$

$$v(t = 2\text{ ms}) = 50e^{\frac{-2\times10^{-3}}{800\times2\times10^{-6}}} = 14.33\text{ V}$$

11. (a)

$$\text{Energy stored maximum} = \frac{1}{2}L_{eq}i^2 = \frac{1}{2}\times9\times2^2 = 18\text{ J}$$

12. (a)



Apply KVL,

$$(10 + j5)I_2 - jI_1 = 0$$

$$I_1 = \frac{(10 + j5)}{j} I_2 = (5 - 10j)I_2$$

$$-60j + (4 + 8j)I_1 - jI_2 = 0$$

$$(4 + 8j)\ (5 - 10j)I_2 - jI_2 = 60j$$

$$I_2 = 0.6\angle 90°$$

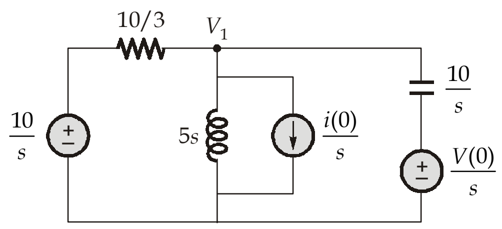
$$V_0 = -10 \times I_2$$

$$= -10 \times 0.6j = -6j$$

13. (d)

$$i(0) = -1\text{ A}$$
$$V(0) = 5\text{ V}$$

Apply node analysis



$$\frac{\left(V_1 - \frac{10}{s}\right)}{\frac{10}{3}} + \frac{V_1}{5s} - \frac{1}{s} + \frac{\left(V_1 - \frac{5}{s}\right)}{\left(\frac{10}{s}\right)} = 0$$

$$V_1\left(\frac{3}{10} + \frac{1}{5s} + \frac{s}{10}\right) - \frac{10 \times 3}{s \times 10} - \frac{1}{s} - \frac{5}{s} \times \frac{s}{10} = 0$$

$$V_1\left(\frac{3s + 2 + s^2}{10s}\right) = \left(\frac{3}{s} + \frac{1}{s} + \frac{0.5s}{s}\right)$$

$$V_1 = \frac{10s}{(s^2 + 3s + 2)} \times \frac{(0.5s + 4)}{s}$$

$$V_1 = \frac{(5s + 40)}{s^2 + 3s + 2} = \frac{5(s + 8)}{(s + 1)(s + 2)}$$

$$V_1 = 5\left(\frac{7}{s + 1} - \frac{6}{s + 2}\right)$$

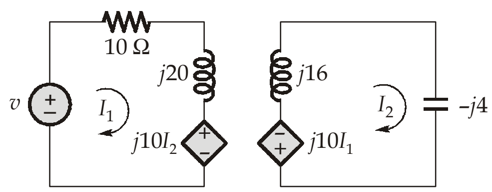
$$v_1(t) = \left(35e^{-t} - 30e^{-2t}\right)u(t)$$

14. (a)

$$X_{L1} = j\omega L = j4 \times 5 = j20\ \Omega$$
$$X_{L2} = j\omega L_2 = j4 \times 4 = j16\ \Omega$$

$$X_C = \frac{1}{j\omega C} = \frac{16}{j4 \times 1} = -j4\Omega$$

$$X_m = j\omega M = j \times 4 \times 2.5 = j10\ \Omega$$



$$-60\angle 30° + (10 + 20j)I_1 + j10I_2 = 0 \qquad \text{...(i)}$$

$$(j16 - j4)I_2 + j10I_1 = 0$$

$$I_1 = -1.2I_2 \qquad \text{...(ii)}$$

$$-(10 + j20) \times 1.2I_2 + j10I_2 = 60\angle 30°$$

$$I_2 = 3.25\angle 160.6\ \text{A}$$

$$I_2 = 3.25 \cos(4t + 160.6°)$$
$$I_1 = 3.9 \cos(4t - 19.4°)$$

At $t = 1$ sec,
$$4t = 4 \text{ rad} = 229.18°$$
$$I_2 = 2.82 \text{ A}$$
$$I_1 = -3.38 \text{ A}$$

Total energy stored in the coupled inductor is

$$E = \frac{1}{2}L_i I_i^2 + \frac{1}{2}L_2 I_2^2 + MI_1 I_2$$

$$E = \frac{1}{2}\times 5\times(-3.38)^2 + \frac{1}{2}\times 4\times(2.82)^2 - 2.5\times 3.38\times 2.82 = 20.5 \text{ J}$$

15. (b)

$$\text{T.F.} = \frac{s}{(s+50)^2+(1000)^2} = \frac{s}{s^2+100s+100.25\times 10^4}$$

$$s^2 + \frac{1}{RC}s + \frac{1}{LC} = 0$$

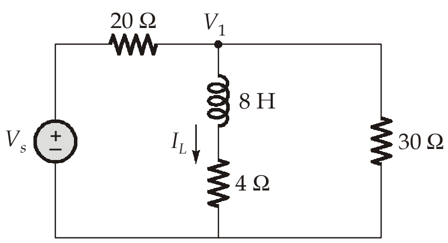
$$\frac{1}{RC} = 100;$$

$$\frac{1}{LC} = 100.25 \times 10^4 = \frac{1}{L\times 1\times 10^{-6}}$$

$$L = 0.9975 \text{ H}$$

16. (a)

$$V_S(s) = \frac{-5}{s} + \frac{12}{s} + 3 = \left(\frac{7}{s}+3\right)$$



$$\frac{(V_1 - V_s)}{20} + \frac{V_1}{8s+4} + \frac{V_1}{30} = 0$$

$$V_1\left(\frac{1}{20} + \frac{1}{8s+4} + \frac{1}{30}\right) = \frac{1}{20}\left(\frac{7+3s}{s}\right)$$

$$V_1\left(\frac{24s+12+60+16s+8}{60(8s+4)}\right) = \frac{1}{20s}(7+3s)$$

$$V_1 = \frac{7+3s}{20s}\times\frac{60(8s+4)}{(40s+80)}$$

$$= \frac{3}{s}\frac{(7+3s)(8s+4)}{(40s+80)}$$

$$I_L = \frac{3}{s}\frac{(7+3s)(8s+4)}{(40s+80)(8s+4)} = \frac{3}{s}\times\frac{(7+3s)}{40(s+2)}$$

$$I_L = \frac{3}{40}\left[\frac{7}{2s}+\frac{-1}{2(s+2)}\right]$$

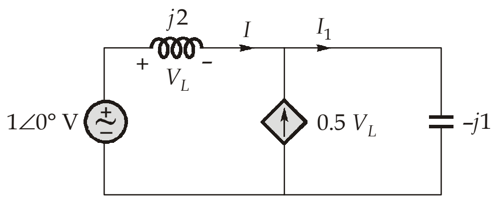
$$i_L(t) = \frac{3}{40}\left(\frac{7}{2}-\frac{1e^{-2t}}{2}\right)u(t)$$

$$i_L(t) = \left(\frac{21}{80}-\frac{3}{80}e^{-2t}\right)u(t)$$

17. (c)

$$X_L = \omega L = 2$$

$$X_C = \frac{1}{1} = 1$$



$$I = 0.5\ V_L + I_1$$
$$= -0.5\times(j2)I + I_1$$
$$I = -jI + I_1$$

$$I(1+j) = \frac{(1-j2I)}{-j1}$$

$$I(-j+1) = (1-j2I)$$
$$I(1+j) = 1$$

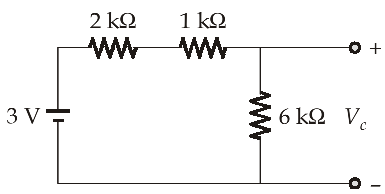
$$I = \left(\frac{1}{2}-\frac{j}{2}\right)$$

$$Y_{in} = I\times 1 = \left(\frac{1}{2}+\frac{1}{j2}\right)s$$

$$R = 2,\ L = 2$$

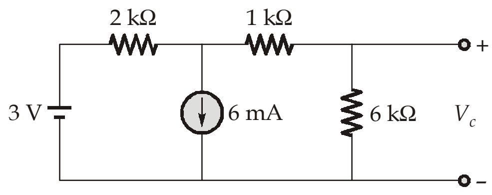
18. (a)

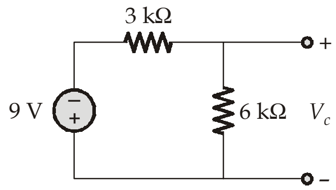
At $t < 0$,



$$V_c(0^-) = 3\times\frac{6}{(6+3)} = \frac{18}{9} = 2\text{ V}$$

At $t > 0$,





$$v_c(\infty) = \frac{6}{9}\times(-9) = -6 \text{ V}$$

$$v_c(t) = -6 + (2 + 6)e^{-t/\tau}$$

$$\tau = \frac{18}{9}\times 1 = 2\ \mu\text{s}$$

$$V_c(t) = -6 + 8e^{-\frac{t}{2}}$$

$$V_c(2\ \mu\text{s}) = -6 + 8e^{-1} = -3.06 \text{ V}$$

19. **(a)**

The equivalent resistance across x-y is

$$R_{x\text{-}y} = \frac{mr}{2}+\frac{r}{m} = \frac{m^2r+2r}{2m}$$

It may be noted that I will be maximum when $R_{x\text{-}y}$ will be minimum,

$$\frac{\delta R_{x-y}}{\delta m} = 0$$

i.e., $$2m\,(2mr) - 2(m^2r + 2r) = 0$$

i.e., $$m = \sqrt{2}$$

20. **(a)**

$$(V_{\text{rms}})^2 = \frac{1}{T}\left[\int_0^{t_1} v^2 dt + \int_{t_1}^{T} v^2 dt\right]$$

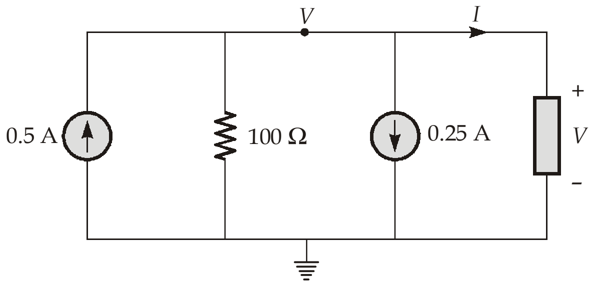
$$= \frac{1}{2}\left[\int_0^1 10^4(1-2e^{-10t}+e^{-20t})\,dt + \int_1^2 10^4 e^{-20t}\,dt\right]$$

$$= (5000)\left[[(t+0.2e^{-10t}-0.05e^{-20t})\Big|_0^1 - \left(\frac{1}{20}\right)e^{-20t}\Big|_1^2\right]$$

$$= (5000)\,[1 + 0.2e^{-10} - 0.2 + 0.05 - 0.05\,e^{-40}]$$

$\therefore$ $$V_{\text{rms}} = 65.25 \text{ V}$$

21. (b)



Voltage across 0.5 A current source is

$$V = \frac{\text{Power}}{\text{Current}} = \frac{1\text{ W}}{0.5\text{ A}} = 2\text{ V}$$

Applying nodal analysis at node

$$0.5 = \frac{V}{100} + 0.25 + I$$

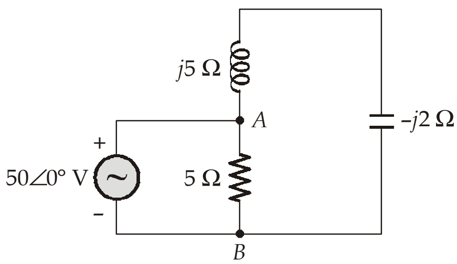
$$0.5 = \frac{2}{100} + 0.25 + I$$

$$I = 0.23\text{ A}$$

Power absorbed by unknown element = 0.23 × 2 = 0.46 W

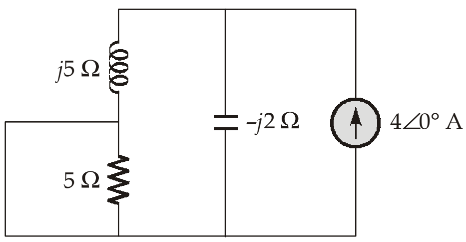
22. (c)

Step-I: When the 50∠0° V source is acting alone.



$$V'_{AB} = 50\angle 0° + 0\text{ V} = 50\angle 0°\text{ V}$$

Step-II: When the 4∠0° A source is acting alone.



$$V''_{AB} = 0\text{ V}$$

By superposition theorem, $V_{AB} = V'_{AB} + V''_{AB}$

$$= 50\angle 0° = 50\angle 0°\text{ V}$$

23. (b)

$$X_{L1} = 2\pi \times 50 \times 0.01 = 3.14\ \Omega$$

$$X_{L2} = 2\pi \times 50 \times 0.02 = 6.28\ \Omega$$

$$X_C = \frac{1}{2\pi\times50\times200\times10^{-6}} = 15.92\ \Omega$$

$$\bar{Z}_1 = 6 + j3.14\ \Omega$$

$$\bar{Z}_2 = 4 + j6.28\ \Omega$$

$$\bar{Z}_3 = 2 - j15.92\ \Omega$$

$$\bar{Z} = \bar{Z}_1 + \frac{\bar{Z}_2\bar{Z}_3}{\bar{Z}_2+\bar{Z}_3}$$

$$= (6+j3.14)+\frac{(4+j6.28)(2-j15.92)}{(4+j6.28)+(2-j15.92)} = 17.27\angle30.75°\ \Omega$$

$$\text{Power factor} = \cos\phi = \cos(30.75°) = 0.86\ \text{(lagging)}$$

24. (a)

RMS value of the rectangular wave = I_m

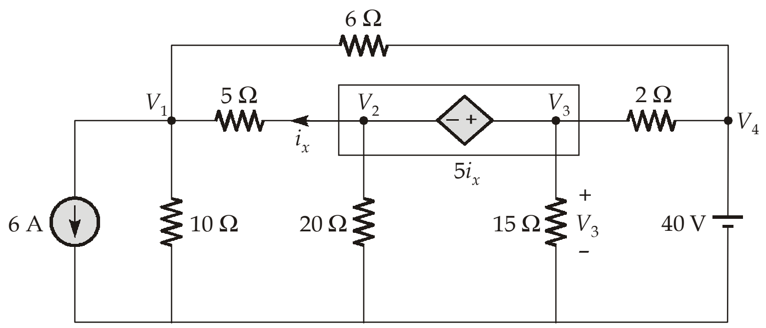
RMS value of sinusoidal current wave = $\frac{I_m}{\sqrt{2}}$

Heating effect due to rectangular current wave = $I_m^2 RT$

Heating effect due to sinusoidal current wave = $\left(\frac{I_m}{\sqrt{2}}\right)^2 RT$

$$\text{Relative heating effects} = \left(\frac{I_m}{\sqrt{2}}\right)^2 RT : I_m^2 RT = 1:2$$

25. (b)



Nodes 2 and 3 form a super node:

$$V_3 = 5i_x + V_2$$

$$= 5\left[\left(\frac{V_2-V_1}{5}\right)\right]+V_2 = 2V_2 - V_1$$

Applying KCL at node 1,

$$6+\frac{V_1}{10}+\frac{V_1-V_2}{5}+\frac{V_1-V_4}{6} = 0$$

$$6+\frac{V_1}{10}+\frac{V_1}{5}-\frac{V_2}{5}+\frac{V_1-40}{6} = 0$$

$$\frac{7}{15}V_1-\frac{1}{5}V_2 = \frac{2}{3} \quad ...(3)$$

Applying KCL for the super node:

$$\frac{V_2-V_1}{5}+\frac{V_2}{20}+\frac{V_3}{15}+\frac{V_3-V_4}{2} = 0$$

$$\frac{V_2-V_1}{5}+\frac{V_2}{20}+\frac{(2V_2-V_1)}{15}+\frac{(2V_2-V_1)-40}{2} = 0$$

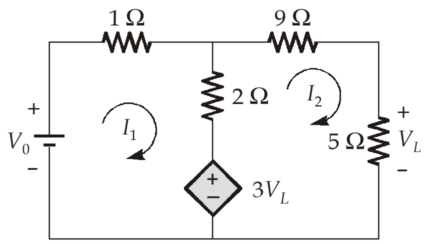
$$-\frac{23}{30}V_1+\frac{83}{60}V_2 = 20 \quad ...(4)$$

Solving equation (3) and (4),

$$V_1 = 10\text{ V}$$
$$V_2 = 20\text{ V}$$
$$V_3 = 2V_2 - V_1$$
$$= 40 - 10 = 30\text{ V}$$

26. **(b)**

Let us apply a voltage source V_0 at the input terminals such that the current in the loops be I_1 and I_2.



Obviously, $V_L = R_L I_2 = 5I_2$

∴ The dependent voltage source is $3V_L = 15I_2$

Again applying KVL in loop-1,

$$V_0 = 3I_1 + 15I_2 - 2I_2$$
$$= 3I_1 + 13I_2 \quad ...(1)$$

In loop-2,

$$0 = -2I_1 + (2 + 9 + 5)\, I_2 - 3V_L$$
$$0 = -2I_1 + 16I_2 - 15I_2$$
$$I_2 = 2I_1 \quad ...(2)$$
$$V_0 = 3I_1 + 13 \times 2I_1$$
$$V_0 = 29I_1$$
$$\frac{V_0}{I_1} = R_{input} = 29\ \Omega$$

27. **(b)**

$$Z_{ph}\text{ (Phase impedance)} = \frac{V_{ph}}{I_{ph}} = \frac{400}{75\sqrt{3}} = 3\ \Omega$$

$$\left[\text{In star connection } I_{ph} = I_{\text{line}}, V_{ph} = \frac{V_L}{\sqrt{3}}\right]$$

$$\frac{\text{Power}}{\text{Phase}} = I_{ph}^2 R_{ph}$$

$$\frac{10\times10^3}{3} = (75)^2 R_{ph}$$

$$\therefore \quad R_{ph} = \frac{10\times1000}{3\times75\times75} = 0.6\ \Omega$$

$$\therefore \quad X_{ph} = \sqrt{Z_{ph}^2 - R_{ph}^2} = \sqrt{3^2-(0.6)^2} = 2.94\ \Omega$$

As the current is leading, X_{ph} must be capacitive.

$$\therefore \quad X_c = 2.94\ \Omega$$

or,
$$\frac{1}{\omega C} = 2.94\ \Omega$$

$$\therefore \quad C = \frac{1}{2.94\times2\pi f} = \frac{1}{2.94\times2\times\pi\times50} = 1083\ \mu\text{F}$$

28. (b)

For a series RLC circuit operating at resonance,

$$V_R = V = 200\text{ V}$$

$$P_R = \frac{V^2}{R}$$

$$15.3 = \frac{(200)^2}{R}$$

$$R = \frac{200\times200}{15.3} = 2.61\text{ k}\Omega$$

$$Q = \frac{f_0}{\Delta f} = \frac{10}{1} = 10$$

Now,
$$Q = \frac{\omega_0 L}{R}$$

$$10 = \frac{2\pi(10^4)(L)}{2.61\times10^3}$$

$$\therefore \quad L = 416\text{ mH}$$

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$10^4 = \frac{1}{2\pi\sqrt{416\times10^{-3}C}}$$

$$C = 610\text{ pF}$$

29. (c)

$$V_1 = 5I_1 + 2I_2 \quad ...(1)$$

$$V_2 = 2I_1 + I_2 \quad ...(2)$$

and $$V_2 = -I_2R_L = -3I_2 \quad ...(3)$$

From equation (2) and (3),

$$-3I_2 = 2I_1 + I_2$$

or, $$-4I_2 = 2I_1$$

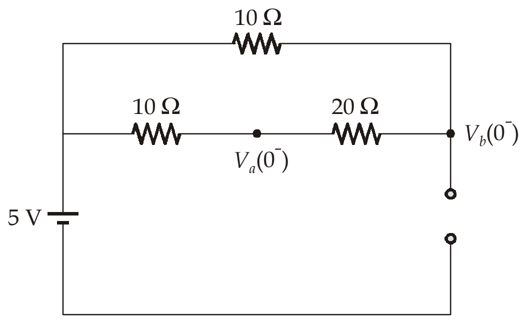
$$I_2 = -\frac{I_1}{2} \text{ put this value in equation (1)}$$

$$V_1 = 5I_1 + 2\left(-\frac{I_1}{2}\right) = 4I_1$$

∴ $$Z_{in} = \frac{V_1}{I_1} = 4\ \Omega$$

30. (b)

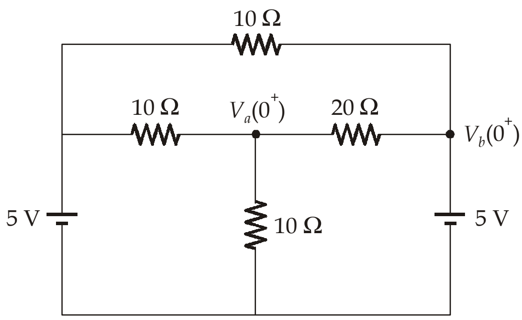
At $t = 0^-$, the network attains steady state condition. Hence, the capacitor acts as an open-circuit.



$$V_b(0^-) = 5\text{ V}$$

At $t = 0^+$, the capacitor acts as a voltage source of 5 V,

$$V_b(0^+) = 5\text{ V}$$



Writing KCL equation at $t = 0^+$

$$\frac{V_a(0^+)-5}{10} + \frac{V_a(0^+)}{10} + \frac{V_a(0^+)-5}{20} = 0$$

$$0.25\ V_a(0^+) = 0.75$$

$$V_a(0^+) = 3\text{ V}$$

■■■■